Staff Paper P90-49

Staff Papers Series

July 1990

RISK MANAGEMENT FOR LIVESTOCK PRODUCERS:

HEDGING AND CONTRACT PRODUCTION

John Lawrence
and
Michael S. Kaylen

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St. Paul, Minnesota 55108

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John D. Lawrence
Department of Agricultural and Applied Economics
University of Minnesota

and

Michael S. Kaylen
Department of Agricultural Economics
University of Missouri

Livestock producers operate in a dynamic and uncertain environment. Their decisions are implemented at specific times in the ongoing production process and are influenced by two stochastic variables, production and price. Production risk is due to stochastic growth rate and feed efficiency; market risk results from uncertain output prices. Since both production and price uncertainty impact net revenue, both must be incorporated into the decision making process.

Several methods exist for managing both production and market risk. Production risk can be reduced by improved animal management. The impact from market risk may be reduced via hedging in the futures market. However, an alternative way to avoid both types of risk is to not own the animals (custom or contract feeding). While the production and market price uncertainty still exists, it has been transferred to another party.

Previous Research

Previous studies have examined the use of hedging in the futures market as a response to price uncertainty: Peck; Leuthold and Peterson; and Holt, et al. These studies suggest that routine hedging does not reduce year-to-year variability in producer revenue, but that strategically placed and lifted hedges can result in higher net returns than straight hedging and lower variability than straight cash sales.

Contract feeding became more common during the 1980s as hog producers looked for a low risk way to market their production expertise and facilities. This decision is consistent with safety-first behavior for a producer concerned with the long run survivability and profitability of his farming operation. Safety-first models were examined earlier by Roy, Telser and Kataoka, and more recently by Atwood, Watts and Helmers (1985 and 1988). This model assumes that returns are maximized subject to a constraint on the maximum probability of failing to achieve an arbitrarily stated goal, i.e., farm mortgage payment. Safety-first behavior is typically modeled via chance-constrained programming (Charnes and Cooper).

Dynamic programming (DP) is often used to model livestock selling decisions and diet selection (Hochman; Yager et al.; Karp, et al.; and Rodriguez and Taylor). At least two studies have modeled hog production as a dynamic process (Chavas, et al.; and Glen). Both studies modeled production as deterministic and strictly affected by diet selection, the control variable. While they do solve for the optimal diet and market weight, the impact of risk on the producer's decisions is ignored.

The research reported here models a hog finishing operation to determine the optimal ownership and hedging decisions under stochastic prices and production. The ownership decision is whether to own or custom feed the hogs. Although a full range of contractual agreements may exist (Zearing and Beals), only a zero risk, pen rental agreement will be considered here. Hedging decisions are revised at the start of each stage and allow the producer to reduce his exposure to market risk. Thus, for a given level of animal management, how can custom feeding and hedging be used to maximize long-term returns while maintaining an acceptable level of risk?

Chance Constrained Stochastic Dynamic Programming Model

Dynamic programming explicitly incorporates the sequential nature of the decision making process. The 10-year planning horizon is divided into 120 monthly stages. At the beginning of each stage the producer decides (1) whether to place pigs and, if so, whether to custom fed or own them and (2) whether to revise his futures market position.

Production is modeled as though hogs enter the building at the start of stage n weighing 50 pounds and are fed for NP stages. Because risk management is the primary interest of this study, average daily gain and feed efficiency are assumed nonstochastic until the start of phase NP+1, when the animals randomly enter one of the NW weight classes. Hogs are then sold and new placement decisions are made.

The state vector at the beginning of stage n, X_n, contains the number of groups of hogs in phase of production i (i=2,...,NP) under each management strategy (custom fed, XC, not hedged XO, and hedged, XH); and the number of hedged and unhedged groups in weight class k (k=1,..,NW), $XHWT_n^k$ and $XOWT_n^k$, respectively. In addition, the producer's financial position impacts the optimal management decision and is treated as a state variable, XM_n. Five discrete cash balances from -$20,000 to $60,000 in $20,000 increments were selected. Cash hog, feed, and feeder pig prices at the beginning of a stage are correlated and are treated as a single price vector contained in state variables, XP_n (Table 1). Relevant futures prices are assumed to be perfectly correlated with cash hog prices.[1]

The decision vector at stage n is denoted by D_n. Placement decisions are the number of groups to place as owned unhedged (DO_n), owned hedged (DH_n), and custom fed (DC_n). Hedging decisions are the

[1] This simplification can be justified because rollover hedging is used and the nearby futures price is highly correlated with cash price.

Table 1. Price Vectors and Markovian Price Transition Matrix Identified by Cluster Analysis, 1977-1987

Vector	Feed	Feeder Pig	Cash Hog
1	2.62	12.12	16.37
2	1.69	13.10	15.51
3	1.99	19.43	20.08
4	2.79	22.79	24.30
5	3.60	18.77	22.13

Markovian Price Transition Matrix

i/j	1	2	3	4	5
1	0.9235	0.0410	0.0205	0.0075	0.0075
2	0.0214	0.9422	0.0214	0.0075	0.0075
3	0.1095	0.1095	0.7662	0.0075	0.0075
4	0.0425	0.0074	0.0074	0.9353	0.0074
5	0.0074	0.0074	0.1630	0.0074	0.8148

Note: Prices are deflated by CPI-W (1967=100)
Units of measure: Feed, $/cwt.; pigs, $/head; and hogs, $/cwt.

number of groups in phases of production i to hedge (DH_n^i), and to lift hedges from (DL_n^i).

There are also constraints on the model. First, let NP=5 and NW=3, then the capacity constraint, NG, is

$$(1)\quad \Sigma_{i=2}^{5}(XO_n^i + XH_n^i) + \Sigma_{i=2}^{5} XC_n^i + DO_n + DH_n + DC_n \le NG.$$

Second, no speculation is allowed in the futures market,

$$(2)\quad DH_n^i \le XO_n^i\ ; \quad DL_n^i \le XH_n^i \qquad\qquad i = 2,...,5.$$

Third, a chance constraint on the operating net worth (ONW) will monitor the producer's financial health with respect to this facility.[2] The

[2] Operating net worth is defined as the sum of the producer's cash balance dedicated to this unit and the value of owned hogs in the facility.

chance constraint limits the probability of a large decrease in the producer's ONW from the beginning of one stage to the next to some acceptable level, say ". Now define * as the maximum acceptable percentage loss in the producer ONW. Thus, the chance constraint compares ending and beginning ONW,

(3a) $\text{Prob}\ (ONW_e \le (1 - *) * ONW_b) \le$ " $\quad$ if $ONW_b > 0$.

(3b) $\text{Prob}\ (ONW_e \le ONW_b) \le$ " $\quad$ if $ONW_b \le 0$.

Decisions that violate the constraint are infeasible. Should all possible decisions be infeasible, the decision set with the probability nearest to " is selected.

Deterministic transition equations define the movement of hogs in production phases one through NP,

(4) $XC^2_{n-1} = DC_n, \quad XO^2_{n-1} = DO_n, \quad XH^2_{n-1} = DH_n$

(5) $XC^{i+1}_{n-1} = XC^i_n \qquad i = 2, 3, 4$

(6) $XO^{i+1}_{n-1} = XO^i_n - DH^i_n + DL^i_n \qquad i = 2, 3, 4$

(7) $XH^{i+1}_{n-1} = XH^i_n - DL^i_n + DH^i_n \qquad i = 2, 3, 4.$

Stochastic transition equations explain the movement of hogs from phase NP to one of the NW weight classes. Let D_k be the probability that a group in phase NP at the start of stage n enters weight class k at the start of stage n-1. Then the expected number of hogs in a weight class is,

(8) $E(XOWT^k_{n-1}) = D_k(XO^{NP}_n - DH^{NP}_n + DL^{NP}_n) \qquad k = 1,...,NW$

(9) $E(XHWT^k_{n-1}) = D_k(XH^{NP}_n + DH^{NP}_n - DL^{NP}_n) \qquad k = 1,...,NW.$

The price vector is assumed to follow a Markov process (Table 1). The Markovian transition probabilities were estimated using cluster analysis to locate closely related price vectors (Everitt). The probability that an observed vector moved from cluster i at the start of stage n to cluster j at the start of stage n-1 is represented by Markovian matrix element S_{ij}.

The single stage return from each management strategy is a function of state and decision vector and consists of the following.

Custom feeding return:

$$(10a) \quad CFR_n = DC_n * C^1 + \Sigma_{i=2}^{5} XC_n^i * C^i$$

Owned - unhedged returns:

$$(10b) \quad OR_n = \Sigma_{k=1}^{3} XOWT_n^k * R_n^k - DO_n * (P_n + W_n^1) - \Sigma_{i=2}^{5} (XO_n^i - DH_n^i + DL_n^i) * W_n^i - \Sigma_{k=1}^{3} XOWT_n^k * W_n^{5+k}$$

Owned - hedged returns:

$$(10c) \quad HR_n = (\Sigma_{i=2}^{5} XH_n^i + \Sigma_{k=1}^{3} XHWT_n^k) * F_n + \Sigma_{k=1}^{3} XHWT_n^k * (R_n^k - BF) - DH_n^*(P_n + W_n^1) - \Sigma_{i=2}^{5} (XH_n^i - DL_n^i + DH_n^i) * W_n^i - \Sigma_{k=1}^{3} XHWT_n^k * W_n^{5+k} - \Sigma_{i=2}^{5} DL_n^i * BF.$$

Interest income (expense):

$$(10d) \quad IR_n = (XM_n - FC) * [(1+i)^s-1]$$

where C^i is the stage return to custom feeding, R_n^k is the return per group in weight class k sold in the cash market, P_n is the feeder pig cost per group, W_n^i is the single stage production cost per group in phase i or weight class NP+k, F_n is the return per futures contract, BF is the brokerage fee per futures contract, FC is out-of-pocket fixed cost per stage, and s is the number of days per stage. Given these definitions, the cash balance transition equation is given by

$$(11) \quad XM_{n-1} = XM_n + IR_n + CFR_n + OR_n + HR_n.$$

Now define the single stage return as a function of state variables, X_n; decision variables, D_n; and stochastic elements, Z_n; as

(12) $r_n(X_n, D_n, Z_n) = IR_n + CFR_n + OR_n + HR_n$.

The optimal decisions maximize equation 13, subject to the constraints in equations one through three.

(13) $$f(X_n) = \max_{D_n} E\,[r_n(X_n,D_n,Z_n) + \$*(f_{n-1}(t_n(X_n,D_n,Z_n))]$$

The transition equations, $t_n(X_n,D_n,Z_n)$, are equations four through nine and eleven. The system is completed with specifications of the Markovian price transition matrix for the vector of random prices Z and the probabilities for weight class assignments, D_k.

Production and Price Data

The production variables are based on "close-out" sheets of a large custom feeding operation and are summarized in Table 1. Price observations are the weekly averages for the first week of each month, January 1, 1977, through December 31, 1987, are for cash hogs, feeder pigs, and feed (USDA, AMS).[3] All prices are deflated by the CPI-W[4] using 1967 = 100.

A nonstochastic custom feeding return is the fourth price variable. This payment is to the producer for his expertise in livestock management, but does not reflect a return to business management or risk bearing. The rate is set at approximately half the long-term expected return from hog finishing.

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[3] Five-market barrow and gilt price, Missouri feeder pig price, Chicago corn price, and Decatur SBM price.

[4] Consumer Price Index for Urban Wage Earners and Clerical Workers: U.S. City Average, Major Group, All Items (Bureau of Labor Statistics).

Results of Alternative Management Strategies

Four strategies are compared over a 120-stage planning horizon for one group of hogs (64 head). The strategies are: (1) only own (OO), (2) custom own (CO); (3) hedge own (HO); and (4) all alternatives (AA). Under any strategy, the optimal placement decision may be to leave the facility empty for at least one stage in hope of better placement conditions. All hedging decisions are reviewed and revised, if necessary, at the start of each stage. Although the model determines the optimal decision for each possible state combination, with up to 475 possible combinations, reporting of the results must be simplified. Therefore, optimal decisions are reported as the ratio of the number of state combinations in which that decision is optimal to the number of state combinations in which that decision is possible.

The optimal placement decisions for the $0 and $20,000 cash balances are summarized in Table 2. Under the OO strategy, placement was optimal in 25 and 60 percent of the state combinations at the $0 and $20,000 cash levels, respectively. The alternative to placing hogs is to wait at least one more stage (with an empty pen) in hope of more profitable placement conditions. This option is more common at the $0 level because of the likelihood of violating the chance constraint. The initial purchase of feed and pigs almost guarantees a decrease in ONW in the first month violating the chance constraint for producers with no cash reserves. Relative to the OO strategy, HO increases placements to full capacity at $20,000; however, the chance constraint still limits placement at the $0 cash level, increasing total placements only slightly.

Table 2. Placement Decisions by Cash Balance

Strategy[1] Type	Cash Level	OO	CO	HO	AA
		Percent			
Hedged	$ 0	--	--	8.5	0.0
	$20,000	--	--	60.0	55.0
Custom fed	$ 0	--	88.0	--	87.5
	$20,000	--	80.0	--	25.0
Unhedged	$ 0	25.0	12.0	20.0	12.5
	$20,000	60.0	20.0	40.0	20.0

1) Strategies are: (OO) only own; (CO) custom own; (HO) hedge own; and all alternatives.

Contrasting CO to OO shows total placements increasing to full capacity for both cash balances. Custom feeding is used much more under CO than hedging is under HO. It accounts for nearly 90 percent of placements at the $0 cash balance and 80 percent at the $20,000 level. The larger percentage of custom placements at the $0 cash balance is probably due to the fact that custom feeding guarantees satisfaction of the chance constraint.

The AA strategy also results in a full facility for both cash balances. At the $0 level, the placement decisions are almost identical to the CO strategy. The slight increase in unhedged placements is due to the fact that the hedging strategy is dynamic. That is, the producer reevaluates his futures market position at the start of every month.

Optimal hedging decisions in the intermediate phases of production were nearly identical for the two cash levels. As may be expected, hedges were placed at high prices (vectors three, four, and five) and lifted at low prices (vectors one and two).

In general, the farmer who does not consider alternatives to only owning hogs incurs large opportunity costs. As shown in Table 3, a farmer beginning with an empty facility and $20,000 lowers his increase in PV by 40 to 50 percent if he only owns as compared to considering all alternatives. This difference is smaller and even negative at the $0 level. The latter result is explained by the high percentage of custom placements in the AA strategy. Custom feeding is not always as profitable as owning the hogs, but it does guarantee nonviolation of the constraint. Thus, the AA strategy sacrifices some incrase in PV for safety relative to the OO strategy.

Table 3. Expected Increase in Present Value by Management Strategy and Initial Cash Balance

Strategy[1]	OO	CO	HO	AA
Price Vector		Cash Balance = $0		
1	2,885	3,060	4,744	3,156
2	3,294	3,063	5,163	3,160
3	2,802	3,061	5,075	3,158
4	2,058	3,055	5,415	3,161
5	2,502	3,060	4,907	3,157
Price Vector		Cash Balance = $20,000		
1	3,212	4,108	5,477	5,329
2	3,700	4,406	5,977	5,706
3	3,195	4,175	5,868	5,608
4	3,023	3,976	6,162	5,818
5	2,924	4,116	5,711	5,431

Note: Values assume producers begin with an empty building.

1) Strategies are: (OO) only own; (CO) custom own; (HO) hedge own; and all alternatives.

The cost of using custom feeding to meet the chance constraint is demonstrated by comparing the HO and AA strategies. At the $0 cash balance, AA results in declines of 50 to 70 percent compared to HO. When the chance constraint is less important (at the $20,000 level), the decline in PV is only 3 to 6 percent.

In summary, the chance constrained stochastic dynamic programming model solved for the optimal placement and hedging decisions for a hog finishing operation. Placement decisions were affected by the constraint as seen by comparing decisions at the $0 and $20,000 cash balances. When no alternative to owning is available, the optimal decision often is to wait for more profitable conditions. Hedging decisions are largely price-driven and are not affected by the cash position.

Hedging and custom feeding offer producers viable alternatives to owning and selling in the cash market. This result is evident in the all alternative strategy which includes both placement alternatives. Although hedging increased PV of returns, custom feeding was the optimal placement decision for some states. The ultimate decision depends on the producer's ability to bear risk and his willingness to consider the alternatives.

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