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# Including Transport Rate and Rate Variability In Grain Hedging Decisions

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## ABSTRACT

Portfolio analysis has been demonstrated as a means of implementing grain hedging decisions that addresses the concerns of profit and managing risks. Absent from portfolio modelling, however, has been a consideration of transport rate and rate variability. The objective of this paper is to include transport rates in the portfolio framework. Three models are developed. The first model assumes that transport rates are ignored by the decision maker. The second includes rate expectations. The third allows for the forward contracting of transport services. Results indicate that including transport rates in the hedging decision framework will reduce, especially when expected future returns are negative, the portfolio recommended hedging ratio. It is also demonstrated that including transport rates increases expected and actual returns when compared to either the decision that neglects rates or the decision to fully hedge contracted quantity at a minimal increase in market risks. As is expected, the portfolio recommended hedges also significantly reduce the risk when compared to a strictly cash sales strategy.


## AN INTRODUCTORY EXAMPLE

In May, 1987, a barge loading elevator contracts with corn producers for harvest delivery at $1.72 per bushel. At the same time, the elevator, to hedge, sells December futures at $1.95. At harvest, the futures position is offset at $1.83 and the contracted corn is sold for Gulf export at $2.05. The net futures market gain is $0.12 ($1.95-$1.83). The cash market gain is $0.33 ($2.05-$1.72). The combined return is $0.45. Barge rates to the Gulf, however, have not been accounted for.

Barge rates, traded daily for immediate and forward delivery at the St. Louis Merchants Exchange, are quoted as a percentage of a benchmark tariff established in 1976. At Peoria, Illinois 100 percent of tariff is $4.81 per ton or $0.13 per bushel. In May, 1987, barge services for harvest delivery were trading at 168 percent of tariff (about 23 cents per bushel). The gain from contracting barges, when compared to the 1987 harvest delivery rate of 202 percent (27 cents), was 34 percent of tariff or $0.04 per bushel shipped. In the above example, the total return, including transport rates, increased from $0.18 to $0.22 because barge services were forward contracted.

It is not always the case, however, that hedging grain and contracting barges increases returns. The Gulf harvest price, the harvest futures quote, and harvest barge rates are variable. A similar decision made in May, 1988 would have allowed for a greater return, in total, about $0.38. However, included in this return is a $0.40 futures market loss and a $0.02 loss from forward contracting barge services. It is market risk such as this that makes marketing decisions difficult. An uncertainty that is surely compounded by the fact that decisions are made based upon expectations; that is, in May, harvest cash and futures prices and harvest rates are unknown.

Portfolio analysis has been used to consider the hedging decision in light of the trade-offs between market risks and returns.

> Minimum risk strategies (100% hedge) may have potential for profits, but this potential may be too small .... Alternatively, maximum profit strategies may be too risky and create such low returns that the firm cannot survive.(Luethold et al.)

The optimal hedge as derived within the portfolio framework seeks to balance return and risk considerations (Heifner,1973, and Peck,1975). Given an individual's aversion to risk, the optimal hedge suggests the combination (or portfolio) of cash and futures positions that will maximize expected returns. Although, the size of these maximized returns, on average, may not compare favorably to those expected from the more risky alternative, the consistency of returns, also required for firm survival, is more fully guaranteed. More recently, authors have included production risks (Rolfo, 1980), financial risks (Alexander, Musser, and Mason, 1986) and grain forward contracting (Miller, 1986) within the portfolio model.

The objective of this paper is to extend the portfolio framework to include transportation rates and rate variability. Three models are developed: 1) a model that captures cash and future market returns without considering transport rates, 2) a model that captures cash and future market returns given rates and rate variability and, 3) a model allowing forward contracting in the barge market. Data from 1981 to 1986 establish forecasts for hedging decisions made in 1987 through 1989. The optimal hedge of contracted quantity for each of seven months, March through September, is estimated. It is assumed the contracted grain is deliverable to Gulf export in October or November of the same year. Although this neglects storage, the method establishes a return that could be compared with the return from storing grain and transporting at a later period.

## DATA DEVELOPMENT

Portfolio analysis uses the variance and covariance between expectations of choice variables to indicate the risk associated with decisions. In this study, the choice variables are expected Gulf price, expected futures price and the transportation rate. Futures prices are, however, as variable as cash prices. Following Peck's example, variation in futures prices will be accounted for by recognizing that the futures price is equivalent to a local price adjusted for the basis. The basis is the difference between the cash and futures price at a specific location. The basis is considered to be more stable than either cash or futures prices because, first, the basis reflects local conditions that do not vary considerably between years, and, second, cash and futures prices react to the same information. The future price at which the elevator hedges and contracted price are known.

The Illinois Grain and Livestock Market News and local basis summaries developed by the Illinois Extension Service were the source for elevator contract and Chicago December futures prices. Mississippi Gulf FOB prices were collected from U.S. Grain and Livestock Market News. Illinois river rates for immediate and forward delivery are traded on the St. Louis Merchants Exchange.

The first step in determining variances and covariances of expectations is the development of models to predict unknown choice variables. Two forecasts, regression and point forecasts, were developed. Assuming the elevator chooses a forecast that works reasonably well, a decision is then made between the alternative forecasts. Table 1 presents summary statistics of the regression models developed for each choice variable. In this table the $R^2$ and F-statistics are presented.

Two types of models simulate simple forecasts based upon known information. First, models project choice variables given either past or current values. For example, the first entry in the table projects the upcoming Gulf harvest price (GHP) given last years Gulf harvest price (GHP1). Secondly, combinations of variables were used to reflect interyear variation of the choice variables. For example, the third entry projects GHP given last years Gulf harvest price (GHP1) and the difference between the current Gulf price and last years Gulf price for the same month (GCP-GCP1). As indicated, regression forecasts performed well in forecasting the upcoming Gulf harvest price. The fifth entry for Gulf price explained 77 percent of the price variation. The basis and rate regression forecasts, however, did not do as well. The $R^2$ are low and F-statistics insignificant. Point forecasts were developed for these variables. Based upon the Theil coefficients,[1] which measure the seriousness of prediction errors in such a way that when the coefficient equals zero, the error between the actual and predicted values is zero, the models selected to forecast the choice variables were:

a) for Gulf basis: point forecast using last year's harvest Gulf basis.

b) for rates: point forecast using last year's harvest rate.

c) for Gulf price: regression forecast with the upcoming Gulf harvest price as a function of last year's Gulf harvest price and the current Gulf price.

These forecasts required updating for the 1988 and 1989 crop seasons.[2] With each update, the prediction errors, and hence, the variance and covariances changed. The variance and covariance matrices are presented in Table 2.

## DEVELOPMENT OF OBJECTIVE FUNCTIONS

The first model assumes that transportation rates and variability are ignored by the decision maker. Expected returns, [E(R)], can be expressed as:

$$E(R)=(P^*-LP)Q+(F-(P^*-B^*))QH \qquad [1]$$

Where $P^*$ is the unknown harvest corn export price at Gulf ports, LP is the known cost of corn contracted prior to harvest, F is the known December futures price of corn prior to harvest, and $B^*$ is the expected Gulf corn basis defined as current Gulf price minus the December futures price. The expected harvest futures price is equivalent to $P^*-B^*$. Following the portfolio framework, expected returns [E(R)], is maximized subject

**TABLE 1**

**Summary Statistics for Forecasting Models**

| Choice Variable[a] | Independent Variables | $R^2$ | F-test[b] | Theil Coefficient[c] |
|---|---|---|---|---|
| GHP | GHP1 | .005 | 0.16 | .2365 |
| | GCP | .68 | 69.85 | .1343 |
| | GHP1, (GCP-GCP1) | .62 | 26.58 | .1453 |
| | GCP, (GHP1-GCP1) | .69 | 35.51 | .1321 |
| | GHP1, GCP | .77 | 52.43 | .1147 |
| GHB | GHB1 | .00 | 0.00 | .6317 |
| | GHBA | .17 | 6.82 | .7207 |
| | CGB, (GHB1-CGB1) | .07 | 1.16 | 1.1899 |
| | GHB1, (CGB-CGB1) | .003 | .05 | 1.1899 |
| | CGB | .05 | 1.76 | 1.2968 |
| HR | HR1 | .09 | 3.39 | .2818 |
| | MR | .00 | .02 | .4021 |
| | HR1, (MR-MR1) | .09 | 1.67 | .3276 |
| | MR, (HR1-MR1) | .07 | 1.24 | .3276 |
| | TR, (HR1-TR1) | .10 | 1.86 | .4781 |

[a] GHP = Gulf Harvest Price
GCP = Current Gulf Price
GHB = Gulf Harvest Basis
GHBA = Average GHB of the last three years
HR = Harvest Delivery Rate
MR = Current Delivery Rate
TR = Traded Rate (for harvest delivery)

A '1' after any variable means last year's value.

[b] Critical F-statistic at 99% confidence level for 1,33 df=7.48 for 2,32 df=5.35.

[c] Theil Coefficients from regression (GHP), point (GHB,HR).

to the Mean Square Error MSE(R) of returns or:

$$\text{Max } L = E(R) + (Z)*MSE(R) \qquad [2]$$

$$\text{and } MSE(R) = (Q-QH)^2\sigma_p^2 + QH^2\sigma_b^2 + 2QH(Q-QH)\,\sigma_{pb} \qquad [3]$$

Where $\sigma_p^2$ is the variance of the prediction error of Gulf prices, $\sigma_b^2$ is the variance of the prediction error of Gulf basis, and $\sigma_{pb}$ is the covariance between prediction errors of Gulf prices and basis. The variable Z is an unknown risk parameter which reflects the decision maker's preference for risk and is assumed to be negative for a risk adverse decision maker.

The second model explicitly introduces expected barge rates and rate variability into the objective function. The expected barge rate, T*, reduces expected cash returns and also impacts the MSE(R). The objective function is:

$$\text{Max } L = (P^*-LP-T^*)Q + (F-(P^*-B^*))\,QH + (Z) * MSE(R) \qquad [4]$$

The variance of transport rate expectations, $\sigma_t^2$, as well as the covariance of these expectations with price, $\sigma_{pt}$, and basis, $\sigma_{bt}$, affect the MSE(R).(see note 3).

**TABLE 2**

**Covariance Matrices Developed From Forecasts**

| Forecasting Period | | Covariance Matrix | | |
|---|---|---|---|---|
| | | GHP | GHB | HR |
| 1981-86 | GHP | 1060.72 | 160.05 | 45.42 |
| | GHB | | 219.85 | -6.02 |
| | HR | | | 37.12 |
| | | GHP | GHB | HR |
| 1981-87 | GHP | 900.03 | 141.15 | 36.47 |
| | GHB | | 221.99 | 1.33 |
| | HR | | | 31.79 |
| | | GHP | GHB | HR |
| 1981-88 | GHP | 1094.61 | 113.82 | 41.00 |
| | GHB | | 195.55 | -2.60 |
| | HR | | | 29.51 |

The third model allows forward contracting in the barge market. The objective function incorporates two additional variables. The difference between the predicted barge rate (T*) and the traded barge rate (TR) represents the expected gain, if positive, or loss, if negative, from forward contracting barge services. When multiplied by the quantity forward contracted at the traded rate (QT), expected transport returns are determined. With these additions, the objective function is:

$$\text{Max } L = (P^*\text{-}LP\text{-}T^*)Q + (F\text{-}(P^*\text{-}B^*))\,QH + (T^*\text{-}TR)QT + (Z)^*MSE(R) \quad [5]$$

In addition to the variance of transport rate expectations, $\sigma_t^2$, and the covariance of these expectations with price, $\sigma_{pt}$, and basis, $\sigma_{bt}$, the quantity forward contracted to barge, QT, will also impact MSE(R) (see note 4).

## DEVELOPMENT OF OPTIMAL HEDGE

Heifner points out that without knowledge of Z, the decision maker's preference for risk, direct maximization of the objective functions would not be possible. He does, however, demonstrate that for firms "with the same mix of production activities, the same set of profit expectations and profit variances and covariances, a single estimate of an optimum hedging level may apply." This seems reasonable in this case, since barge loading facilities would be reacting to the same futures and Gulf prices and exhibit per unit handling margins that would not be expected to vary greatly because of either similar firm characteristics and/or competitive pressures. Furthermore, as pointed out by Peck, "the optimal hedge (is in large part) proportional to the amount produced." In this case, although contract prices are readily available, contracted quantities are not. Heifner, does however, demonstrate that the optimal hedging ratio, QH/Q, can be estimated from first order conditions obtained when the objective function is maximized as follows:

$$QH/Q = \frac{FR\sigma_c - CR\sigma_{cf}}{CR\sigma_f - FR\sigma_{cf}} \quad [6]$$

Where: FR = futures return
CR = cash returns
$\sigma_c$ = variance of cash returns
$\sigma_f$ = variance of futures return
$\sigma_{cf}$ = covariance between cash and futures returns

The optimal hedging ratios as estimated in this paper have a similar structure. In the first model, where transport rates and variability are not considered, the optimal hedging ratio[5] is:

$$QH/Q = \frac{(F\text{-}P^*+B^*)\sigma_p^2 + (P^*\text{-}LP)(\sigma_p^2\text{-}\sigma_{pb})}{(P^*\text{-}LP)(\sigma_p^2+\sigma_b^2\text{-}2\sigma_{pb}) + (F\text{-}P^*+B^*)(\sigma_p^2\text{-}\sigma_{pb})} \quad [7]$$

or given the above general notation:

$$FR = F\text{-}P^*+B^* \quad [7a\text{-}7e]$$

$$CR = P^*\text{-}LP$$

$$\sigma_c = \sigma_p^2$$

$$\sigma_f = \sigma_p^2+\sigma_b^2\text{-}2\sigma_{pb}$$

$$\sigma_{cf} = \sigma_p^2\text{-}\sigma_{pb}$$

The second model includes transport rate and variability but does not allow for forward contracting of barge services. In terms of the general notation:

$$FR = F\text{-}P^*+B^* \quad [8a\text{-}8e]$$

$$CR = P^*\text{-}LP\text{-}T^*$$

$$\sigma_c = \sigma_p^2+\sigma_t^2\text{-}\sigma_{pt}$$

$$\sigma_f = \sigma_p^2+\sigma_b^2\text{-}2\sigma_{pb}$$

$$\sigma_{cf} = \sigma_p^2\text{-}\sigma_{pb}\text{-}\sigma_{pt}+\sigma_{bt}$$

Future returns and variability are not affected by the introduction of transport rates and variability. Adjustments in cash returns (CR), the variability of cash returns ($\sigma_c$) and, hence the covariance of cash and futures returns $\sigma_{cf}$, result from the introduction of transportation rates.

To determine the optimal hedge ratio when forward contracting for barge services is allowed requires the substitution of QT, as determined from first order conditions, into the partial derivatives of the objective function with respect to QH and Q. The general structure of the optimal hedge ratio, however is not affected. In model three,

$$FR = F\text{-}P^*+B^* + \frac{TR(\sigma_{pt}\text{-}\sigma_{bt})}{\sigma_t^2} \quad [9a\text{-}9e]$$

$$CR = P^*\text{-}LP\text{-}T^* + \frac{TR(\sigma_t^2\text{-}\sigma_{pt})}{\sigma_t^2}$$

$$\sigma_c = \sigma_p^2+\sigma_t^2\text{-}2\sigma_{pt} - \frac{(\sigma_t^2\text{-}\sigma_{pt})^2}{\sigma_t^2}$$

$$\sigma_f = \sigma_p^2+\sigma_b^2\text{-}2\sigma_{pb} - \frac{(\sigma_{pt}\text{-}\sigma_{pb})^2}{\sigma_t^2}$$

$$\sigma_{cf} = \sigma_p^2\text{-}\sigma_{pb}\text{-}\sigma_{pt}+\sigma_{bt} + \frac{(\sigma_{pt}\text{-}\sigma_{pb})(\sigma_t^2\text{-}\sigma_{pt})}{\sigma_t^2}$$

Both cash and futures returns and variability are adjusted to account for the covariance of transport rates with cash and futures returns, respectively. For example, the covariance between cash returns and transport rates is $(\sigma_t^2\text{-}\sigma_{pt})$. The covariance between future returns and transport rates is equal to $(\sigma_{pt}\text{-}\sigma_{bt})$.

## RESULTS

The expected monetary returns, given the forecasting techniques developed earlier, are presented in Table 3. These expected returns highlight a number of considerations to keep in mind as results are reviewed. First, futures returns, F-P*+B*, with few exceptions, are negative in both 1987 and 1989. In 1988, futures returns are positive. The average of these returns are -16.45 cents in 1987, 10.43 cents in 1988, and -25.44 cents in 1989. A risk averse manager, given these expectations, might be thought to avoid hedging and therefore the negative expected returns in 1987 and 1989. It must be remembered, however, that both the upcoming Gulf price and the Gulf basis are subject to variability. Hedging may still be advisable. Second, considerable price appreciation is expected for cash returns, P*-LP.

**TABLE 3**

**Predicted Monetary Returns, 1987-1989[a]**

| Year | Month | P*-LP | P*-LP-T* | F-P*+B* | T*-TR |
|---|---|---|---|---|---|
| | | cents/bushel | | | |
| 1987 | MAR | 43.81 | 23.53 | -12.31 | -2.19 |
| | APR | 42.27 | 21.98 | -12.57 | -2.95 |
| | MAY | 47.62 | 27.33 | -18.82 | -2.40 |
| | JUN | 42.54 | 22.26 | -14.04 | -1.29 |
| | JUL | 52.16 | 31.88 | -22.96 | -1.65 |
| | AUG | 48.35 | 28.06 | -18.25 | -1.94 |
| | SEP | 46.66 | 26.37 | -15.66 | -2.61 |
| 1988 | MAR | 35.92 | 13.93 | 9.28 | -4.10 |
| | APR | 27.76 | 5.76 | 17.84 | -1.34 |
| | MAY | 22.18 | 0.19 | 23.22 | -2.92 |
| | JUN | 41.31 | 19.32 | 9.89 | -2.00 |
| | JUL | 41.80 | 19.80 | 9.60 | -5.18 |
| | AUG | 42.51 | 20.51 | 5.29 | -1.30 |
| | SEP | 50.51 | 28.52 | -2.11 | 0.45 |
| 1989 | MAR | 69.03 | 43.20 | -22.53 | -0.66 |
| | APR | 67.32 | 41.49 | -22.82 | 0.58 |
| | MAY | 79.03 | 53.20 | -35.23 | 2.99 |
| | JUN | 73.58 | 47.74 | -29.58 | 1.97 |
| | JUL | 60.02 | 34.19 | -17.02 | 1.82 |
| | AUG | 55.79 | 29.95 | -16.79 | 2.69 |
| | SEP | 49.36 | 23.53 | -15.26 | 2.85 |
| 1987 | MEAN | 46.20 | 25.92 | -16.37 | -2.14 |
| 1988 | MEAN | 37.43 | 15.43 | 10.43 | -2.34 |
| 1989 | MEAN | 64.88 | 39.04 | -22.75 | 1.75 |
| 87-89 | MEAN | 49.50 | 26.80 | -9.56 | -1.50 |

[a] P* = expected Gulf harvest price
LP = local contracted cash price
T* = expected harvest barge rate
F = current Dec. corn futures price
B* = expected Gulf harvest basis
TR = current traded barge rate for harvest delivery

The average expected cash returns are 46.2 cents in 1987, 37.4 in 1988, and 64.9 cents in 1989. This return, however, neglects transportation rates. Accounting for expected barge rates, T*, reduces expected cash returns. It is this return that must cover handling charges and allow for elevator profits. The term, T*-TR, is the expected return received from forward contracting barge services. The average expected return is negative in 1987 and 1988, but positive in 1989.

The optimal hedge ratios as estimated from the three models developed in this paper are presented in Table 4. In this table, Model 1 refers to the model in which a hedge is made without consideration of transport rate and variability. In Model 2, the decision maker

**TABLE 4**

**Comparison of Optimal Hedge Ratios, 1987-1989**

| Year | Month | Optimal Hedge Ratios[a] Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| | | % | | |
| 1987 | MAR | 85.2 | 62.4 | 55.2 |
| | APR | 84.5 | 57.6 | 36.0 |
| | MAY | 79.6 | 41.5 | 17.5 |
| | JUN | 83.0 | 50.4 | 43.9 |
| | JUL | 76.9 | 35.5 | 21.8 |
| | AUG | 80.6 | 47.6 | 36.3 |
| | SEP | 82.8 | 55.1 | 41.0 |
| 1988 | MAR | 95.7 | 98.0 | 96.5 |
| | APR | 100.7 | 109.8 | 110.9 |
| | MAY | 104.1 | 118.4 | 118.4 |
| | JUN | 95.4 | 96.1 | 97.4 |
| | JUL | 95.2 | 95.8 | 94.0 |
| | AUG | 93.2 | 92.1 | 94.0 |
| | SEP | 89.3 | 84.0 | 88.1 |
| 1989 | MAR | 84.0 | 68.6 | 71.7 |
| | APR | 83.5 | 66.5 | 72.4 |
| | MAY | 78.8 | 55.9 | 67.5 |
| | JUN | 80.9 | 60.5 | 69.6 |
| | JUL | 85.5 | 70.2 | 78.8 |
| | AUG | 84.9 | 65.7 | 78.0 |
| | SEP | 84.6 | 57.5 | 75.1 |
| 1987 | MEAN | 81.8 | 50.0 | 36.0 |
| 1988 | MEAN | 96.3 | 99.2 | 99.9 |
| 1989 | MEAN | 83.2 | 63.6 | 73.3 |
| 87-89 | MEAN | 87.1 | 70.9 | 69.7 |

[a] Model 1 = Transportation variability excluded
Model 2 = Transportation variability included
Model 3 = Forward barge contracting allowed

recognizes transport rate and variability, and in Model 3, forward contracting of barge services is allowed.

Three conclusions can be drawn from this table. First, the optimal hedge ratio varies by model, that is, recognizing transport rates and their variability will impact the grain elevators hedging decision. For example, in March, 1987, the recommended hedging ratio from Model 1 is 85.2 percent of contracted quantity. Model 2 recommends 62.4 percent and Model 3, 55.2 percent. For the three year forecasting period, barge rate and rate variability reduces the recommended hedge of contracted quantity from 87 percent to about 70 percent. Second, the hedging ratios vary between years. In 1988, the mean hedge ratio is greater than 95 percent regardless of model. Expected futures returns were positive in this year. In 1987 and 1988, given negative expected futures returns, the recommended hedge is much smaller. And third, in general, the optimal hedge ratios are less than 100 percent. In other words, it is not recommended that the entire contracted quantity be hedged.

The difference between models during a given year can be partially explained by the predictions shown in Table 4. Expected transport rates not only decrease the predicted cash return, but also impact the relative contribution of cash and future returns to total returns. This is especially important when reviewing Models 1 and 2. For example, the cash return, without regard to transport rate, in March, 1987 is 43.8 cents. Including the expected transport rate reduces cash returns to 23.5 cents. An expected futures loss of 12.3 cents would offset, to a greater degree, the smaller cash return and the hedging ratio is correspondingly smaller. In March, 1988, on the other hand, the expected futures returns of 9.3 cents adds a greater proportion to total expected returns when cash returns are 13.9 cents, and transport rates included, than when cash returns are 35.9 cents. The hedging ratio would be expected to increase, and in general, for 1988, with positive futures returns, it does.

The difference between Model 2 and Model 3 depends upon the contribution of transport returns (T*-TR) to total expected returns. The sign of the expected transport return is important. In 1987, expected transport returns are negative, in 1989, positive. In general, the hedging ratio decreases from Model 2 in 1987, and increases in 1989. In addition, the magnitude of the expected transport gain or loss must be considered. For example, in April, 1987, expected transport losses are 2.9 cents (see Table 4), the optimal hedging ratio declines about 21 percent. In August, 1987, an expected transport loss of 1.9 cents causes the hedging ratio to decline by 11 percent. The opposite occurs in April and May of 1989. The increase in the hedging ratio is larger in May because the expected positive transport return is larger. It is also the case that the small covariance between the basis and transport rates, $\sigma_{bt}$ ( -1.6 averaged over 1987-1989, see table 2), means that expected futures returns are adjusted, mathematically, to a greater degree than expected cash returns when the optimal hedge is solved for in the third model.[6] The hedging ratio declines to a greater degree from Model 2 in 1987 when both expected futures and transport returns are negative than in 1988 when only transport returns are negative. In 1989, the positive transport returns lessen the impact of negative futures returns on total returns and the hedging ratio increases.

The expected monetary return associated with a given strategy are presented in Table 5. To aid comparison, expected harvest transport rates of 20.3 cents per bushel in 1987, 22 cents in 1988 and 25.8 cents in 1989 are subtracted from the recommended hedge returns for Model 1. In other words, the decision maker is assumed to hold the same barge rate expectations as in the other models; these expectations are not, however, incorporated into the hedging decision. Expected returns assuming the elevator hedges 100 percent of contracted quantity and a no hedge strategy are also presented. In March of 1987, the expected return from the optimal hedge was 13.04 cents per bushel for Model 1, expected returns were 15.84 cents and 16.73 cents for Models 2 and 3, respectively. The expected returns from the full hedge and no hedge strategies were 11.21 and 23.53 cents, respectively. In general, the difference between Model 2 and Model 3 are small. The small difference results because the major change in expected returns occurs once cash returns are reduced by transport costs and the hedging ratio adjusted. For example, average expected returns are about 4 cents larger when barge rates are included in the decision framework. Except for 1987, Model 3, the optimal hedge, regardless of the model, reduced the risk associated with marketing corn, as indicated by STD, the standard deviation of returns, from the no hedge strategy. Over the three year period, the strategies that included transport rates exhibited greater returns, about 7 cents, when compared to the full hedge, while increasing market risks by about 1 cent per bushel. On the other hand, market risks were reduced by a full 4 cents per bushel from the no hedge strategy at a sacrifice of 3.5 cents in monetary returns. Viewing the three year averages, however, masks some important considerations. Certainly average returns are higher for the more risky no hedge alternative, but for particular decisions (May, 1988, for example), no hedge returns are expected to be approximately zero. Furthermore, it appears that decisions made in 1989 contribute to the higher returns of the more risky strategy. These are, however, expected returns and there is no guarantee that the optimal hedges will perform as well after the fact; that is, after the optimal hedge ratios are initiated.

The actual market returns, if the optimal hedge had been taken and held to harvest, are presented in Table 6. These returns are determined from actual harvest cash and futures prices and rates as they occurred in each year. In general, the expected return is less than the actual in 1987, but greater in 1988 and 1989. The differences are due to the fact that actual prices and basis did not equal their expectations.[7] The optimal hedge strategies still significantly reduced risk from the no hedge strategy on average about 15

**TABLE 5**

**Comparison of Expected Market Returns, In Cents Per Bushel, From Optimal, Full, and No Hedge Strategies 1987-1989**

| | | Optimal Hedge Returns[a] | | | | |
|---|---|---|---|---|---|---|
| Year | Month | Model 1 | Model 2 | Model 3 | Full Hedge | No Hedge |
| 1987 | MAR | 13.04 | 15.84 | 16.73 | 11.21 | 23.53 |
| | APR | 11.36 | 14.74 | 17.45 | 9.41 | 21.98 |
| | MAY | 12.34 | 19.53 | 24.03 | 8.51 | 27.33 |
| | JUN | 10.60 | 15.18 | 16.09 | 8.21 | 22.26 |
| | JUL | 14.22 | 23.72 | 26.88 | 8.91 | 31.88 |
| | AUG | 13.35 | 19.37 | 21.43 | 9.81 | 28.06 |
| | SEP | 13.41 | 17.75 | 19.95 | 10.71 | 26.37 |
| 1988 | MAR | 22.81 | 23.02 | 22.88 | 23.20 | 13.93 |
| | APR | 23.74 | 25.36 | 25.54 | 23.60 | 5.76 |
| | MAY | 24.35 | 27.67 | 27.69 | 23.40 | 0.19 |
| | JUN | 28.75 | 28.82 | 28.95 | 29.20 | 19.32 |
| | JUL | 28.95 | 29.00 | 28.83 | 29.40 | 19.80 |
| | AUG | 25.45 | 25.39 | 25.49 | 25.80 | 20.51 |
| | SEP | 26.63 | 26.74 | 26.66 | 26.40 | 28.52 |
| 1989 | MAR | 24.27 | 27.74 | 27.03 | 20.67 | 43.20 |
| | APR | 22.43 | 26.31 | 24.97 | 18.67 | 41.49 |
| | MAY | 25.43 | 33.50 | 29.43 | 17.97 | 53.20 |
| | JUN | 23.81 | 29.85 | 27.15 | 18.17 | 47.74 |
| | JUL | 19.64 | 22.24 | 20.78 | 17.17 | 34.19 |
| | AUG | 15.70 | 18.92 | 16.86 | 13.17 | 29.95 |
| | SEP | 10.62 | 14.76 | 12.07 | 8.27 | 23.53 |
| 1987 | MEAN | 12.62 | 18.02 | 20.37 | 9.54 | 25.92 |
| | STD | 1.17 | 2.93 | 3.73 | 1.03 | 3.31 |
| 1988 | MEAN | 25.81 | 26.57 | 26.57 | 25.86 | 15.43 |
| | STD | 2.23 | 1.99 | 2.00 | 2.46 | 8.94 |
| 1989 | MEAN | 20.27 | 24.76 | 22.61 | 16.30 | 39.04 |
| | STD | 4.99 | 6.02 | 5.85 | 3.89 | 9.61 |
| 87-89 | MEAN | 19.57 | 23.12 | 23.19 | 17.23 | 26.80 |
| | STD | 2.80 | 3.65 | 3.86 | 2.46 | 7.29 |

[a] Model 1 = Transportation variability excluded
Model 2 = Transportation variability included
Model 3 = Forward barge contracting allowed

**TABLE 6**

**Comparison of Actual Market Returns From
Optimal, Full, and No Hedge Strategies
1987-1989**

| | | Optimal Hedge Returns[a] | | | | |
|---|---|---|---|---|---|---|
| Year | Month | Model 1 | Model 2 | Model 3 | Full Hedge | No Hedge |
| 1987 | MAR | 29.05 | 31.57 | 32.37 | 27.40 | 38.50 |
| | APR | 25.85 | 26.28 | 26.63 | 25.60 | 27.20 |
| | MAY | 22.12 | 17.27 | 14.23 | 24.70 | 12.00 |
| | JUN | 22.26 | 18.15 | 17.33 | 24.40 | 11.80 |
| | JUL | 27.21 | 30.97 | 32.22 | 25.10 | 34.20 |
| | AUG | 29.26 | 34.80 | 36.70 | 26.00 | 42.80 |
| | SEP | 28.94 | 32.20 | 33.86 | 26.90 | 38.70 |
| 1988 | MAR | 19.05 | 17.63 | 18.60 | 16.42 | 77.92 |
| | APR | 16.41 | 11.42 | 10.85 | 16.82 | 71.82 |
| | MAY | 14.56 | 7.40 | 7.36 | 16.62 | 66.82 |
| | JUN | 21.19 | 21.38 | 21.73 | 22.42 | -4.28 |
| | JUL | 20.62 | 20.85 | 20.12 | 22.62 | -19.18 |
| | AUG | 17.57 | 17.33 | 17.73 | 19.02 | -2.28 |
| | SEP | 17.44 | 16.36 | 17.21 | 19.62 | -0.68 |
| 1989 | MAR | 6.98 | 6.49 | 6.59 | 7.50 | 4.30 |
| | APR | 6.11 | 6.73 | 6.52 | 5.50 | 9.20 |
| | MAY | 7.06 | 9.51 | 8.28 | 4.80 | 15.50 |
| | JUN | 8.53 | 12.30 | 10.61 | 5.00 | 23.50 |
| | JUL | 6.90 | 9.96 | 8.24 | 4.00 | 24.00 |
| | AUG | 5.36 | 12.16 | 7.81 | 0.00 | 35.50 |
| | SEP | 0.08 | 8.88 | 3.18 | -4.90 | 27.50 |
| 1987 | MEAN | 26.38 | 27.32 | 27.62 | 25.73 | 29.32 |
| | STD | 2.88 | 6.52 | 8.03 | 1.03 | 11.89 |
| 1988 | MEAN | 18.12 | 16.05 | 16.23 | 19.07 | 27.16 |
| | STD | 2.17 | 4.66 | 4.81 | 2.46 | 39.50 |
| 1989 | MEAN | 5.86 | 9.43 | 7.32 | 3.12 | 19.92 |
| | STD | 2.52 | 2.14 | 2.11 | 3.89 | 10.06 |
| 87-89 | MEAN | 16.79 | 17.60 | 17.06 | 15.98 | 25.47 |
| | STD | 2.52 | 4.44 | 4.98 | 2.46 | 20.48 |

[a] Model 1 = Transportation variability excluded
Model 2 = Transportation variability included
Model 3 = Forward barge contracting allowed

cents, and offered higher returns at similar risk when compared to the full hedge strategy. More particularly, note that the quite variable actual returns in 1988, from positive and large in the first three months to negative in the remainder of the year, are avoided when the optimal hedge strategies are implemented.

## CONCLUSIONS

Profitable marketing decisions and the management of market risks are two important concerns of grain handlers. Higher returns seem to be gained only with the consequence of more variable returns and reducing risks through strategies such as hedging 100 percent of cash commitments, over time, are less favorable return-wise. The portfolio framework seeks a balance between risk and return. In this paper the general portfolio framework was extended to include transport rates and rate variability. Although this work was limiting in that it did not include the storage function of grain elevators, it was demonstrated that including transport rates and rate variability in hedging decisions will affect the portfolio recommended hedge. In particular, when expected futures returns are negative, failure to recognize transportation rates would cause the decision maker to hedge a larger than required proportion of cash commitments. Over the forecasting period it was demonstrated that expected returns, and actual returns, are higher when transport rates are included in the hedging decision framework compared to either a strategy that followed an optimal hedge, but neglected rate variation, or a full hedge strategy. It was also demonstrated that including transport rates and rate variability in the hedging decision framework significantly reduced the market risks when compared to a no hedge strategy.

## ENDNOTES

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1. The Theil coefficient (U) is defined as:

$$U^2 = \frac{\Sigma (P_i - A_i)^2}{\Sigma A_i^2}$$

where $P_i$ is the predicted value for period i, $A_i$ is the actual value that occurs in i.

2. The regression equations used to forecast Gulf price are:

1987: GHP = 61.14 -.4765 (GHP1) + 1.16 (GCP) $R^2$=.77

1988: GHP = 68.04 -.4856 (GHP1) + 1.15 (GCP) $R^2$=.79

1989: GHP = 89.92 - .4648 (GHP1) + 1.20 (GCP) $R^2$=.72

3. The MSE(R) for this model is equivalent to:

$$MSE(R) = (Q-QH)^2\sigma_p^2 + QH^2\sigma_b^2 + 2QH (Q-QH)\sigma_{pb} + Q^2\sigma_t^2 - 2QQH\sigma_{bt} - 2Q\,(Q-QH)\,\sigma_{pt}$$

4. The MSE(R) for this model is equivalent to:

$$MSE(R) = (Q-QH)^2\sigma_p^2 + QH^2\sigma_b^2 + 2QH (Q-QH)\,\sigma_{pb} + Q^2\sigma_t^2 - 2QQH\sigma_{bt} - 2Q\,(Q-QH)\sigma_{pt}$$

$$+QT^2\sigma_t^2 - 2QT\,(Q-QH)\,\sigma_{pt} + 2QQT\sigma_t^2 - 2QQH\sigma_{bt} - 2QTQH\sigma_{bt}$$

5. Derivations of the optimal hedge ratios are quite lengthy, but are available, as well as derivations of the MSE(R), from the authors upon request.

6. For example, in March, 1987 $\sigma_t^2$-$\sigma_{pt}$ is equal to -8.2 and $\sigma_{pt}$-$\sigma_{bt}$ equals 51.4. Mathematically the adjustment to cash returns increases cash returns for computational purposes from 23.5 to 24.0 cents. Futures returns are adjusted from -12.3 to -15.4 cents. The more negative futures returns offsets to a greater degree the cash returns than the offset in Model 2.

7. Average actual(predicted) cash returns were, in cents per bushel, 28.5(25.9), 28.0(15.4), and 15.3(39.0) for 1987, 1988, and 1989, respectively. Average actual (predicted) futures returns were -2.7(-16.4), -9.0(10.4), and -9.9(-23.0) for the same years.

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