MULTIPLE DELIVERY POINTS, PRICING DYNAMICS, AND HEDGING EFFECTIVENESS IN FUTURES MARKETS FOR SPATIAL COMMODITIES

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INTRODUCTION

Commodity futures exchanges often allow shorts to deliver multiple grades of commodity at one of several geographic locations as a means of expanding delivery capacity. This is intended to thwart market manipulations by large long traders and ensure proper price convergence at expiration. The Chicago Board of Trade (CBT), for instance, has followed such a policy for many years in its

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grain futures contracts. Similarly, cotton, live hog, sugar, cocoa, and coffee futures (to name but a few) confer delivery options on shorts.

The literature on futures contract delivery options implies that allowing a short to choose the place, time, or grade delivered affects a contract's price dynamics. This theory implies that adding a location as a delivery point, for example, makes the futures price a function of the spot price at the newly designated point.[1] This influences the correlation between the futures price and the spot price at that location. The delivery options may also affect the correlations between the futures price and prices at other locations. These correlations determine how basis risk (and hence hedging effectiveness) varies across locations and among grades.

Since the hedging performance of a futures contract is a primary determinant of its success, it is extremely important for an exchange to select an appropriate delivery specification. A particular set of delivery locations and grades may achieve better hedging effectiveness than would occur under an alternative specification. The exchange may also face trade-offs when designing a delivery specification. Hedgers at location 1 may prefer delivery specification *A* to specification *B*, while hedgers at location 2 may prefer *B* to *A*. The optimal delivery specification therefore depends upon many factors, including price relations between locations and grades, and the distribution of hedger characteristics.

Some academic investigations of these issues do exist. Working (1954) analyzed how a change in the type of wheat allowed for delivery on the Kansas City Board of Trade's futures contract affects various groups of hedgers. He showed that the addition of delivery options can change the hedging performance of a futures contract. Garbade and Silber (1983) employed a three equation structural model to show that the addition of a new delivery point increases hedging effectiveness at that location, but reduces hedging effectiveness at the original delivery point. Similarly, Tashjian et al. (1992) used a Black–Scholes type model to estimate the effect of delivery specifi-

[1]The exact functional relation depends upon time to contract expiration, the prices of other deliverables, relative price variability, and delivery premia and discounts. The empirical and simulation analyses which follow explicitly incorporate these dependencies.

cation on hedging effectiveness.[2] Their results are similar to those of Garbade–Silber. Kamara and Siegel (1987) used a Black–Scholes type model to demonstrate that hedging effectiveness improves when traders use the model to adjust hedge ratios to reflect changes in the relative prices of deliverables. Gay and Manaster (1984) found that the option to deliver the cheapest of hard or soft wheat was incorporated in wheat futures prices in the 1975–1979 period. Hemler (1990) estimated the value of the quality option in Treasury-bond futures prices.

This article expands upon the previous research in four ways. First, it demonstrates empirically that the price of a *location* option is incorporated into the price of Chicago Board of Trade corn and soybean futures as the theory predicts. Second, simulation analysis shows that the hedging effectiveness of a contract varies with delivery specification. Third, it examines the effect of delivery specification changes on hedging in both deliverable and non-deliverable locations, while previous studies examine only deliverables. Since most cash trade in grain occurs outside of delivery markets—i.e., at "out-of-position" locations—good hedging performance at non-delivery points is a crucial characteristic of commodity futures contract. Fourth, it discusses other implications of delivery specification for cash price distributions and market liquidity.

The results of the simulation analysis are striking. Based on Black–Scholes type option pricing techniques, the simulations imply that (a) adding delivery points, and (b) changing the differentials at which shorts can deliver, can significantly improve hedging effectiveness. The estimates imply that a reduction in the discount on deliveries at Toledo and the addition of St. Louis as a delivery point at a premium would have improved hedging effectiveness appreciably for both corn and soybeans at commercially important locations throughout the United States during the 1984–1989 period. Two factors are responsible for this improvement. First, St. Louis is more integrated into current

[2]Tashjian et al. claim that their methodology allows one to explicitly consider the effect of squeezes on hedging effectiveness. This claim is incorrect for two reasons. They assume that in the event of a squeeze the futures price converges to the spot price plus a premium. This cannot occur, as it would imply the existence of an arbitrage opportunity (i.e., buy the cash, sell the future, delivery immediately). The model of Pirrong (1993) implies that cash and futures prices in the delivery market must be equal during the delivery period, and that manipulation artificially drives apart the delivery market and out-of-position spot market prices. Also, they assume that the probability of a squeeze is independent of delivery specification. Since allowing a delivery option increases the elasticity of supply to delivery markets, adding delivery points should reduce the probability of manipulation.

cash grain trading patterns than Chicago [Thompson, Hauser, and Eales (1990)]. This reflects the long run decline in the importance of Chicago as a major cash grain market. Therefore, St. Louis prices are more highly correlated with prices at major production, processing, and export points than Chicago prices. Second, expanding the number of delivery points diversifies away some delivery-point-specific risk. This makes the futures price a better measure of systemic demand and supply conditions.

These results are extremely important to market participants and policy makers because it is commonly believed [see Edwards and Edwards (1984)] that liberalizing a contract's delivery specification to reduce the likelihood of manipulation impairs hedging performance. The finding that the designation of multiple delivery points at discounts/premia that reflect typical commercial price differences may actually *improve* hedging performance implies that the anti-manipulation goals of the Commodity Exchange Act of 1936 are consonant with the interests of hedgers.

The remainder of this article is organized as follows: it reviews the effect of delivery options on the pricing of futures contracts and demonstrates how correlations between spot and futures prices vary as delivery specification changes, and presents an empirical analysis of the location option model for corn and soybean futures contracts over the 1984–1989 period. The results are stronger than those of Gay–Manaster, and serve to validate the relevance of higher dimension delivery option formulae and spot price data used in the simulations that are described. These simulations show how changing the delivery specification can affect hedging performance. The final section provides a summary of the work and briefly discusses some of the other possible effects of adding delivery points.

DELIVERY LOCATION OPTIONS, PRICING, AND HEDGING EFFECTIVENESS: THEORY

A futures contract on a particular commodity that allows the short to deliver (a) one of several grades of that commodity, and/or (b) at one of several locations, extends valuable delivery options to shorts. According to the analyses of Stulz (1982) and Johnson (1987), the price of such a futures contract equals the value of an option to buy the cheapest to deliver (C.T.D.) variety at the C.T.D. location, where the option bears a strike price of zero. This is true because shorts tender the C.T.D. to minimize the costs of satisfying their contractual obligation. Thus, during the delivery period, the futures price converges to the price of the

C.T.D. (This article focuses upon multiple delivery points exclusively, even through most of the conclusions are also relevant for contracts allowing delivery of different varieties or qualities.)

The Stulz/Johnson analyses imply that the delivery option is valuable if the prices of deliverables are not perfectly correlated. Prices of spatial commodities—costly to transport goods produced and consumed in geographically dispersed locations—are typically imperfectly correlated because spatially separated goods are imperfect substitutes, and demand and supply shocks are usually imperfectly correlated across locations. Thus, the option to deliver at one of several locations is likely to be valuable in markets for commodities such as grains, industrial metals, coffee, sugar, and cotton.

To determine at time t a futures price for a contract with multiple deliverables, assume that:

1. Shorts can delivery at any one of n locations.
2. The forward prices at all these locations are distributed lognormally.
3. Trading in futures contracts and the deliverable commodities is continuous and costless.
4. There are no delivery discounts or premia (this assumption is waived below).
5. There are τ years to expiration of a futures contract.

Given these assumptions, Johnson (1987) proved that the futures price at t equals:

$$F(t) = \sum_{i=1}^{n} P_i(t) w_i(t)$$

where $P_i(t)$ is the *forward price* at t for delivery at location i at time $t + \tau$, and

$$w_i(t) = N_{n-1}(\{z_{ij}\}_{j=1,\ldots,n}^{j \neq i}; \rho_i)$$

The expression $N_{n-1}(.)$ is the $n - 1$ variate cumulative normal distribution function. The arguments of the normal c.d.f. are:

$$z_{ij} = \frac{\ln(P_j(t)/P_i(t)) - 0.5\sigma_{ij}^2 \tau}{\sigma_{ij}\sqrt{\tau}}$$

where $\sigma_{ij}^2 = \mathrm{var}(d\ln(P_j(t)/P_i(t)))$. The correlation vector is:

$$\rho_i = \{\rho_{i1i}, \rho_{i2i}, \ldots, \rho_{ini}, \rho_{i1j} \ldots\}$$

where

$$\rho_{iji} = \frac{\sigma_i - \rho_{ij}\sigma_j}{\sigma_{ij}}$$

$$\rho_{ijk} = \frac{\sigma_i^2 - \rho_{ij}\sigma_i\sigma_j - \rho_{ik}\sigma_i\sigma_j + \rho_{ik}\sigma_j\sigma_k}{\sigma_{ij}\sigma_{jk}}$$

with $\sigma_i^2 = \text{var}(\text{dln } P_i(t))$ and $\rho_{ij} = \text{corr}(\text{dln } P_i(t), \text{dln } P_j(t))$. The elements of the correlation vector ρ_i give the correlations between the relative prices at the deliverable locations.

Expression (1) states that the futures price is a weighted sum of the forward prices of the deliverables. The weights on the prices in (1)—the cumulative normal terms—depend upon the relative prices in the various delivery markets. Low price markets receive greater weights. To see why, note that for location i, $P_i(t)$ is in the denominator of the relative price ratios in the z_{ij}. As a result, given the prices for $j \neq i$, z_{ij} varies inversely with $P_i(t)$. Since the normal c.d.f. is increasing in its arguments, $w_i(t)$ increases as $P_i(t)$ declines. This is an intuitive result. A market with a relatively low price prior to the delivery period is more likely to have a relatively low price during the delivery period. It is therefore more likely to be cheapest to deliver at contract expiration. Since the futures price is the expected value of the C.T.D. commodity (under the risk neutral density) at contract expiration, such relatively inexpensive locations receive greater weight in determining the futures price prior to expiration.

In many futures markets, deliveries at certain locations are subject to discounts or premia. For example, a short who delivers corn in Toledo receives \$0.04 less per bushel than one who delivers simultaneously in Chicago. To account for such premia and discounts, one can replace each $P_i(t)$ in (1) and (2) with:

$$P_i^*(t) = P_i(t) + d_i$$

where d_i is the adjustment applied to the futures settlement price of deliverable i. Since discounts penalize delivery at a particular place while premia reward delivery, $d_i > 0$ for discounts, and $d_i < 0$ for premia. Thus, increasing the premium or reducing the discount of deliverable i increases $w_i(t)$, certeris paribus

It is well known that a futures contract's hedging effectiveness depends upon the correlation between spot and forward prices [Ederington (1979)]. It is possible to demonstrate that the instantaneous correlation between the percentage change in the futures price [given by (1)] and the percentage change in the price at any location z equals:[3]

$$\rho_{Fz}(t) = \sum_{i=1}^{n} \frac{\rho_{iz}\sigma_i}{\sigma_F(t)} w_i(t) \tag{4}$$

where $\rho_{iz}(t) = \text{corr}(\text{dln } P_i(t), \text{dln } P_z(t))$, and the standard deviation of the futures price equals

$$\sigma_F(t) = \sqrt{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_i(t)w_j(t)\rho_{ij}\sigma_i\sigma_j\right)} < \max_{i\le n}[\sigma_i] \tag{5}$$

Since the $w_i(t)$ depend upon the delivery specification, these equations imply that the choice of delivery points and differentials affect the hedging performance of a futures contract.

An examination of (4) and (5) reveals three salient facts. First, an increase in the $w_i(t)$ of deliverables with large values of ρ_{iz} (due, for instance, to an increase in the premium or reduction in a discount for such a deliverable) tends to increase hedging effectiveness.

Second, if the $\rho_{ij} < 1$, a diversification effect tends to improve hedging effectiveness at *non-deliverable* locations under multiple delivery point contracts vis-à-vis single delivery point contracts. Certeris paribus, diversification reduces the variance of the futures price. According to (4), the spot-futures correlation at z varies inversely with the futures price variance, so this reduction in σ_F improves hedging effectiveness. This is an intuitive result. Specifying a large number of deliverables means that the idiosyncratic price movements of any single deliverable are diversified away, so the futures price reflects only the systemic variability in the underlying commodity prices.

A somewhat extreme example illustrates how expanding the number of delivery points can reduce the variance of the futures price. Assume $\sigma_i = \sigma_j = \sigma$ and $\rho_{iz} = \rho_{jz} = \rho_{ij} = \rho < 1$ where $z \neq i, j$ for all i, and j, then

$$\sigma_F = \sigma\sqrt{\sum_{i=1}^{n} w_i^2(t) + \sum_{i=1}^{n}\sum_{j\neq i} w_i(t)w_j(t)\rho^2}$$

Note that since (a) $w_i(t) < 1$ for all i, and (b) the weights at each location approach 0 and n increases, the first summation term approaches

[3]This location may or may not be a delivery point.

0 for large n. Thus, for large n

$$\sigma_F \approx \sigma\rho\sqrt{\sum_{i=1}^{n} w_i(t) \sum_{j \neq i} w_j(t)} \approx \sigma\rho$$

where the second approximation is due to the fact that $\sum_{i=1}^{n} w_i(t) \approx 1$. Moreover, under the assumptions of this example, the numerator in (4) approximately equals $\sigma\rho$. Thus, for large n, $\rho_{Fz} \approx 1$ even though $\rho_{Fz} < 1$ for small n.

It should be noted that adding more delivery points does not *always* improve hedging effectiveness. The reason for this is clear. As noted earlier, adding low correlation delivery points tends to reduce hedging effectiveness. The adverse effect of adding such a delivery point could well dominate the diversification effect. However, when the correlation at the new delivery point is not much below the correlations of existing delivery points, the diversification effect tends to improve hedging performance.

Under more general conditions, diversification magnifies the effect of the correlation between high variance deliverables and P_z, as $\sigma_i/\sigma_F > 1$ for these deliverables. The diversification effect may either magnify or diminish the effect of the correlation between low variance deliverables and P_z. Along with the previous results, this implies that an increase in the weight of high variance, high correlation deliverables may improve out-of-position hedging performance substantially. Increasing the weight of high variance, low correlation deliverables may degrade hedging performance.

Third, the preceding two points imply that adding new delivery locations tends to reduce hedging effectiveness at the old ones and improve it at the new ones. This is true for two reasons. First, hedging effectiveness at a point is maximized if it is the sole delivery point. In this case, the futures price is then perfectly correlated with the spot price; adding more delivery points necessarily reduces this correlation. Second, adding z as a delivery point leads to the incorporation of $\rho_{zz} = 1 > \rho_{iz}$, $i \neq z$ in (4).

Two major conclusions flow from the foregoing analysis. The futures price should incorporate the prices of all deliverables as implied by (1). Moreover, varying the delivery specification of a futures contract by adding or deleting delivery points, or changing delivery differentials, should change hedging effectiveness. Changes in specification that increase the probability that delivery will occur at high correlation locations should improve hedging effectiveness. Increasing the number of deliverables also introduces a diversification effect which may also improve hedging effectiveness by reducing delivery-market-specific variations in the futures price. The following sections present tests of these implications using data from the corn and soybean markets for the period 1984–1989.

AN EMPIRICAL ANALYSIS OF EXISTING DELIVERY OPTIONS

This section tests whether the model given by (1) accurately explains the observed relationship between the futures and spot prices of corn and soybeans. The corn and soybean contracts do not embed an option equivalent to the hard wheat–soft wheat choice implicit in the wheat contract studied by Gay–Manaster. Although the short can deliver different qualities of corn and soybeans against the contract at fixed differentials, this option is of secondary importance for these commodities because the relative prices of these grades do not vary much. Thus, $n = 2$ for corn and soybeans, so one can rewrite (1) as:

$$F(t) = P_C(t)N_1(d_1(t)) + P_T(t)N_1(d_2(t)) \tag{6}$$

where $P_C(t)$ is the forward price of corn (soybeans) in Chicago, $P_T(t)$ is the forward price of corn (soybeans) in Toledo, $N_1(.)$ is the univariate normal c.d.f., and

$$d_1(t) = \frac{\ln(P_T(t)/P_C(t)) - .5\sigma_{CT}^2\tau}{\sigma_{CT}\sqrt{\tau}} \qquad d_2(t) = -d_1(t) - \sigma_{CT}\sqrt{\tau}$$

where

$$\sigma_{CT}^2 = \text{var}\left(\text{dln}\ \frac{P_T(t)}{P_C(t)}\right)$$

Noting that $N_1(x) = 1 - N_1(-x)$ and rearranging terms in (6) implies

$$\begin{aligned} F(t) &= P_C(t) - [P_C(t)N_1(-d_1(t)) - P_T(t)N_1(d_2(t))] \\ &= P_C(t)[1 - N_1(-d_1(t)) + \frac{P_T(t)}{P_C(t)} N_1(d_2(t))] \end{aligned} \tag{7}$$

The bracketed term on the first line of (7) is the value of an option to exchange corn (soybeans) in Chicago for corn (soybeans) in Toledo [see Margrabe (1979)].

Taking natural logarithms of (7) produces:

$$\ln F(t) = \ln P_C(t) + \ln Z(t) \tag{8}$$

where

$$Z(t) = \left[1 - N_1(-d_1(t)) + \frac{P_T(t)}{P_C(t)} N_1(d_2(t)) \right]$$

In words, $Z(t)$ is the futures price (which embeds a delivery option) as a fraction of the Chicago forward price (which does not). As a result, $Z(t)$ varies inversely with the value of the exchange option. Thus, (7) and (8) demonstrate that the futures price can change because (a) the forward price in Chicago changes, and/or (b) the value of the delivery option rises relative to the Chicago forward price.

Testing whether (8) accurately describes corn and soybean prices requires data on futures prices and Toledo and Chicago cash forward prices. The futures prices used are daily settlement prices reported by the Chicago Board of Trade. Unfortunately, there are no data available on cash forward prices in the delivery markets. The available cash price data report spot bids by terminal market elevators to purchase grain to arrive within 15 days. The United States Department of Agriculture collects these bids from the major elevators in each market at the close of each day's futures trading, and reports the highest and lowest bid in each market.

These prices are potentially noisy estimates of equilibrium prices for grain because elevators do no necessarily transact at their bids. Moreover, since the elevator bids are spot prices, they do not reflect the costs of carry that elevators incur over the period ending with the expiration date of the futures contract; this cost is embedded in forward prices. It is necessary, therefore, either to adjust the price data to reflect the cost of carry, or to alter the specification of the econometric tests. Gay and Manaster attempt to correct for this problem by adjusting spot prices by the posted price of storage that terminal elevators charge, and the time value of money until contract expiration to calculate a synthetic forward price. These adjustments may introduce a measurement error because holders of inventories of grain may receive a stream of benefits—a convenience yield—that depresses the forward price relative to the spot price. This implicit return on grain inventories is unobserved, which may cause random deviations between the forward price imputed in this fashion and the true forward price.

There is an alternative approach to the problem posed by the inability to observe the true returns to storage. Specifically, one can express the relationship between the forward price $P(t)$ and the spot price $S(t)$ as follows:

$$P(t) = S(t)e^{(r(t) - r_c(t))\tau} + w(t) \tag{9}$$

$r(t)$ is the risk free interest rate at t, $w(t)$ is the cost regular delivery elevators charge to store the commodity until contract expiration, and $r_c(t)$ is the convenience yield accruing to holders of inventories of the commodity at t. If there are implicit benefits to storing the commodity this convenience yield is positive; i.e., $r_c(t) > 0$. Empirical evidence dating from Working (1948) and Brennan (1958) implies that this yield is a decreasing, convex function of inventories.

If $r(t) - r_c(t)$ in Chicago equals $r(t) - r_c(t)$ in Toledo, substitution of (9) into (8) produces:

$$\ln F^*(t) \equiv \ln(F(t) - w(t)) - r(t)t = \ln S_C(t) + \ln Z^*(t) - \tau r_c(t) \tag{10}$$

In this expression, $\ln F^*(t)$ is the log futures price net of carrying costs, and $Z^*(t)$ is computed by replacing $P_C(t)$ and $P_T(t)$ in the expression for $Z(t)$ with $S_C(t)$ and $S_T(t)$, respectively. Taking first differences of (10) implies

$$\Delta\ln F^*(t) = \Delta\ln S_C(t) + \Delta\ln Z^*(t) - \Delta\tau r_c(t) \tag{11}$$

This equation implies that three factors determine percentage changes in the cost of carry adjusted futures price: (i) changes in the Chicago spot price, (ii) changes in the value of the delivery option relative to the Chicago price, and (iii) changes in the convenience yield.

Recall that $\Delta r_c(t)$ cannot be observed independently, so (11) cannot be estimated directly. The model of French (1986) implies, however, that (a) changes in the convenience yield are correlated with changes in the spot price, and (b) the size of this correlation depends upon $r_c(t - 1)$.[4] By exploiting this relationship, it is possible to specify a model that can be estimated using the available data.

Specifically, when *current* shocks to supply and demand conditions predominate, the changes in the spot price and changes in the convenience yield are *positively* correlated. To see why, note that in response to a positive current demand shock, the spot price rises and inventories decline. The decline in inventories increases the convenience yield. Furthermore, recall that the convenience yield is a convex function of inventories; i.e., a one-unit change in inventory has a larger effect on $r_c(t)$, the smaller the initial level of stocks. Therefore, when $r_c(t - 1)$

[4]Note that $r_c(t - 1)$ is related to inventory conditions immediately prior to the shock that generates the return at t, while $r_c(t)$ includes the effects of the shock. Thus, variations in $r_c(t - 1)$ measure variations in initial supply and demand conditions. Therefore $r_c(t - 1)$ is in the relevant information set, while $r_c(t)$ is not.

is large, the correlation between $\Delta \ln S_C(t)$ and $\Delta r_c(t)$ is large as well. When $r_c(t-1) \approx 0$ (i.e., the market is at full carry), however, a change in inventories has a very small affect on the convenience yield; the correlation between the change in the spot price and the change in the convenience yield is approximately 0 as a result.

Conversely, when *future* demand and supply shocks predominate, changes in the spot price and changes in the convenience yield are *negatively* correlated. To understand this relationship, consider the effects of an increase in the expected future harvest. This leads to a reduction in both the spot price and the level of inventory because it lowers the need to carry over stocks. The decline in stocks increases the convenience yield, so the spot price and $r_c(t)$ move in opposite directions. Again, convexity implies that (a) when $r_c(t-1) \approx 0$, this correlation is approximately 0, and (b) the correlation between $\Delta \ln S_C(t)$ and $\Delta r_c(t)$ is increasing (in absolute value) in $r_c(t-1)$.

Thus, the French model implies that $r_c(t-1)\, \Delta \ln S_C(t)$ can serve as a proxy for $\Delta r_c(t)$ because $\Delta \ln S_C(t)$ and $\Delta r_c(t)$ are correlated, and because this correlation varies directly (in absolute value) with the level of the convenience yield. This suggests the following model specification:

$$\Delta \ln F^*(t) = \alpha + \beta_1 \Delta \ln S_C(t) + \beta_2 \Delta \ln Z(t) + \beta_3 \Delta \ln S_C(t) r_c(t-1)(\tau + 1) \quad (12)$$

French's theory and (10) imply $\beta_1 = 1$; given the value of the delivery option, if the convenience yield does not change, spot prices and futures prices should change by identical amounts. The term $\beta_3 \Delta \ln S_C(t) r_c(t-1)(\tau+1)$ is the proxy for $-\Delta \tau r_c(t)$ in (10). The foregoing discussion implies $\beta_3 < 0$ if current shocks dominate, while $\beta_3 > 0$ if future shocks do so. Since shocks to the impending harvest are the most likely source of future shocks for corn and soybeans, one would expect $\beta_3 > 0$ during the summer and early fall months when the most information about the future harvest is forthcoming. It is consistent with the theory to observe $\beta_3 < 0$ after the harvest.[5]

[5]Exclusion of the convenience yield term from (12) does not affect the empirical results in any important way; the delivery option and spot price coefficients are almost always statistically indistinguishable from 1.00 even when this variable is excluded. This term is included in the reported results because it is sometimes statistically significant, and to demonstrate that the delivery option variable is not proxing for some convenience yield effect.

Equation (12) is estimated as follows. For each separate futures contract, the Chicago and Toledo spot prices and the futures settlement price (which should be contemporaneous with the spot price proxies) are determined for each day during a period beginning 90 calendar days prior to the last trading date of each futures contract. The spot price proxy for each location is the average of the high and low bids in that location. The CBT's regular storage rate (5¢ per month over the sample period) is used to calculate $w(t)$. Finally, the Eurodollar interest rate is employed to calculate $r(t)\tau$.

It is also necessary to calculate σ_{CT}^2 to estimate $Z^*(t)$. For the entire 90-day sample window for each contract, the variance of $\Delta \ln (P_C(t)/P_T(t))$ is calculated from daily data; σ_{CT}^2 is set equal to this sample variance. Given the estimate of this parameter, $Z^*(t)$ is calculated. In general, $Z^*(t)$ is close to 1. In the entire corn sample, for instance, the average of $Z^*(t)$ equals 0.970. In the soybean sample, this average equals 0.991. These results imply that the delivery option, on average, equals 0.9% (3%) of the Chicago spot price for soybeans (corn). These values are similar to those found by Gay and Manaster (1984) for the wheat quality option and Hemler (1990) for the Treasury Bond quality option. The disparity between the average value of $Z^*(t)$ for the two commodities is readily explained by the fact that soybeans are the higher valued commodity, but each is equally costly to transport. Thus, smaller relative price variations in soybeans are sufficient to induce spatial arbitrage. This smaller relative price variability in soybeans makes the delivery option relative to the value of the Chicago spot price smaller for soybeans than for corn. The greater integration of the soybean market is also manifest in the generally higher across-location price correlations for soybeans (see Tables V and VI).

Finally, since $(\tau + 1)r_c(t - 1)$ is not observed directly, it is inferred from futures and spot prices. Rewriting (10) implies:

$$(\tau + 1)r_c(t - 1) = \ln S_C(t - 1) + \ln Z(t - 1) - \ln F^*(t - 1) \quad (13)$$

Thus, under the joint null hypothesis that (a) the futures market is in equilibrium at $t - 1$, and (b) the delivery option model is correct, plugging the observed spot and futures prices, the interest rate, and the storage charge into (13) produces $r_c(t - 1)$.

To estimate (12), the observations for a given commodity are pooled *across years by contract month*. For example, all observations for March soybean contracts for each of the years 1984–1989 are combined into a data set for a single regression. Since there are seven soybean and five corn contracts per year, seven soybean regressions and five corn regressions are estimated. This pooling is motivated by the fact that the Chicago spot-futures basis is considerably more volatile in the summer months than in the winter and spring. For comparison, all observations for each commodity are also pooled into a single data set.

Several problematic observations are excluded from the analysis. In particular, days are not included when a limit price move occurs during that day. Several observations where the spot price moved by an extreme amount due to congested or manipulated conditions at the expiration of a contract expiring in an earlier month are also omitted. For example, data from the period July 19, 1989–July 21, 1989 are deleted from the September regressions because of the impact of the Ferruzzi squeeze of the July contract on spot prices.[6]

Tables I and II report for soybeans and corn, respectively, the estimates of α, β_1, β_2, and β_3 and their White heteroskedastic consistent standard errors. The results reveal that the delivery option is embedded into the futures price. For both corn and soybeans for all delivery months, the delivery option coefficient (β_2) is positive and significantly different from zero. More importantly, the values of β_2 are close to the theoretical value of 1.00. As a result, one cannot reject at the 5% level the hypothesis that this coefficient equals 1.00 for four of five corn regressions (March, May, July, and September) and for six of seven soybean regressions. The spot price coefficients are also large and positive, and are statistically different from 1.00 only for March soybeans.

The tables also report the F-statistic to test the hypothesis $\beta_1 = \beta_2 = 1$. This hypothesis is rejected at the 5% level for only May and December corn, and March soybeans. Finally, one cannot reject the hypothesis that $\beta_1 = \beta_2 = 1$ in the entire sample for soybeans. Although one can reject this hypothesis for corn, it is not rejected when the December data are excluded; the F-statistic in this case is 2.35. The results demonstrate that the delivery option is embedded in futures prices as theory predicts.

Given that in the sample period the CBT considered Toledo a safety valve delivery point, some may find it surprising that the delivery option coefficients are so close to their theoretical values. Since appreciable deliveries occurred in Toledo during this period, however, these results are plausible. Shorts delivered each commodity there in each year of the sample except for soybeans in 1985. During the sample period, 22.2%

[6]A list of excluded data points and the circumstances surrounding each episode is available from the authors on request.

TABLE I

Soybean Regressions (Robust Standard Errors in Parentheses)

Contract Month	α	β_1	β_2	β_3	F-Stat.	N	DW	R^2
Jan.	−2.5E-4	0.9507	0.8356	−6.97E-3	2.96	297	2.22	0.9426
	(2.78E-4)	(0.0287)	(0.1757)	(6.40E-3)				
Mar.	3.66E-5	0.8685	0.4142	−0.0220	15.47[a]	355	2.33	0.9662
	(2.57E-4)	(0.0322)	(0.1808)	(0.66E-3)				
May	1.22E-4	0.9797	0.8415	7.19E-3	2.39	378	2.30	0.9561
	(2.55E-4)	(0.0249)	(0.2788)	(5.40E-3)				
July	2.07E-4	1.037	0.9938	7.78E-3	0.311	373	2.14	0.9589
	(5.19E-4)	(0.0477)	(0.1739)	(3.65E-3)				
Aug.	1.82E-4	1.058	0.8658	0.01870	2.05	372	2.13	0.9472
	(5.36E-4)	(0.0717)	(0.1950)	(0.0130)				
Sep.	2.85E-4	1.2154	1.153	0.0465	0.58	372	2.18	0.8402
	(7.64E-4)	(0.2005)	(0.3320)	(0.0230)				
Nov.	−8.90E-4	1.0662	0.6881	0.0268	2.39	376	2.15	0.9197
	(5.14E-4)	(0.0678)	(0.1654)	(0.0120)				
All	−1.08E-5	0.9677	0.8002	7.08E-4	2.23	2523	2.14	0.9230
	(2.01E-4)	(0.0217)	(0.1253)	(4.43E-4)				

This table reports the parameter estimates for the following model:

$$\Delta \ln F^*(t) = \alpha + \beta_1 \Delta \ln S_c(t) + \beta_2 \Delta \ln Z(t) + \beta_3 r_c(t-1)(\tau+1) \Delta \ln S_c(t)$$

The column labeled "F-Stat" reports the F-statistic to test the hypothesis $\beta_1 = \beta_2 = 1$. This statistic has $(2, N)$ degrees of freedom, where N is the sample size. The column labeled "N" reports the number of observations for each regression; that labeled DW reports the Durbin–Watson statistic; and that labeled R^{-2} reports the adjusted R^2.

[a]Significant at the 5% level.

TABLE II

Corn Regressions (Robust Standard Errors in Parentheses)

Contract Month	α	β_1	β_2	β_3	*F-Stat.*	*N*	*DW*	R^2
Mar.	−3.66E-4	0.8779	0.6763	1.98E-3	2.16	356	2.14	0.8683
	(4.48E-4)	(0.0699)	(0.1695)	(0.0171)				
May	−7.32E-4	0.9753	0.7922	0.02493	1.23	376	2.09	0.8800
	(3.56E-4)	(0.0352)	(0.1398)	(8.87E-3)				
July	−1.23E-3	0.9353	0.9966	1.75E-3	0.87	373	2.19	0.9262
	(7.86E-4)	(0.0492)	(0.1594)	(1.25E-3)				
Sep.	5.314E-4	0.8749	1.328	0.0281	2.01	373	2.00	0.8342
	(7.09E-4)	(0.0972)	(0.2074)	(0.0115)				
Dec.	2.19E-3	0.8818	0.4293	0.0167	18.25[a]	372	1.93	0.8154
	(5.48E-4)	(0.0837)	(0.0965)	(0.0107)				
All	−2.47E-4	0.8845	0.7079	3.29E-4	38.08[a]	1850	2.00	0.8562
	(2.48E-4)	(0.021)	(0.0702)	(1.43E-4)				

This table reports the parameter estimates for the following model:

$$\Delta \ln F^*(t) = \alpha + \beta_1 \Delta \ln S_c(t) + \beta_2 \Delta \ln Z(t) + \beta_3 r_c(t-1)(\tau+1) \Delta \ln S_c(t)$$

The column labeled "*F*-Stat" reports the *F*-statistic to test the hypothesis $\beta_1 = \beta_2 = 1$. This statistic has $(2, N)$ degrees of freedom, where N is the sample size. The column labeled "*N*" reports the number of observations for each regression; that labeled *DW* reports the Durbin–Watson statistic; and that labeled R^{-2} reports the adjusted R^2.

[a]Significant at the 5% level.

of soybean deliveries and 17.8% of corn deliveries occurred in Toledo [Commodity Futures Trading Commission (1991), Table 8].

The somewhat superior performance of the models in the summer months suggests that measurement error is primarily responsible for the differences between the theoretical values of the coefficients implied by the delivery option model and the estimated parameters. Anderson (1985) shows that grain futures prices are more volatile in the summer months. If the variability of the measurement error is of similar magnitude in summer and winter/spring, one would expect to reject the model more frequently in the post-harvest months as the relative impact of measurement error is larger during this period. The results presented here are generally supportive of this hypothesis.[7]

These findings provide considerable support for the delivery option model. They are, moreover, somewhat stronger than those of Gay and Manaster. The coefficients on the quality option variable in their wheat regressions are typically considerably less than 1.00. Indeed, their parameter estimates are close to the theoretical value only for observations from the 30-day period prior to contract expiration. The estimates presented here include observations from the entire three-month period prior to contract expiration. Heavy trading occurs for each contract throughout this entire 90-day interval. Moreover, their estimated spot price coefficients are all significantly less than one while the coefficients reported here are almost always insignificantly different from one.

DELIVERY SPECIFICATION AND OUT-OF-POSITION HEDGING EFFECTIVENESS

The results of the preceding section demonstrate that the location option is a crucial determinant of corn and soybean futures prices. According to the analysis of the second section, this implies that hedging effectiveness depends upon delivery specification. This section presents simulation results that demonstrate that changes in the delivery specification can substantially affect hedging performance for both in-position and out-of-position hedgers. These results provide a striking illustration of how

[7]Reverse regressions of $\Delta \ln S_C(t) - \Delta \ln Z(t)$ against $\Delta \ln F^*(t)$ and $(\tau + 1)r_c(t - 1)\Delta \ln F^*(t)$ are estimated also to determine whether errors in measuring the spot price have appreciable effects on these results. In this specification, the theoretical value of the coefficient on the change in the futures price equals 1. This hypothesis is not rejected this hypothesis for any of the delivery months. Thus, it is possible that measurement error has some adverse effects on the estimates reported in Tables I and II.

changes in delivery specification can significantly improve the hedging performance of a futures contract for a spatial commodity.

Simulations are the most revealing way to examine the relation between delivery specification and hedging performance because ρ_{Fz} in (4) changes as the prices of the deliverables change. This is due to the fact that relative price changes alter the $w_i(t)$, which affects the correlation both directly and through its effect on the futures price volatility. There may be, therefore, no unique ranking by delivery specification of instantaneous hedging effectiveness at a particular location. For some price vectors, specification A may dominate specification B, while the opposite may be true for other vectors. Since the simulations compute measures of the hedging effectiveness of different delivery specifications over a wide range of prices, it is possible to determine whether one specification generally produces superior risk reduction even if it does not do so for all possible combinations of deliverable prices.

The pricing of corn and soybean futures contracts under the following three delivery specifications are examined.

1. The first specification is that employed by the Board of Trade prior to the end of 1993; Toledo delivery is discounted \$0.08/bu for soybeans and \$0.04/bu for corn. These discounts are fairly, large, and purposely so. Until recently the CBT intended delivery to occur at Toledo only in the event of congestion in Chicago; i.e., Toledo was a safety valve.
2. The second delivery system retains Chicago and Toledo as delivery points, but eliminates the Toledo discount for both corn and beans. That is, under the second specification, shorts may deliver both corn and soybeans in Toledo at "par". Since the average Chicago soybean (corn) price was roughly equal to the average Toledo soybean (corn) price during the 1984–1989 period, this is a two-point "economic par" delivery system because each location was nearly equally likely to be C.T.D.
3. The third delivery system adds St. Louis as an economic par delivery point for both corn and soybeans. Since St. Louis prices tend to exceed Chicago and Toledo prices by a wide margin it is necessary to give shorts a premium for deliveries in St. Louis to make it economical to deliver there. The analysis uses the average difference between the St. Louis and Chicago prices during the 1984–1989 period—\$0.10/bu for both corn and beans—as the premium. This system is somewhat more liberal than the one recently adopted by the CBT, which retains a discount for Toledo deliveries and which

specifies a smaller \$0.07/bu premium for St. Louis deliveries. The more liberal system is employed in the simulations to provide a more striking comparison of hedging effectiveness under different delivery systems.

The simulation design is as follows. On Wednesday of each week from 1984–1989 the averages of the high and low bid prices for spot corn and soybeans at Chicago, Toledo, and (for the third specification) St. Louis are determined. Using these prices and formula (1), the price of three synthetic futures contracts for both corn and soybeans which expire five weeks from that Wednesday are calculated (i.e., $\tau = 5/52$). The first synthetic futures price is calculated assuming delivery specification 1, the second assuming delivery specification 2, and the third assuming delivery specification 3.[8] Proceeding to the following Wednesday, the prices of the three synthetic futures contracts are calculated using the prices prevailing on that day and assuming $\tau = 4/52$. The logarithm of the ratio of the five-week-to-expiration to the four-week-to-expiration synthetic futures prices equals the percentage change in the futures price over the week long holding period.

For each Wednesday-to-Wednesday holding period, the percentage changes in the corn and soybean cash prices at several commercially important locations are also calculated. These locations are: Chicago, Toledo, St. Louis, Central Illinois, the Gulf of Mexico (NOLA), Central Iowa, Minneapolis, and Kansas City. Each is an important storage, processing, export or production point. A viable futures contract should hedge changes in spot prices at these locations. A particular synthetic futures contract delivery specification is superior to another if its hedging performance dominates that of the alternatives for a sufficiently large number of hedgers.

The R^2 of a regression of the percentage change in a spot price against the percentage change in a futures price equals the square of the sample correlation between these two variables, and is the most common measure of the hedging effectiveness of a contract. It is therefore possible to determine whether spot and futures prices are generally more highly correlated under one specification than another by comparing R^2's of regressions of the form:

$$\ln \frac{S_i(t)}{S_i(t-1)} = \alpha + \beta \ln \frac{F(t)}{F(t-1)} + \epsilon(t)$$

[8]It is assumed that futures contracts expire every week. In other words, the existing expiration cycle is not used.

where $S_i(t)$ is the spot price at location i at time t, $F(t)$ is a synthetic futures price, and $\epsilon(t)$ is a random error term. Since there are three synthetic futures prices, three regressions are run for each location. The hedging effectiveness of the competing synthetic contracts are ranked by comparing R^2's across these regressions. To determine whether relative hedging effectiveness varies over time, six sets of regressions are performed, one set for each of the years 1984–1989.

Table III (IV) reports the R^2's for the soybean (corn) regressions. In each table, rows labelled "1", "2," and "3" present hedging effectiveness estimates across the locations for delivery specifications 1, 2, and 3, respectively. These results reveal that liberalizing the delivery specification systematically improves hedging effectiveness outside of Chicago. For virtually every location for each year for each commodity, R^2's for specifications 2 and 3 exceed those for specification 1. Moreover, for all locations other than Chicago and Toledo, hedging effectiveness is almost always largest for specification 3. Indeed, while the gains in hedging effectiveness resulting from the elimination of the Toledo discount are frequently modest, the gains resulting from the adoption of a three-point economic par delivery system including St. Louis are often substantial. Furthermore, the hedging effectiveness ordering is very stable over time. Given this uniformity and stability, these results strongly suggest that the adoption of an economic par delivery system would have improved hedging effectiveness in 1984–1989 for virtually all hedgers outside of Chicago.

A simple nonparametric approach demonstrates that the consistency of superior hedging for specification 3 across years and locations is extremely unlikely to have resulted from chance. Assume under the null hypothesis that true hedging effectiveness for a particular location is equal for specifications 1 and 3, but in any finite sample the observed hedging effectiveness could differ between specifications due to sampling error. Under this null, in a collection of samples the hedging effectiveness of specification 1 would exceed that achieved under specification 3 about half the time, while specification 3 would dominate about half the time as well. For all locations out-of-position during the sample period (i.e., all points other than Chicago and Toledo), the R^2 for specification 3 exceeds that for specification 1 for 32 out of 36 observations for soybeans and 33 out of 36 observations for corn. One can, therefore, reject the equal effectiveness null at a confidence level of 1.6×10^{-8} for soybeans and 6.1×10^{-10} for corn.

These results are consistent with the implications derived in the preceding section. First, prices in Central Illinois, the Gulf, and the

TABLE III

Soybean Hedging Effectiveness under Alternative Delivery Specifications

Delivery Specification	*CHI*	*TOL*	*SL*	*CIL*	*GULF*	*MN*	*CIA*	*KC*
					1984			
1	0.986	0.977	0.941	0.949	0.951	0.952	0.957	0.966
2	0.906	0.991	0.935	0.948	0.940	0.942	0.958	0.963
3	0.899	0.977	0.971	0.971	0.940	0.934	0.974	0.943
					1985			
1	0.965	0.956	0.899	0.875	0.865	0.734	0.871	0.758
2	0.918	0.990	0.910	0.883	0.881	0.750	0.883	0.769
3	0.898	0.982	0.945	0.905	0.890	0.750	0.901	0.777
					1986			
1	0.896	0.890	0.775	0.855	0.803	0.640	0.694	0.644
2	0.833	0.943	0.789	0.861	0.814	0.658	0.693	0.638
3	0.788	0.953	0.860	0.883	0.841	0.673	0.740	0.643
					1987			
1	0.915	0.875	0.769	0.838	0.857	0.709	0.893	0.862
2	0.901	0.911	0.770	0.849	0.870	0.709	0.904	0.875
3	0.899	0.869	0.903	0.890	0.911	0.832	0.920	0.873
					1988			
1	0.993	0.982	0.964	0.922	0.959	0.921	0.974	0.958
2	0.985	0.986	0.964	0.923	0.961	0.923	0.976	0.961
3	0.977	0.965	0.992	0.959	0.976	0.959	0.989	0.976
					1989			
1	0.957	0.943	0.939	0.952	0.930	0.931	0.944	0.891
2	0.931	0.961	0.941	0.054	0.920	0.932	0.951	0.904
3	0.918	0.949	0.975	0.965	0.958	0.953	0.959	0.883

CHI = Chicago
TOL = Toledo
SL = St. Louis
CIL = Central Illinois
GULF = Gulf of Mexico (NOLA)
MN = Minneapolis
CIA = Central Iowa
KC = Kansas City
Reported statistic equals R^2 from a regression of percentage change in the spot price at the relevant location versus the percentage change in the simulated futures price for the relevant specification.
Specification 1. Chicago at par, Toledo at +8.
Specification 2. Chicago at par, Toledo at par.
Specification 3. Chicago at par, Toledo at par, St. Louis at −10.

TABLE IV

Corn Hedging Effectiveness under Alternative Delivery Specifications

Delivery Specification	*CHI*	*TOL*	*SL*	*CIL*	*GULF*	*MN*	*CIA*	*KC*
					1984			
1	0.975	0.603	0.458	0.518	0.448	0.510	0.493	0.431
2	0.946	0.663	0.485	0.551	0.479	0.527	0.514	0.471
3	0.901	0.655	0.639	0.656	0.622	0.625	0.560	0.558
					1985			
1	0.756	0.627	0.637	0.487	0.563	0.550	0.401	0.446
2	0.616	0.747	0.620	0.509	0.603	0.577	0.479	0.523
3	0.637	0.736	0.782	0.502	0.707	0.697	0.531	0.637
					1986			
1	0.961	0.850	0.669	0.722	0.711	0.646	0.580	0.536
2	0.930	0.894	0.678	0.730	0.727	0.665	0.581	0.548
3	0.720	0.774	0.960	0.919	0.892	0.823	0.643	0.563
					1987			
1	0.968	0.900	0.723	0.809	0.750	0.628	0.716	0.874
2	0.927	0.948	0.737	0.828	0.757	0.646	0.736	0.880
3	0.877	0.932	0.822	0.878	0.796	0.688	0.736	0.870
					1988			
1	0.998	0.960	0.911	0.959	0.892	0.935	0.947	0.891
2	0.994	0.968	0.913	0.963	0.896	0.937	0.951	0.896
3	0.982	0.967	0.962	0.975	0.901	0.955	0.966	0.890
					1989			
1	0.993	0.824	0.827	0.837	0.877	0.673	0.889	0.879
2	0.983	0.853	0.831	0.849	0.884	0.680	0.898	0.890
3	0.942	0.878	0.945	0.907	0.908	0.725	0.932	0.909

CHI = Chicago
TOL = Toledo
SL = St. Louis
CIL = Central Illinois
GULF = Gulf of Mexico (NOLA)
MN = Minneapolis
CIA = Central Iowa
KC = Kansas City

Reported statistic equals R^2 from a regression of percentage change in the spot price at the relevant location versus the percentage change in the simulated futures price for the relevant specification.

Specification 1. Chicago at par, Toledo at +4.
Specification 2. Chicago at par, Toledo at par.
Specification 3. Chicago at par, Toledo at par, St. Louis at −10.

other locations tend to be more closely related to Toledo and St. Louis prices than Chicago prices. Table V (VI) presents the R^2's of annual regressions of percentage soybean (corn) price changes at the out-of-position locations versus the percentage changes in soybean (corn) prices at Chicago, Toledo, and St. Louis, respectively. The Toledo and St. Louis R^2's systematically exceed the Chicago ones. This result reflects the fact that St. Louis and Toledo are currently more integrated into grain trading patterns than Chicago [Thompson, Hauser, and Eales (1990)]. Since the economic par system increases the weights of the former locations in the futures price relative to their weights in the safety valve system,

TABLE V

Soybean Percentage Price Change Squared Correlations

	SL	*CIL*	*GULF*	*MN*	*CIA*	*KC*
			1984			
CHI	0.882	0.888	0.962	0.961	0.927	0.949
TOL	0.942	0.953	0.918	0.950	0.947	0.950
SL	1	0.951	0.919	0.884	0.952	0.884
			1985			
CHI	0.867	0.843	0.825	0.608	0.829	0.687
TOL	0.882	0.857	0.882	0.606	0.886	0.776
SL	1	0.883	0.882	0.586	0.869	0.697
			1986			
CHI	0.770	0.717	0.616	0.528	0.608	0.523
TOL	0.636	0.813	0.792	0.662	0.647	0.503
SL	1	0.835	0.817	0.617	0.785	0.491
			1987			
CHI	0.789	0.757	0.846	0.782	0.881	0.851
TOL	0.897	0.795	0.882	0.777	0.894	0.855
SL	1	0.784	0.905	0.832	0.897	0.800
			1988			
CHI	0.901	0.927	0.954	0.811	0.965	0.951
TOL	0.933	0.955	0.967	0.860	0.960	0.962
SL	1	0.965	0.972	0.890	0.982	0.967
			1989			
CHI	0.813	0.831	0.923	0.710	0.928	0.767
TOL	0.848	0.910	0.900	0.794	0.929	0.820
SL	1	0.919	0.967	0.834	0.941	0.735

TABLE VI
Corn Percentage Price Change Squared Correlations

	SL	*CIL*	*GULF*	*MN*	*CIA*	*KC*
			1984			
CHI	0.380	0.411	0.437	0.537	0.328	0.403
TOL	0.446	0.506	0.463	0.485	0.423	0.505
SL	1	0.819	0.885	0.726	0.463	0.630
			1985			
CHI	0.565	0.428	0.417	0.430	0.502	0.398
TOL	0.575	0.531	0.646	0.603	0.626	0.542
SL	1	0.567	0.744	0.637	0.563	0.579
			1986			
CHI	0.632	0.691	0.645	0.607	0.552	0.529
TOL	0.594	0.660	0.685	0.670	0.669	0.607
SL	1	0.921	0.888	0.809	0.631	0.563
			1987			
CHI	0.672	0.758	0.713	0.567	0.668	0.817
TOL	0.715	0.820	0.722	0.640	0.764	0.825
SL	1	0.916	0.791	0.772	0.665	0.737
			1988			
CHI	0.905	0.952	0.886	0.930	0.939	0.883
TOL	0.929	0.979	0.928	0.929	0.971	0.911
SL	1	0.958	0.897	0.942	0.955	0.850
			1989			
CHI	0.815	0.816	0.958	0.658	0.872	0.860
TOL	0.815	0.886	0.835	0.688	0.890	0.900
SL	1	0.877	0.860	0.693	0.878	0.832

the simulated increase in hedging effectiveness reflects a closer match between the economic par specification and the current structure of grain flows.

Second, there is evidence that diversification also contributes to the superior hedging results achieved under specification 3. For example, spot-synthetic futures R^2's are frequently larger than the maximum of the R^2's from the regressions of the log difference of the spot price of interest on the log difference of each deliverable. Under specification 3, this occurs for 25 out of 30 (12 out of 30) observations for soybeans (corn) in Central Illinois, Central Iowa, Minnesota, and the Gulf of

Mexico. Moreover, there are occasions (such as for Minnesota and Kansas City soybeans in 1985) where hedging effectiveness improves even when low correlation delivery points are added, or delivery is made more economical at low correlation delivery points. These results are consistent with the conjecture made earlier that an economic par futures price is not affected as dramatically by idiosyncratic demand and supply shocks at any single point because it is an average of several prices. Instead, under the economic par specification, the futures price more accurately reflects systemic supply and demand conditions. This increases hedging effectiveness for out-of-position hedgers. Thus, an economic par system is more effectively integrated with the broader cash trade.

These results can be restated in terms of the basis. A high correlation between the prices at two points implies that the basis between these two points is stable. Adding to the delivery set a location with a price that is highly correlated with the price at location z therefore reduces the variability of the basis between the futures price and the spot price at location z. Moreover, reducing delivery point specific price noise through diversification also stabilizes the basis. Thus, the two effects simulated here reduce basis risk.[9]

In sum, the simulations demonstrate that the hedging performance of a futures contract on a spatial commodity depends crucially upon delivery specification. During the sample period, the movement to an economic par delivery specification on corn and soybean futures contracts would have improved hedging effectiveness (i.e., reduced basis risk) over wide ranges of deliverable prices for a number of commercially important locations. These results provide a striking illustration that an increase in the number of delivery points may do more than simply reduce the likelihood of long manipulation. A more expansive delivery specification may also dramatically improve the value of a futures contract as a risk management tool for spatially dispersed hedgers.

To evaluate fully the effects of more liberal delivery specifications, it is necessary to address several other issues. Most importantly, delivery specification changes may alter cash price distributions because traders

[9]A simulation analysis of the variance of the basis of the synthetic futures prices (not reported here) shows that the basis is less variable under delivery specification 3 than under specification 1. Indeed, the ordering of basis variance (from lowest to highest) is identical to the ordering of hedging effectiveness (from highest to lowest) for each location in each year. In principle, a cash settled contract tied to an average of spot prices at several locations could achieve the same results as the economic par futures contract; see Hauser, Thompson, and Chaherli (1992) for an analysis of cash settlement in corn and soybeans. The potential for manipulation of cash prices and price reports in the grain market makes cash settlement for these commodities problematic, however.

sometimes participate in the delivery process for reasons unrelated to cash market fundamentals (e.g., they may take large deliveries to circumvent foreign capital controls, or to squeeze the market). Such behavior can cause erratic movements in relative prices. This would tend to reduce correlations between spot prices in a newly designated delivery market and prices elsewhere, which would degrade hedging effectiveness. However, the addition of a new delivery point would also tend to increase correlations between prices at existing delivery points and prices at other locations, because it would reduce this "delivery pressure" at these existing locations. Thus, the net effect of adding delivery points on cash price distributions and hedging effectiveness is ambiguous. Pirrong et al. (1992) analyzed this issue in detail, and determined that changes in cash price distributions resulting from the adoption of delivery specification 3 would probably not off-set the improvements in effectiveness quantified here. Indeed, since Chicago is now a relatively isolated and small cash market which is vulnerable to this sort of trading (as compared to a market on the Mississippi, like St. Louis), it is plausible that this problem would actually decline in importance in an economic par system. This is true because the more liberal delivery specification would displace delivery pressure from a market where little trading occurs (Chicago), to a market where trading volume is large (St. Louis), thus further improving hedging effectiveness.

Changing delivery specification may have other effects. First, adding delivery points may reduce the likelihood of manipulation by large long traders, but increase the likelihood of manipulation by large short traders. Both types of manipulation can impair market liquidity and increase basis risk. Second, adding delivery points may reduce the value of the delivery mechanism as a means of merchandising the underlying commodity because it is difficult for shorts and longs to coordinate ownership transfers. Third, expanding the deliverable set transforms the futures contract into a market-basket security. This may reduce the severity of adverse selection problems that arise when some traders possess location-specific information,[10] and may improve liquidity as a result. Fourth, it may be costlier to arbitrage a contract with multiple deliverables than one requiring delivery at only a single location. Higher costs of arbitrage could lead to a noisier futures price, and lead to poorer hedging performance. Fifth, movement to an economic par delivery system could increase the value of the futures contract as a price

[10]Subrahmanyam (1991) demonstrates how the adoption of a market basket security can significantly reduce adverse selection costs.

discovery tool. That is, because an economic par futures price is a broader, more diversified index of value than a single delivery point price, it provides a more representative measure of prices across a large geographic area. This price is less influenced by location-specific demand and supply shocks, so it is a more reliable signal of value to traders located away from the delivery markets.

Finally, it is worth noting that the CBT apparently recognizes the potentially beneficial effects of liberalizing delivery specifications for grains, because in 1992 the exchange submitted to the Commodity Futures Trading Commission a proposal to allow delivery of corn and soybeans (as well as wheat) in St. Louis, beginning in late 1993, at a \$0.07/bu premium over Chicago. The CFTC has approved this proposal. This change in delivery specification provides institutional validation of the conclusions of this article.

SUMMARY, CONCLUSIONS, AND EXTENSIONS

This article investigates whether the option to delivery at Chicago or Toledo affects the price of the Chicago Board of Trade's corn and soybean futures contracts. It further examines how adding delivery points and adjusting delivery differentials for these contracts would affect pricing and hedging performance. The results are consistent with the theory of delivery options pricing. Corn and soybean futures prices are discounted by the value of the existing option to deliver at one of two locations, and the coefficients on the estimated location option in the futures price regressions are almost always insignificantly different from the theoretical value of one. Moreover, changes in delivery specification can markedly affect the value of futures contracts as risk management tools. In particular, the addition of delivery points leads to a diversification effect which frequently improves hedging effectiveness, while the addition of high correlation location as delivery points enhances hedging performance even further.

This analysis has significant policy implications for physical commodity futures markets. Most importantly, permitting delivery at several locations at differentials that reflect average price differences between these locations can dramatically alter the correlations between futures prices and spot prices at both deliverable and nondeliverable points. For the specific commodities examined over the sample period, these changes are decidedly beneficial. Reducing the discount for delivery at Toledo, and allowing delivery in St. Louis at a premium that reflects its usually higher spot price, improves corn and soybean hedging effectiveness systematically at several major production, consumption, and export points.

In sum, given the frequent controversy surrounding the delivery specifications of physical commodity contracts, these results and the methods used to derive them are of considerable practical importance. They show that the benefits of an economic par, multiple delivery point system may extend far beyond that traditionally considered—the deterrence of long manipulation. The fact that liquidity considerations drastically constrain the number of viable futures contracts for a particular commodity bolsters this conclusion. In most cases, a futures contract is a "one size fits all" proposition. A sophisticated choice of delivery points, grades, and differentials may create a contract that fits a diverse population of hedgers better than a single delivery point system. The ability to change such features, moreover, allows an exchange to adjust the price behavior of its contracts to reflect changes in the characteristics of the hedging population, and changes in the spatial pattern of cash market trading. The fact that CBT has recently liberalized its delivery rules for grains along the lines suggested here provides market evidence that these benefits can be significant.

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