Price Pooling and the Gains from Hedging: Application to a Swedish Grain Cooperative

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Abstract

Optimal hedging strategies are analyzed for a cooperative operating a price pooling system in the presence of price and quantity risk. A three-period model, accounting for default risk and storage, is developed. Hedging allows the cooperative to increase the pool price offered to the farmers by 2.8 - 4% for moderate risk parameters.

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1. Introduction

ODAL is a farmer-owned cooperative, representing about 30,000 farmers in central Sweden[1]. As a result of recent mergers, ODAL now markets about 70 percent of Swedish wheat. ODAL operates a price pooling system on behalf of its members: all farmers who commit wheat to the pool earn the same price, based on the prospective average of sale prices. Price pooling is a feature of other grain-marketing systems, notably Canada's. However, the Swedish case differs in two important aspects. First, participation is voluntary, as Swedish wheat-farmers have access to other market outlets. Second, ODAL announces its pool price before the bulk of its wheat has been sold. This is in contrast to the practice of the Canadian Wheat Board, which fixes its final pool price up to 18 months after the start of a marketing year.

Although ODAL has not yet incorporated wheat futures in its trading strategy, it is beginning to examine the potential gains from hedging in offshore futures markets (i.e., CBOT, LIFFE and MATIF). Future liberalization of the CAP, induced by expanding EU membership and budget constraints, is likely to bring about higher levels of volatility in European grain markets (Brassley, 1997). In this environment, gains from hedging are likely to become more pronounced.

This paper analyzes optimal hedging strategies in the context of a price pooling system. A conceptual model is used to derive optimal marketing strategies, with and without hedging. Using empirical price data, the model is used to quantify the potential impact of hedging on the pool price offered by ODAL to Swedish farmers.

The analysis is based on a three-period optimization problem. The cooperative can market cash wheat in each period. In the first period, corresponding to pre-harvest, the quantity of wheat handled by the pool is unknown; in the second period this uncertainty is resolved and the cooperative announces its pool price. Hedge positions can be established in either of the first two

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[1] ODAL was founded in 1996 by a merger of three small-sized cooperatives in the middle part of Sweden. In January 1, 2001, ODAL merged with seven other farmer-owned cooperatives into the Swedish Farmers' Cooperative, (Svenska Lantmännen). Their core competency remains the same, which is to supply patrons with production inputs (seeds, fertilizers, feed, etc) and to market grains and oilseeds. This study focuses on the grain intake market area originally served by ODAL.

periods. In the third period hedge positions are closed and remaining grain inventories are liquidated at prevailing cash prices. The cooperative seeks to maximize the pool price offered to farmers subject to a risk constraint. This limits the chance that the cooperative will default on its obligation to farmers due to adverse price movements.

The plan of the paper is as follows. The next section provides some brief background on ODAL's price pooling system. The third section presents the conceptual model of marketing and hedging decisions. Data used in the analysis are described in the fourth section. Model results are presented in the fifth section. The paper concludes with a short discussion of implications.

2. Background on Price Pooling

ODAL operates three different pricing systems for wheat: a weekly spot price system, various grower contracts, and the pool system (Sintorn, 1997). Spot prices are announced on a weekly basis and are paid for grain delivered immediately. However, spot prices are usually lower than prices offered in the other two systems. Grower contracts allow specific business arrangements between the cooperative and its patrons, with prices arrived at through negotiation. Contracting gives ODAL some latitude in its dealings with large producers. The pool system has accounted for nearly two thirds of the grain handled by ODAL in recent years (Table 1).

Within a marketing year, ODAL can offer several pools in succession. The first pool is announced during the growing season and is closed at a predetermined date after harvest. When the first pool is closed, a second pool is opened; and when the second pool is closed (some months hence), a third is opened. In practice, most grain handled by ODAL is committed in the first pooling period, although farmers may have an incentive to defer sales if they expect higher prices in later periods.

Table 1. Grain Handled by ODAL, 1997-1999.

Grain	Total quantities	Share of total quantity	Share of total	Share of total

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Marketing Year	handled by ODAL each year (in million metric tons)	delivered during the first pool period: Delivery from Aug. to Oct. in M metric ton.	quantity delivered under the remaining pool periods	quantity delivered spot and through misc. contracts
1997	1,75	63%	27%	10%
1998	1,40	64%	26%	10%
1999	1,10	64%	26%	10%

Source: Karlsson 1999.

In the analysis that follows, we focus on the operation of the first pool offered during a marketing year. It should be borne in mind that ODAL does not know the quantity that will be marketed until the pool is closed. The pool price is fixed when the pool is closed, and in advance of most grain sales. If the proceeds from grain sales exceed the amount guaranteed to farmers, the extra revenue is returned to coop members (and not limited to participants in a particular pool) in the form of patronage refunds.

3. Conceptual Model

To assess the potential impact of hedging on ODAL's pooling system, we frame a three-period optimization problem. The first period is pre-harvest, when quantities committed to the pool are not yet known. In the second period, which is post-harvest, pool quantities are known, and the price paid to farmers is fixed by ODAL. Marketing and hedging decisions are made in each of the first two periods. In the final period, ODAL liquidates its remaining positions in grain and futures, and the profit or loss on pool operations is determined.

ODAL's objective is to maximize the expected price paid to producers (SEK per ton), subject to a risk constraint. Let Z_t denote the expected price in period t. In period 1, this is simply a planning price; in period 2, ODAL actually fixes the price to producers. In both periods (t=1,2) ODAL solves:

$$\text{Max } Z_t \tag{1}$$

Subject to

$$\Pr ob\left\{ R - Z_t \cdot Q \geq 0 \right\} \geq 1 - a \tag{2}$$

where R is marketing revenue for the pool (million SEK), Q is the quantity of grain marketed by the pool (million tons), and α is the chance of the pool defaulting on its obligation to farmers. The risk constraint (2) has a deterministic equivalent

$$E_t(R) - Z_t \cdot E_t(Q) - K_\alpha \cdot [V_t(R - Z_t \cdot Q)]^{1/2} \geq 0 \qquad (3)$$

where $E_t(\cdot)$ is the expectation operator conditional on period-t information; $V_t(\cdot)$ is the variance operator conditional on period-t information; and K_α is the number of standard deviations associated with a specified probability of default.[2] Marketing revenue is defined

$$R = \delta^2 P_1 X_1 + \delta P_2 X_2 + P_3 X_3 + \delta H_1(F_2 - F_1) + H_2(F_3 - F_2) \qquad (4)$$

where δ is a compounding factor; P_t is the cash price (SEK/ton) in period t; X_t is the quantity sold (million tons) in period t; H_t is the hedge placed in period t (million tons), with $H_t < 0$ implying sale of futures; and F_t is the futures price (SEK/ton) in period t. Market revenue (valued in period 3) includes the proceeds from cash grain sales as well as profits or losses on futures transactions. The difference between market revenue and the amount promised to producers is the patronage refund. If the cooperative pays too high a pool price, pool members will have to refund money to the cooperative. For the sake of simplicity, we assume that ODAL does not charge a handling fee.

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[2] This is a variant of chance-constrained or stochastic programming, see Taha (1976). Chance constrained programming is described in Taha in context of operations research (pp. 588-592).

Grain sales can occur in each of the three periods,

$$Q = X_1 + X_2 + X_3 \tag{5}$$

although the quantity available for sale, Q, is not known until period 2.

There are three sources of uncertainty in the model: cash prices, futures prices, and the pool quantity. By assumption, cash prices evolve according to

$$P_t = b_0 + b_1 P_{t-1} + e_t \tag{6}$$

where b_0 and b_1 are coefficients and e_t is a random disturbance. In line with Kamara (1982) and Myers and Hanson (1996), futures prices are assumed to follow a random walk,

$$F_t = F_{t-1} + f_t \tag{7}$$

with disturbance f_t. Uncertainty about the pool quantity is represented by

$$Q = E_1(Q) + u_2 \tag{8}$$

where u_2 is a forecast error revealed in period 2. The errors (e_t, f_t, and u_2) are assumed to be multivariate normal with zero mean, and are uncorrelated across time. Contemporaneous (positive) correlations exist between e_t and f_t, the errors for cash and futures prices. Correlations may also exist between u_2 and the price errors, for reasons discussed below.

The solution to the overall problem involves backward induction. First, optimal decision rules must be derived for period 2, when pool quantity is known. Then decision rules for period 2 can be embedded in the optimization problem for period 1.

In period 2, first-order conditions for ODAL's optimization problem yield two different strategies. ODAL could store any unsold grain in period 2 and place a futures hedge (Strategy A). Alternately, the cooperative could sell its grain immediately and store nothing until period 3 (Strategy B).

A) Store grain and hedge $\begin{cases} X_2 = 0 \\ X_3 = Q - X_1 \\ H_2 = -X_3 \cdot (\sigma_{ef} / \sigma_f^2) \end{cases}$

B) Sell grain, store nothing $\begin{cases} X_2 = Q - X_1 \\ X_3 = 0 \\ H_2 = 0 \end{cases}$

The choice between these two strategies will depend on price relationships observed in period 2 and the expected returns to storage. ODAL would be indifferent between strategies (A) and (B) under the following condition:

$$\delta P_2 = E_2 P_3 - K \sqrt{\frac{-\sigma_{ef}^2 + \sigma_f^2 \sigma_e^2}{\sigma_f^2}} \tag{9}$$

that is, if the (compounded) period 2 cash price equals the expected period 3 price less a risk adjustment. Here σ_{ef} denotes the covariance of cash and futures prices, σ_f^2 is the variance of futures price, and σ_e^2 is the variance of the cash price. Substituting $P_2 = b_0 + b_1 P1 + e_2$ and $E_2(P_3) = b_0 + b_1 P_2$, equation (10) solves for the critical value of e_2 that leaves ODAL indifferent between strategies (A) and (B).

$$e_2^* = -\frac{1}{\delta - b_1} \left(-b_0 + (\delta - b_1)(b_0 + b_1 P_1) + K \sqrt{\frac{-\sigma_{ef}^2 + \sigma_f^2 \sigma_e^2}{\sigma_f^2}} \right) \tag{10}$$

The probability that ODAL will elect to store and hedge (Strategy A) in period 2 is

$$Prob(A) = \Phi\left(\frac{e_2^*}{\sigma_e}\right) \tag{11}$$

where Φ denotes the standard normal cdf. The probability that ODAL will elect to sell its remaining cash grain in period 2 (Strategy B) is

$$Prob(B) = 1 - \Phi\left(\frac{e_2^*}{\sigma_e}\right) \tag{12}$$

The larger is K, the risk parameter, the less likely is storage with deferral of grain sales to period 3.

Now consider the period-1 decision problem. ODAL seeks to maximize Z_1 subject to risk constraint (3). Choice variables include X_1 (cash grain sale), H_1 (hedge position), and Z_1 (expected pool price). The risk constraint requires specifying the expected value of pool revenue less payout ($R - Z_1 \cdot Q$), and variance of the same. These are given by

$$E_1(R - Z_1 \cdot Q) = \operatorname{Prob}(A) \cdot E_{1/A}(R - Z_1 \cdot Q) + \operatorname{Prob}(B) \cdot E_{1/B}(R - Z_1 \cdot Q) \qquad (13)$$

and

$$\begin{aligned}
V_1(R - Z_1 \cdot Q) &= \operatorname{Prob}(A) \cdot V_{1/A}(R - Z_1 \cdot Q) + \operatorname{Prob}(B) \cdot V_{1/B}(R - Z_1 \cdot Q) \\
&+ \operatorname{Prob}(A) \cdot [E_{1/A}(R - Z_1 \cdot Q) - E_1(R - Z_1 \cdot Q)]^2 \qquad (14) \\
&+ \operatorname{Prob}(B) \cdot [E_{1/B}(R - Z_1 \cdot Q) - E_1(R - Z_1 \cdot Q)]^2
\end{aligned}$$

where $E_{1/A}$ and $E_{1/B}$ are conditional expectations, and $V_{1/A}$ and $V_{1/B}$ are conditional variances, given indicated price relationships in period 2. Equation (14) indicates that the variance of ($R - Z_1 \cdot Q$) equals the mean of conditional variances plus the variance of conditional means (Lindgren, 1976). Formulas for conditional expectations and variances given a truncated normal distribution are found in Greene (p.899 and 927).

4. Data and Parameter Estimates

Data required for the analysis include cash wheat prices (P_t) and wheat futures (F_t). As there are no suitable official spot price quotes for wheat from the Swedish grain market, we sought prices from a related market. A relevant markets for the Swedish grain trade is the French market in Rouen, one of the largest grain markets in the EU (Tkaczyk, 1999). Swedish milling wheat is of higher quality than the standard grade traded at Rouen, but transport cost differentials are assumed to be relatively stable (Sintorn 1999)[3].

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[3] Formally, we can describe the price relationship as in ($P_S = P_R + Prem - Trans$); where P_S is the spot price for Swedish grain, P_R is the spot price for Rouen grain, *Prem* is the quality premium for Swedish grain and *Trans* represents the transportation cost parameter from Rouen to a Swedish harbor.

Currently, there are two wheat futures contracts traded on European futures exchanges, namely the LIFFE feed wheat futures and the MATIF milling wheat futures. However, little historical data are available for the MATIF contract, which started trading in 1998. Therefore, this study uses futures quotes from the nearest-to-mature LIFFE feed wheat contract. The contract size is 100 metric tons and the price is quoted in British pounds (GBP). Bridge in Stockholm provided the futures data (1999). LIFFE operates wheat futures with five maturing months: January, March, May, July, September, and November.

Our model does not explicitly account for fluctuations in exchange rates. Instead, we convert all prices to quarterly averages in Swedish currency (SEK/ton) at prevailing exchange rates. [4]

Using data from October 1993 to September 1999, the following equation was estimated by OLS (t-ratios in parentheses):

$$P_t \quad = \quad 80.6136 \quad + \quad 0.9274 \ P_{t-1} \quad + \quad 0.7648 \ \Delta F_t \tag{15}$$
$$ (1.121) (15.790)^* (7.241)^*$$

* significant at 1% level \qquad R-squared: 0.932 \qquad 24 observations

where ΔF_t is the first difference of futures prices. The coefficient on ΔF_t can be interpreted as a minimum-variance hedge ratio under the maintained hypothesis that futures evolve as a random walk (Myers and Thompson). For purposes of forecasting, (15) collapses to (6) with $b_0 = 80.6136$ and $b_1 = 0.9274$. Let Let v_t denote the residual from (15). Thus, the cash price error e_t is constructed as

$$e_t = v_t + .7648 * \Delta F_t \tag{16}$$

for our 1993-98 sample. With $f_t = \Delta F_t$, the correlation between e_t and f_t is .845 in this period. The variance-covariance matrix of e_t and f_t is shown below.

$$
\begin{bmatrix} \sigma_e^2 & \sigma_{ef} \\ \sigma_{ef} & \sigma_f^2 \end{bmatrix} = \begin{bmatrix} 3814 & 3564 \\ 3564 & 4659 \end{bmatrix}
$$

The expected pool quantity, $E_1(Q)$, is fixed at 1.5358 million tons. This is based on a 70 percent market share for ODAL, planted hectares for 2000 and trend yields (Statistics Sweden 1999). The standard deviation of u_2 (the quantity forecast) is based on residuals from a trend yield model, scaled to reflect actual planted hectares and the assumed 70 percent market share: $\sigma_u = 0.1186$.

Correlations between u_2 and the price errors, e_2 and f_2, are unknown; however, negative correlations seem plausible. Farmers who observe a price increase between periods 1 and 2 might choose to defer their sales to ODAL.[5] Conversely, if prices should fall between periods 1 and 2, farmers would have a greater incentive to commit their grain to the pool (to claim part of ODAL's higher average price). For purposes of sensitivity analysis, correlations between u_2 and price errors are varied in the analysis reported below.

5. Model Results

The base case for our analysis reflects a number of assumptions that can be briefly summarized. The initial cash price for grain sold by ODAL (P_1) is fixed at 1000 SEK/ton. To ensure a positive expected return to storage[6], an adjustment is made to the intercept in price equation (6). The adjusted intercept is $b_0^* = b_0 + 35$. With a quarterly interest rate of 1.5 percent, this implies an expected real price increase of about 2.6 percent in period 2 and period 3. The risk

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[4] Thompson and Bond (1987) present a hedging model that explicitly accounts for exchange rate fluctuations. They conclude from the derived solution that it is not possible to determine effects of exchange rate fluctuations on the optimal hedge ratio.

[5] Recall that ODAL can open several pools in succession during a marketing year. Subscriptions to the second pool begin when the first pool is closed, and so on.

[6] If expected returns to storage are insufficient, ODAL sells all its cash grain immediately. With cash price risk largely eliminated, there is little incentive to hedge.

parameter is set at K=1. Given (10) and (11) and the price adjustment, this implies Prob(A)=.053, or a 5.3 percent chance of storage between periods 2 and 3. The correlations between u_2 and e_2, and between u_2 and f_2, are fixed at -.2 in the base case.

Results for the period-1 decision variables are shown in Table 2.

Table 2. Base Case Results.

Variable		Units	Value
Z_1	Expected pool price	SEK/ton	1029.1
X_1	Physical sales	Million tons	0.187
H_1	Sales of futures	Million tons	-0.991

The optimal solution calls for an immediate cash sale of 0.187 million tons and a short futures position of 0.991 million tons. Since the expected pool quantity is 1.5358 million tons, the hedge ratio (HR) for unsold grain is

$$HR = \frac{-H_1}{E_1(Q) - X_1} = \frac{0.991}{1.5358 - 0.187} = 0.734$$

Note that this is smaller than the minimum-variance hedge ratio implied by regression equation (15).

Figures 1 and 2 show the effects of alternative parameter values on model results. The correlation between price and quantity forecast errors are allowed to vary between 0 and –0.8 (as compared to –0.2 in the base case). The figures also show the effect of a larger price adjustment than assumed in the base case. Expectations of higher cash prices ($b_0^* = b_0 + 50$) in periods 2 and 3 result in lower hedge ratios (Figure 1), as well as higher expected pool prices (Figure 2). Hedge ratios also decline as the correlation increases, in absolute value, between price and quantity forecast errors.
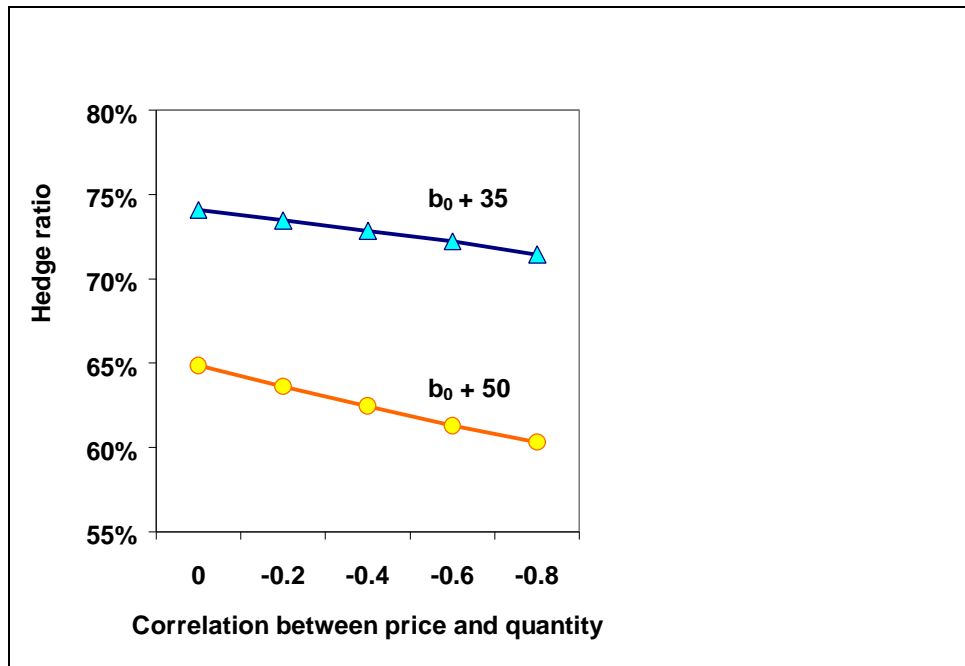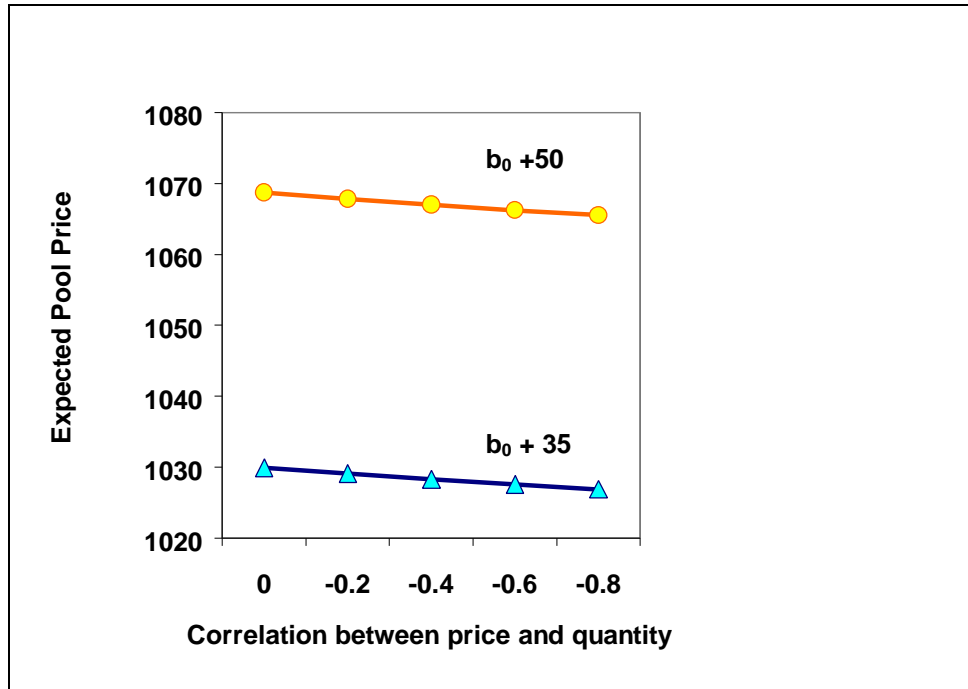
Figure 1. Impact of Price Expectations on Hedge Ratio

Figure 2. Impact of Price Expectations on Expected Pool Price

To measure the impact of hedging on expected pool price, it is necessary to compare model results with and without hedging. In the constrained model, hedging is not allowed ($H_1 = H_2 = 0$). First-order conditions for the period-2 problem are modified accordingly. The term under the radical in (10) is replaced by σ_e^2, and probabilities of period-2 storage (11) and sales (12) are revised to reflect the greater risk associated with cash grain positions. Storage is discouraged, and expected pool price is lowered, relative to the unconstrained case. Optimal values for this case are displayed in Table 3:

Table 3. Results for Period 1 in the Case of No Hedging.

Variable		Units	Value
X_1	Physical sales	Million tons	1.494
H_1	Sales of futures	Million tons	0
Z_1	Expected pool price	SEK/ton	1027.4

Table 4 shows the impact of hedging for different values of K, the measure of risk sensitivity. The base case corresponds to K equal to one. With higher values of K, the probability of period-2 storage goes to zero,[7] and the contribution of hedging to ODAL's expected pool price is inconsequential. However, at lower levels of risk sensitivity (K=0.5), hedging increases the expected pool price by 2.8 percent.

Table 4. Impact of hedging with different levels of risk sensitivity.

K: Risk Sensitivity	Prob(A): Probability of Period-2 Storage		Z_1 (SEK / ton): Expected Pool Price			%Δ in Z_1 due to hedging
	with hedging	No hedging	with hedging	no hedging	difference	
0.5	.924	.110	1060.2	1031.3	28.9	2.8
1.0	.053	.001	1029.1	1027.4	1.7	0.2
1.5	.001	.001	1026.4	1025.9	0.5	0.0
2.0	.001	.001	1024.7	1024.5	0.2	0.0

The impact of hedging is more pronounced when there are higher expected returns to storage. In Table 5, two different price scenarios are compared. The first (+35) corresponds to the base case, and the second (+ 50) represents a larger expected price increase in periods 2 and 3. In the latter case, hedging results in a 4% higher expected pool price.

Table 5. Impact of hedging with different expected returns to storage.

Price Adjustment	Prob(A): Probability of Period-2 Storage		Z_1 (SEK / ton): Expected Pool Price			%Δ in Z_1 due to hedging
	with hedging	No hedging	with hedging	no hedging	difference	
+ 35	.053	.001	1029.1	1027.4	1.7	0.2
+ 50	.819	.001	1067.8	1027.4	40.6	4.0

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[7] To avoid computational errors, a lower bound of 0.001 is placed on Prob(A).

Thus far we have only discussed optimal values of choice variables in period 1. However, the distribution of outcomes in the second and third periods is also of interest and can be evaluated through simulation techniques. Specifically, we take 5,000 random drawings of the disturbance terms in equations (6) through (8) and simulate the impacts of optimal strategies by ODAL. The procedure for simulating error terms is described by Johnson and Wichern (1998). Parameters for the base case are unchanged: the risk parameter K is kept at unity, and the add-factor for price adjustments remains at 35.

Optimal strategies for period 1 are the same as those shown in Table 2. For period 2, the optimal strategy[8] depends on the realization of price disturbances. Strategy A (store grain and hedge) exposes ODAL to continuing price risk, while Strategy B (store nothing) involves liquidating the remaining grain inventories. If Strategy A is pursued, there is a chance that market revenues will not be sufficient to cover ODAL's price commitment (in which case, patronage refunds will be negative in period 3). If Strategy B is pursued, the pool price can be set equal to the average of market revenues, and patronage refunds are zero. The results are compared with hedging and without hedging. Results from the 5,000 iterations on the (period 2) pool price and (period 3) patronage refund are shown in Tables 6 and 7 below.

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[8] Relevant decision rules for X_2 (cash grain sales), H_2 (hedge position), and Z_2 (pool price) under each strategy are derived from the period-2 optimization problem. Details are available from the authors.

Table 6. Simulated Period-2 Pool Prices and Patronage Refunds.

| | With Hedging | | Without Hedging |
	Pool price Z_2	Patronage Refund PR	Pool Price Z_2
Mean	1055.0	0.17	1029.9
Standard Deviation	28.30	9.15	5.48
Kurtosis	0.11	53.40	5.66
Skewness	0.12	0.07	-0.77
Minimum	956.5	-116.3	990.9
Maximum	1177.5	98.4	1054.5

When hedging is allowed, the average period-2 pool price is 2.4 percent higher than otherwise.   When hedging is not allowed, the patronage refund is zero because no risks remain in period 3.   Note that the period-2 pool price has a lower standard deviation when hedging is not allowed.   The reason is that in the absence of futures markets, ODAL markets a larger volume in the first period when the cash price is known. When hedging is allowed, ODAL assumes greater risk in order to realize a higher expected price (through storage).

The period-2 pool price is not normally distributed in either case (with hedging allowed, or hedging not allowed).[9] The positive skewness value for Z_2 (with hedging) indicates that its distribution has an extended right-hand tail. This is in contrast to Z_2 (without hedging), which is characterized by negative skewness.

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[9] The Anderson-Darling test of the null hypothesis of normality is rejected at a high level of significance.

6. Concluding Remarks

This paper presents a multi-period model of price pooling that accounts for both price and quantity uncertainty. The analysis focuses on the potential gains from hedging in the context of a cooperative's price pooling system. When hedging is allowed, a lower share of grain is sold at harvest in the cash market. Simulation results show that the distribution of pool prices also changes considerably when the cooperative is allowed to hedge its cash grain position.

As discussed in Carter (1984), price risk exposure at the farm level originates as early as the time of planting in the spring. Therefore, to take full advantage of hedging within a price pooling system, it is desirable to extend the planning horizon backwards to spring. An alternate route would involve forward contracts between the cooperative and farmer-patrons, signed early in the planting season; this would also reduce the cooperative's uncertainty about quantities to be marketed.

Incorporating hedging in ODAL's marketing strategy will pose a challenge to managers, who to this point have little direct experience with futures markets. Equally important, patrons must accept the new cooperative marketing strategy—a point emphasized by Fulton, Popp and Gray (1998). Buccola and Subaei (1985) add another dimension to the problem on how the cooperative should develop pricing systems. If members are heterogenous in terms of their risk preferences, features of some pooling arrangements might not be acceptable to all patrons. The

latter aspects form an interesting topic for future research of how to optimally manage price pools for subsets of member categories.

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