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Larry Janssen, and James B. Hassler[1]

INTRODUCTION

Swine producers experience large profits and losses over time because of recurring seasonal and cyclical hog price variations and changing slaughter hog price-feed cost relationships. Producer decisions are made with considerable uncertainty of future prices, costs and the economic impact of decisions made by other producers. Swine industry problems of disorderly production and marketing rates are aggravated when feed cost relationships vary as much or more than slaughter hog prices.

Modern swine operations have numerous critical decisions on alternative interdependent production and marketing activities over time. A multiple farrowing system with nursery and finishing operations has a combined set of breeding herd, feeder pig and finishing hog decisions. The rate is affected by past culling decisions, existing replacement stock numbers and purchase availability. Breeding decisions are further constrained by future period requirements for space, labor and other limited resources in the swine operation already committed as a result of previous invariant decisions. Nursery operation decisions may include sale or carry forward of existing inventory or purchase of additional feeder pigs. These decisions are subject to present and future availability of nursery-finishing space or other limiting resources. Decisions in the finishing operation include sale of existing marketable inventory or carrying inventory forward to heavier weights. These management decisions are interdependent over time due to resource limitations and because living inventories and potential placements are growing over time.

Most swine producers do not adopt flexible production-marketing strategies required for making inventory adjustments to present and future changes in price-cost conditions. Instead, they develop and follow a standard production and marketing program emphasizing a relatively constant rate and timing of production flows and marketing slaughter hogs from 210-240 lb (95-109 kg).

Adoption of a standard strategy ignores potential economic gains from varying production rates and market weights in response to

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changing price-cost outlook. Under a flexible breeding strategy, a producer could adjust breeding herd size to reduce potential losses or expand potential gains. Producers could also increase their profits by marketing at heavier weights when hog numbers are low and minimize losses by marketing at lighter weights when hog numbers are high.

Adoption of flexible decision strategies assumes a detailed set of price-cost forecasts which are continually updated as new information becomes available. These forecasts must allow comparison of all possible alternative current inventory decisions in a given time period. Futhermore, forecasts of forward price-cost relationships must have sufficient accuracy over time for flexible strategies to consistently yield economic gains relative to using a standard strategy. The basic issue is whether flexible production-marketing strategies which use price and cost forecast information as part of the decision process can increase returns to swine producers compared to a standard strategy which does not use this information.

OBJECTIVES

This study reports on the development and progress of a forecasting-programming model for swine inventory management and marketing decisions. This model considers interrelationships between breeding herd, feeder pig and finishing hog activities. Objectives were:

1. To structure a dynamic operational decision model for a modern farrow-to-finish swine confinement unit which conforms with economic theory, uses price and cost forecast information and is as consistent as possible with current production scheduling practices.
2. To use and test this model during a combined production and marketing decison process and to compare economic results with results of a standard strategy.

DESCRIPTION OF MODEL

This section reports on the decision process and quantitative decision model used in this study. This is followed by a description of the representative firm used in the analysis of the combined marketing and placement decision process.

Decision Process

A flow diagram of a sequential decison process is presented in Figure 1. A sequential decision process represents a logical strategy for making livestock inventory decisions when:

1. Management has the goal of maximizing net revenue to the firm over time.

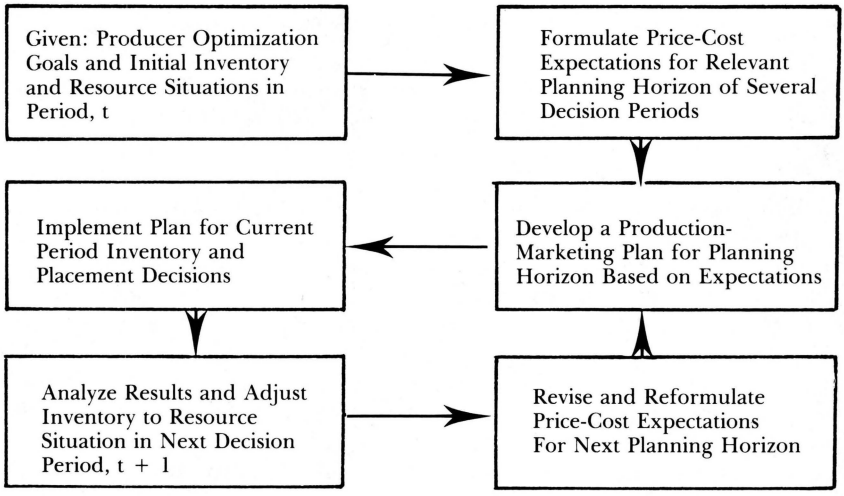

Figure 1. Flow diagram of a sequential decision model for livestock producers.[a]

[a] Adapted from Figure 1 of a research publication by Ying I. Chien and Garnett L. Bradford. 1972. *A Multiperiod Linear Programming-Simulation Model of the Farm Firm Growth Process*, Univ. of Kentucky Res. Rep. 21, September, pp. 12.

2. Alternative decision activities with differing expected outcomes are under consideration by management.

3. Decision activities are interrelated across a finite time (planning) horizon with each activity spanning one or more periods in a time horizon.

4. Imperfect knowledge exists of decision outcomes.

This decision process emphasizes:

1. The use of knowledge from forward outlook information for making the best possible set of decisions for the current decision period.

2. Reformulation of plans as new outlook information becomes available. The decision process is continuous as new information becomes available.

3. That each plan is conditioned by past actions.

The sequential element of the decision process is the use of outlook information to make current period decisions and to revise future plans as new outlook information becomes available. Outlook information is used to develop expected net revenues of alternative inventory activities. Although tentative plans are made for all activities in the planning horizon only current period decisions, which cannot be postponed, are executed. As one moves to the next decision period, plans are reformulated if expectations are revised from knowledge gained by available new outlook information. This process is repeated sequentially as the firm progresses through time.

Development of Decision Model

A literature search reveals multi-period linear programming and recursive linear programming models are the most popular choices for optimizing decisions over time. These models are widely used in farm firm growth research and have seen limited use in livestock marketing decision problems. K. Nelson and Purcell[2], G. Nelson and Eisgruber[3], Schwarz and Hassler[4] have developed quantitative models for analyzing beef feedlot placement-marketing decisions. The Schwarz-Hassler forecasting-programming model used a set of forecast equations to estimate monthly costs and beef prices over a two-year planning horizon. Price-cost information was related to all current inventory and future placement-sales activities in the programming model which properly accounted for time-growth curve relationships and estimated net returns for all activities in the planning horizon. All inventory placement-transfer and sale decisions and forecasted price-cost relationships were updated monthly. Several alternative management strategies were analyzed with the model.

The decision model developed for this study applies the Schwarz-Hassler approach to a modern swine firm environment. The decision process described above is formulated as a sequence of polyperiod linear programming models for consecutive planning horizons which use endogenous (current decision period) and exogenous (future decision period) feedback information. The objective function is to maximize expected net revenue from the set of alternative decision activities available in each planning horizon of a performance period (performance period is defined as a series of consecutive planning horizons).[5] Expected net revenues for decision activities are revised across consecutive planning horizons as new projections of future output prices and input costs become available.

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[2]Kenneth E. Nelson and Wayne Purcell. 1972. A Quantitative Approach to the Feedlot Replacement Decision. *Southern Journal of Agric. Econ.*, Vol. 4, No. 1, pp. 143-149.

[3]A. Gene Nelson and Ludwig M. Eisgruber. 1970. A Dynamic Information and Decision System for Beef Feedlots. *Western Journal of Agric. Econ.-Proceedings*, pp. 96-102.

[4]Franz Schwarz and J. B. Hassler. 1979. *A Forcasting Programming Method for Placement-Sales Decisions for a Beef Feedlot.* Agric. Exp. Sta. Res. Bull. 286. Univ. of Nebr., Lincoln, Nebraska.

[5]The terms *decision period, planning horizon* and *performance period* are used throughout this report. These terms are defined as: *Decision period* represents a single two-week time period in which inventory decisions must be made. *Planning horizon* represents a relevant planning time period of 12 months wherein current and future decision period activities are interdependent and bear on the making of inventory decisions for the current period. *Performance period* represents a sequence of planning horizons wherein current period decisions are made over time. The performance period examined in this report is 1975-76.

This linear programming decision model encompasses a 12-month planning horizon consisting of 26 two-week decision periods. The 715 column activities contain all possible current period and future decision period breeding herd, feeder pig, finishing hog and unused space activities in the planning horizon. Column activities are used for breeding, placement, sales and inventory transfer decisions. Row constraints (RHS) represent all possible inventory usage of current and future period gestation, farrow, nursery and finishing space in the planning horizon. The CJ values represent expected net revenues from all activities based on forecasted hog and feed prices and all other estimated nonfeed costs.

For the first planning horizon, the RHS constraints are set for starting inventory and capacity limits representative of an ongoing farrow-to-finish operation. The optimal solution maximizes expected net revenue for all current and future decision period activities in the planning horizon; but only current period decisions are activated. Results from these activated inventory decisions (in conjunction with the old RHS) generate the new RHS for the second planning horizon. At the same time, a revised set of CJ's reflecting revised price-cost forecasts have become available. The optimal solution for the second planning horizon is thus affected by revised RHS (inventory structure) and CJ's (expected net revenue) which can alter plans of previous inventory decisions concerning breed, sell, place, or transfer. This solution process is continued for 52 planning horizons in the 1975-1976 performance period.

The 52 solutions are obtained from linking Fortran program statements with Mathematical Programming System-Extended (MPSX) statements without having to manually restart each solution. Fortran statements are used to calculate RHS constraints from the level of column activities and old RHS in the previous solution. It also obtains a new set of expected net revenues (CJ) for all activities for the next planning horizon. CJ files for all activities for each of 52 planning horizons are obtained from a second Fortran program used to calculate expected net revenues from forecasted price-cost data, assumed nonfeed cost data and assumed technical (inventory growth curve) coefficients. Information on revised RHS constraints and expected net revenues (CJ) is transferred to the main program (MPSX) and is used to obtain a solution for the next planning horizon. This process is repeated 52 times before an exit is made from the MPSX control program.[6]

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[6]Further details on the mathematical structure of the decision model, The MPSX-Fortran control program and the Fortran program to calculate CJ coefficients are available in: Larry Janssen, "Objective Decision Procedures for Economic Management of Swine Firms", Unpublished Ph.D. dissertation, Depart. of Agric. Econ., Univ. of Nebr., Lincoln, Nebraska. 1978.

This decision model, which revises expected net revenues across consecutive planning horizons, captures some of the stochastic properties of a dynamic decision process. This decision model does not look at long-run investment and swine firm growth decisions as the technical coefficients are fixed over time. Adjustments to future outlook are made by breeding, feeder pig placement, feeder pig sale and market hog sale decision options. Within these limitations, the model provides a framework for optimizing short-run swine production, placement and marketing decisions using knowledge gained from new information and conditioned by previous actions.

DESCRIPTION OF MODEL SWINE FIRM

The major purpose of the model swine firm is to represent a management decision environment that accounts for interdependence of swine production-marketing decisions over time. The model firm has farrow-to-finish environmentally regulated facilities with annual capacity for 192 sows farrowing twice per year and sufficient capacity to market all pigs produced at finishing weights.

Production-Marketing Environment Assumptions

Major assumptions of the production-marketing environment are:

1. The shortest decision period is two weeks.
2. The longest planning horizon for an activity is one year and is updated every two weeks as new forecasts on swine market prices and feed costs become available.
3. Marketing (placement, sale) decisions can be made every two weeks. Breeding decisions are made monthly.
4. The initial breeding stock includes 6 herds of 32 bred gilts and sows plus replacement gilts, cull female stock and boars. Female breeding stock is subdivided into four breeding herd categories which vary in age, litters weaned and number of pigs produced per litter. Replacement gilts are raised.
5. The production cycle (breed, gestation, farrow, lactation and wean) for the breeding herd is 6 months or 26 weeks. The breeding-gestation activity period is 18 weeks, while the farrow-lactation-wean activity period is 8 weeks.
6. The swine confinement system includes separate capacity constraints for gestation-breeding, farrowing-lactation, nursery and finishing functions.
7. Swine growth rates, feed efficiency, ration composition, labor efficiency and breeding herd efficiency are considered as fixed, technical relationships.
8. No constraints are assumed on availability of labor, feed, or financing. These inputs are available at a specified opportunity cost.

9. Investment, start-up and cash flow problems of swine firms are not considered.

Decision periods are used to make breeding, placement and sales decisions. Decisions are made at the beginning of a two-week decision period and are activated in the second week. Maximum planning horizon length is determined by time requirements from a breeding decision to sale of resulting pigs at the maximum allowable weight.

Description of Inventory Classes and Economic Decision Options

Separate inventory classes are required for each two-week production period in the life cycle of breeding herd and nursery-finishing swine. Economic decisions (breed, sell, place or transfer) are made for selected inventory classes while inventory transfer or mandatory sale decisions are made for other inventory classes. Economic decision options associated with breeding stock, feeder pigs and finishing hogs are listed in Table 1 (production coefficient assumptions for the breeding herd and nursery-finishing hogs are discussed in Appendix 1).

Three nursery (feeder) pig weight classes and nine growing-finishing weight classes are included in the model. Raised pigs are weaned 6 weeks from birth at 26 lb (12 kg) and transferred from the farrowing house to nursery facilities. A decision is made to sell these nursery pigs at the end of 2 weeks when they weigh 40 lb (18 kg) or to carry them to heavier weights. Similar economic decisions are made as pigs approach 56 lb (25 kg) and 74 lb (34 kg). Feeder pigs may also be purchased at three alternative weights provided unused nursery or finishing space is available. Purchased feeder pigs can only be sold at finishing hog weights.

Unsold 74 lb (34 kg) pigs are transferred from nursery to finishing space and cannot be sold for 10 weeks until they reach a minimum weight of 187 lb (85 kg). There are 5 alternative finishing hog sale weights varying from 187 lb (85 kg) to 287 lb (130 kg).

The breeding stock consists of six herds of sows and bred gilts plus replacement gilts and purchased boars. Breeding decisions are made monthly and all herds are farrowed twice per year. Each breeding herd is composed of four age groups based on number of litters weaned. Animal weight, culling rates and productivity (as measured by number of pigs weaned per litter) vary with age group. The decision model contains 52 breeding herd inventory classes which account for all combinations of 4 age groups and 13 decision periods in the 6-month production cycle. An additional inventory class represents final disposition of post-wean fourth litter sows. Another 5 inventory classes of replacement gilts represent the 10-week period in which gilts are selected from finishing hogs and held as replacements.

Economic decisions are required on the number of replacement

Table 1. List of economic decisions available in decision model.

Inventory class	Economic decision options
Female breeding stock	
Gilts	Breed gilts for first litter or sell
Sows	Breed sows for next litter or sell
	All sows which have weaned four litters of pigs are automatically sold
Raised feeder pigs	
Weight class[a]	
under 40 lb (18 kg)	Carry forward
40 lb (18 kg)	Sell or carry forward
56 lb (25 kg)	Sell or carry forward
74 lb (34 kg)	Sell or carry forward
Purchased feeder pigs	
Weight class	
40 lb (18 kg)	Purchase pigs and hold to finishing weights
56 lb (25 kg)	Purchase pigs and hold to finishing weights
74 lb (34 kg)	Purchase pigs and hold to finishing weights
Finishing hogs	
Weight class	
94 lb (43 kg)	None, carry forward
116 lb (53 kg)	None, carry forward
139 lb (63 kg)	None, carry forward
163 lb (74 kg)	None, carry forward
187 lb (85 kg)	Sell or carry forward
212 lb (96 kg)	Sell or carry forward
237 lb (108 kg)	Sell or carry forward
262 lb (119 kg)	Sell or carry forward to 287 lb (130 kg) with automatic sale at that weight

[a]Weight class refers to feeder pig or finishing hog weight at the end of a two-week decision period.

gilts and sows to breed or sell at the beginning of the breeding herd production cycle. Minimum restrictions are placed on the number of sows and gilts bred to prevent a complete shutdown and the associated start-up problems when future outlook becomes more favorable. Once a decision to breed sows and gilts is made, there are no opportunities to sell bred females; only non-breeders (sows and gilts which did not conceive within three weeks after exposure to a boar) are sold.

Description of Column Activities

The sequential decision model contains 715 activities representing alternate uses of available gestation, farrow, nursery and finishing capacity over a planning horizon of 12 months. Activities are divided into current and future period inventory and unused space transfer activities. Inventory activities are subdivided into breeding herd, nursery pig and finishing hog activities.

Unused gestation, farrow, nursery or finishing space is transferred from one decision period to the next in the planning horizon. There are 4 current and 92 future unused space transfer activities. These activities permit management to leave space empty per decision period at specified costs for each type of space.

Inventory activities represent a complete mapping of all inventory classes and their time-space requirements in the planning horizon. Each inventory activity may be described by its beginning inventory class (weight level or production period), beginning decision period and ending decision period in the planning horizon. There are 117 current period and 502 future decision period inventory activities in this model.

Inventory activities are used for making two types of management decisions:

1. Decisions on current activities—activities which consider breeding, transfer, or sale of breeding inventory on hand and sale or transfer of nursery pig and finishing hog inventory on hand.
2. Decision on placements and tentative future period inventory decisions—activities which describe all future breeding, placement and marketing decisions in the planning horizon.

Gross revenues from inventory sale activities and purchasing costs from inventory purchase activities were estimated from forecast models. Simple forecasting models for slaughter hog, slaughter sow and feeder pig prices were estimated using multiple regression techniques for relationships existing before each performance period. Base weight, 50-60 lb (23-27 kg), feeder pig prices and base weight, 200-220 lb (91-100 kg), slaughter hog prices were forecasted for decision periods in all planning horizons of the performance period. Prices of all other slaughter and sow weight classes were linked to forecasted prices of 200-220 lb (91-100 kg) slaughter hogs. Prices of all other feeder pig weight classes were linked to forecasted prices of 50-60 lb (23-27 kg) feeder hogs. The swine price forecasting equations used in this study are described in Appendix 2.

Production Costs

Production costs are divided into feed and nonfeed expenses. Feed expense is a variable cost while nonfeed expense consists of fixed and variable costs. Nonfeed costs are 30-40% of total operating costs in the model swine confinement firm. Variable (carrying) costs are 80-85% of total operating costs. Carrying costs occur for all inventory activities and are incremental production (nonfeed and feed) costs for each activity from its beginning decision period to its ending decision period. Carrying costs do not include past costs associated with existing inventory because they do not influence future economic decisions concerning existing inventory.

Feed costs were estimated from forecast models of corn and soybean meal prices using multiple regression techniques. The specific feed price equations used in this study were developed by Dr. Franz Schwarz, UNL, and are published in Janssen (1978).

Nonfeed costs were budgeted for each decision period. Costs were allocated to all inventory classes and unused space classes per unit of space per two-week period. Representative non-feed costs and production coefficients were developed from information available in published studies.[7] Production coefficients were assumed invariant over time, while all nonfeed costs were assumed to increase at a 6.5% annual inflation rate over the performance period. A list and summary of nonfeed costs per unit of capacity by facility type for the initial decision period is shown in Table 2. Initial nonfeed costs are $3,000-$3,200 per two-week period if the facilities are operating at full capacity.

Labor requirements and costs are assumed to have fixed and variable components. Labor requirement assumptions for specific production practices are shown in Appendix Table 3-1. Fixed labor costs represent a payment for production supervision functions and supervisory labor availability to the swine operation regardless of short-term variation in output level. Assumed fixed labor requirements are 60-hours per 2-week period representing 18% of total labor requirements. Fixed supervisory labor is paid twice the variable labor rate of $3 per hour for the initial decision period. Total annual fixed and variable labor requirements per sow and two litters are 28.3 hours in the standard strategy of marketing finishing hogs at 212 lb (96 kg).

Fixed nonfeed costs occur regardless of output level; it is a direct

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[7]Reference sources used to develop nonfeed cost estimates were:

1. David H. Bache and James R. Foster. 1976. *Pork Production Systems With Business Analysis—The High-Investment High-Intensity Confinement System (Farrow-to-Finish).* ID-117, Purdue Univ., West Lafayette, IN.
2. David H. Bache and James R. Foster. 1977. *Pork Production Systems with Business Analysis—Determining Capital Requirements.* ID-124, Purdue Univ., West Lafayette, IN.
3. Larry L. Bitney. 1975. Swine Facilities to Fit Your Management Plans. *Proceedings-Swine Housing Conference*, Univ. of Nebr., Lincoln, Nebr.
4. Duty D. Greene. 1977. *Alternative Swine Housing Systems: An economic Analysis.* Paper prepared for Swine Feeders Days, Univ. of Minn., St. Paul, Minn.
5. Hong Y. Lee, R. W. Willis and T. R. Owens. 1975. *Supplement for 1975 to Input Requirements and Production Costs Complete Confinement Swine Rearing Operations Texas High Plains.* Agric. Sci. Pub. No. T-1-145, Texas Tech Univ., Lubbock, Texas.
6. T. E. Owens, J. C. Snodgrass and H. Y. Lee. 1971. *Labor Utilization Confinement Rearing of Swine Texas High Plains.* ICASALS Special Rep. No. 45, Texas Tech Univ., Lubbock, Texas.
7. T. E. Owens, J. C. Snodgrass and H. Y. Lee. 1971. *Input Requirements and Production Costs Complete Confinement Swine Rearing Operations Texas High Plains-1971.* ICASALS Special Rep. No. 46, Texas Tech Univ., Lubbock, Texas.

Table 2. List and summary of nonfeed costs per unit of capacity by facility type for initial decision period, 1975-76.[a,b]

Cost item	Type of cost	Facility (unit of space)			
		Gestation (sow)	Farrowing (sow)	Nursery (pig)	Finishing (hog)
		—Dollars per unit of capacity per two-week decision period—			
Interest on investment[c]-land, bldg, and equip	Fixed	0.2344	3.7617	0.2297	0.2725
Property taxes and insurance[c]—land, bldg, and equip	Fixed	0.0552	0.8852	0.0541	0.0640
Depreciation[c]-bldg and equip	0.5 Fixed 0.5 Variable	0.2500	3.9548	0.2416	0.2842
Repair and maintenance[c]-bldg and equip	0.5 Fixed 0.5 Variable	0.0600	0.9500	0.0578	0.0680
Fixed labor[d]	Fixed	0.1632	2.1938	0.1309	0.1368
Variable labor costs	**($3.00/hr)**				
Feed and care of replacement gilts, cull sows, nursery-finishing hogs	Variable	0.3000	---	0.3900	0.0900
Feed and care of sows and bred gilts	Variable	0.5167	4.4250	---	---
Purchasing swine[e]	Variable	---	---	0.3000	0.3000
Selling swine[e]	Variable	0.3000	---	0.2400	0.2400
Medical and vet expense for					
Replacement gilts and nursery-finishing hogs	Variable	0.0300	---	0.0300	0.0300
Sows and bred gilts[f]	Variable	0.5000	0.5000	---	---
Purchasing hogs	Variable	---	---	0.3000	0.3000
Marketing and transportation expense for					
Purchasing hogs	Variable	---	---	1.5800	1.5800
Selling hogs	Variable	1.7000	---	1.2800	1.7000
Utilities	Variable	0.1050	1.4422	0.1384	0.0256
Miscellaneous	Variable	0.0900	0.0900	0.0400	0.0400
SUMMARY:					
Total fixed cost per unit of capacity	Fixed	0.6076	9.2931	0.5644	0.6494
Total variable nonfeed cost per unit of capacity for:					
Feed and care of replacement gilts, nursery-finishing hogs	Variable	0.6800	---	0.7481	0.3617

Table 2. (continued)

Cost item	Type of cost	Facility (unit of space)			
		Gestation	Farrowing	Nursery	Finishing
		(sow)	(sow)	(pig)	(hog)
		—Dollars per unit of capacity per two-week decision period—			
Feed and care of sows and bred gilts	Variable	1.3667	8.9096	---	---
Purchasing hogs[g]	Variable	---	---	2.1800	2.1800
Selling hogs[h]	Variable	2.6800	---	1.8781	2.2117

[a]Nonfeed costs for remaining decision periods in 1975-76 are adjusted for a 6.5 percent annual inflation rate relative to the initial decision period.

[b]All nonfeed costs are included except relatively minor costs as interest on operating capital and property taxes on animals. They are not included because the amount is dependent on market value of hogs and feed. The cost per decision period for both items would be less than $0.10 for any inventory class.

[c]Interest on investment, property taxes, insurance, depreciation and repair-maintenance costs per unit of capacity for gestation, farrowing, nursery and finishing facilities include budgeted costs for each facility and related equipment plus budgeted costs for general equipment prorated by type of facility.

[d]Fixed labor is a charge for production supervision functions such as breeding herd scheduling, variable labor supervision, accounting and overhead labor. It is also a payment for supervisory labor availability to the firm regardless of output level.

[e]Labor cost for purchasing and selling swine represents additional labor costs for loading and unloading animal and veterinary time above normal time requirements for feed and care of swine.

[f]Veterinary and medical expense for sows and bred gilts includes estimated expenses for a litter of pigs prorated across the 26-week production cycle.

[g]Swine may be purchased at the end of a decision period. Variable nonfeed costs (above the purchase cost) associated with swine purchases are marketing-transportation expense, labor expense and veterinary expense.

[h]Existing swine inventory may be sold in the second week of a decision period. Nonfeed variable costs in this decision period include: 1) labor expense for feed, care and loading, 2) veterinary expense, 3) variable depreciation, repair and maintenance expense and 4) marketing and transportation expense.

charge for space use. Fixed costs include insurance, property taxes and interest on investment in building facilities, general equipment and land; half of depreciation, repair and maintenance charges on building facilities and general equipment; and a portion of labor expense. All fixed costs except labor are related to replacement costs for fixed facilities (buildings and general equipment). Initial capital investment cost assumptions are shown in Appendix Table 3-2. Estimated replacement costs over time in the performance period are related to initial capital investment by a 6.5% annual inflation rate.

Insurance expense is 0.5% of replacement cost while property tax levies are 45 mills on 35% of replacement cost. Interest expense is 8.5% of replacement cost. Depreciation expense is based on straight-line rates for replacement cost with no salvage value. Useful life of 12 years is assumed for buildings and 7 years for general equipment. Repair and maintenance expense are 2% annually of building replacement cost and 2.4% annually of general equipment replacement cost.

Nonfeed carrying costs include variable labor costs, property tax on breeding herd and market animals, medical and veterinary ex-

pense, marketing and transportation expense for purchasing and selling hogs, utilities and miscellaneous expenses and half of depreciation, repair and maintenance expense. Selected carrying costs only occur (marketing and transportation expense) or are increased (labor, medical and veterinary expense) when hogs are purchased or sold. All other variable nonfeed costs occur when inventory groups are present in the operation. Of course, all fixed costs associated with space capacity are also present.

Description of Row Constraints

The decision model contains 419 row constraints including 74 current decision period and 345 future decision period constraints. Current period constraints include 70 current inventory classes (rows) containing all necessary combinations of weight classes, breeding herd production periods and age groups. Also, four unused space capacity rows are needed to transfer space restrictions from present to future periods. Current inventory and unused space constraints establish: 1) overall space restrictions in the planning horizon, and 2) constraints on the set of inventory decisions which can be activated in the current period. Activities corresponding to current inventory and unused space capacity rows assume values of one or zero.

Future period constraints are facility (gestation, farrowing, nursery and finishing) space constraints, inventory transfer rows and minimum restrictions on breeding herd and replacement gilt numbers. Facility constraints limit space availability by type for decision periods in the planning horizons. Finishing space is closed at the end of one year (26 periods). All other space constraints are closed in earlier periods because activities are linked to later period finishing hog activities. Gestation space is used to close out post-wean sows one period after they leave the farrowing house. Activities corresponding to the 96 future space constraints assume alternative values of -1, 0, or 1.

Inventory transfer rows number 228 of the 419 row constraints. These rows transfer inventories from one type of space to another or from one major inventory classification to another (gilts to breeding herd) using the same space. Transfer rows also account for pig production rates (number of weaned pigs transferred from farrowing to nursery space per sow) and breeding herd culling rates.

Minimum breeding herd constraints establish the minimum number of sows and/or gilts farrowing nine periods after a breeding decision is made. The constraint is set at the farrowing level and is linked by transfer rows to breeding decision activities. Breeding decisions are considered in the current period and nine future decision periods in the model. Only current period breeding decisions are activated.

Replacement gilts are selected from finishing hogs at 187 lb (85

kg) and must be properly scheduled with future breeding decision periods. Furthermore, a sufficient number of gilts must be available in the finishing space. Replacement gilt constraints are designed to handle these requirements.

Selection of Management Strategies

Three management strategies (standard, semiflexible and flexible) are examined in this study for the 1975-1976 performance period. The standard strategy assumes production from the breeding herd at 95-100% of capacity and sale of finishing hogs at 212 lb (96 kg). Raised gilts were used as replacements and no feeder pigs were purchased or sold. The semiflexible strategy assumes standard strategy conditions except for additional finishing space and marketing of finishing hogs at 5 possible weight classes from 187 lb (85 kg) to 287 lb (130 kg). The flexible strategy permits variation in breeding herd composition from about 50-100% capacity, sale of raised pigs at three nursery level weights or five finishing weights and purchase of feeder pigs at three possible weights for resale as finishing hogs. Specific economic decision options and constraints for each strategy are summarized in Table 3.

The standard strategy represents a swine firm that maintains a breeding herd at near capacity levels at all times and markets

Table 3. Selected characteristics of management strategies.

Decision option availability		Management strategy		
		Standard	Semiflexible	Flexible
Sale of finishing hogs				
187 lb (85 kg)		N[a]	Y[b]	Y
212 lb (96 kg)		Y	Y	Y
237 lb (108 kg)		N	Y	Y
262 lb (119 kg)		N	Y	Y
287 lb (130 kg)		N	Y	Y
Sale of raised feeder pigs				
40 lb (18 kg)		N	N	Y
56 lb (25 kg)		N	N	Y
74 lb (34 kg)		N	N	Y
Purchase feeder pigs				
40 lb (18 kg)		N	N	Y
56 lb (25 kg)		N	N	Y
74 lb (34 kg)		N	N	Y
Breeding herd capacity %		95-100	95-100	50-100
Maximum capacity				
Farrow	No. of	65	65	65
Nursery	Spaces	500	500	500
Finishing		750	1000	1000

[a] N = NO
[b] Y = YES

finishing hogs at a premium (no price discount) weight. Nursery and finishing spaces are established at levels permitting this flow of pigs through the production system. Space is not available for carrying finishing hogs to heavier weights.

The semiflexible strategies represent a flexible finishing market weight strategy. Economic gains, relative to the standard strategy, may occur from carrying finishing hogs to generally heavier weights than 212 lb (96 kg) and from flexibility of marketing weights varying from 187 lb (85 kg) to 287 lb (130 kg). The average weight of barrows and gilts marketed by farmers since 1970 has exceeded 230 lb (104 kg) in most months. Many hogs, in actual practice, are not marketed at the 200-220 lb (91-100 kg) premium weight because price discounts for 220-240 lb (100-109 kg) hogs are relatively low and marginal gains in revenue often exceeds marginal carrying costs of hogs from 220 (100 kg) to 240 lb (109 kg).

The flexible strategy allows for potential economic gains from proper timing of feeder pig purchases, feeder pig sales, finishing hog sales and levels of breeding. The breeding herd restriction permits a herd reduction of about half from normal (32 farrowing sow spaces) capacity; while a maximum of 22 replacement gilts permits more rapid herd buildup than the usual number of 13 replacement gilts. When additional gilts are not required by the breeding herd, they are sold at 270 lb (122 kg). A combination of future farrowing, nursery and finishing capacity constraints and the previous breeding herd decision are evaluated when making a current breeding decision in this strategy.

RESULTS AND PERFORMANCE EVALUATION

Procedures for Evaluation of Management Strategies

A specific cost structure, set of forecast models and starting inventory positions are assumed for the beginning of 1975. Each management strategy has the same starting inventory position of sows, gilts, nursery pigs and finishing hogs representative of an ongoing swine farm. Each management strategy is examined for 52 two-week decision periods (1975 and 1976).

Forecasted net revenues are first used to select the set of decisions activated in each planning horizon of the performance period. Actual revenues and past costs are then calculated for each inventory class at point of sale to determine actual profit or loss. Streams of actual net revenues for each strategy are compared over the performance period. Major similarities and differences in patterns of decisions made under each strategy are examined for their profit contribution.

This process is repeated for each strategy using certainty net revenues (perfect knowledge assumption) to select the set of decisions in

each planning horizon of the performance period. This set of decisions represents the optimal solution for the firm, given the maximum range of allowable decision options in the LP model.

Results from the semiflexible and flexible strategies using certainty net revenues are compared to the standard strategy to determine the maximum potential economic gains available from two levels of flexibility. Both of these strategies must increase gross receipts from hog sales over the standard strategy to cover the extra cost of 250 additional finishing spaces. The extra cost for the 1975-1976 performance period was about $8,500. Actual results from semiflexible and flexible strategies using forecasted net revenues are also compared to standard strategy results. This comparison represents the actual economic gains or losses from two levels of flexibility under forecasted price-cost conditions. Finally, results from semiflexible and flexible strategy solutions using forecasted net revenues are compared to certainty net revenue solutions for the same strategies.

Results are reported by management strategy as follows:

I—Standard strategy
II—Semiflexible strategy—forecasted prices
III—Semiflexible strategy—actual prices
IV—Flexible strategy—forecasted prices
V—Flexible strategy—actual prices

Selected summary statistics on profitability, feeder pig inflow and hog sales patterns by management strategy are presented in Table 4. Net returns from and timing of finishing hog sales for the standard and semiflexible strategies (I, II and III) are presented in Table 5. Feeder pig production and breeding herd sales decisions are nearly identical for these strategies and are not separately reported. All of the information reported in Tables 4 and 5 are obtained from detailed inventory accounting tables available in Janssen (1978).

Solution for the Standard Strategy (I)

The standard strategy involved monthly sales of 212 lb (96 kg) finishing hogs, monthly breeding decisions and sale of sows and gilts. Thirty-six or 37 sows and gilts were exposed to a boar in each breeding decision period. The number of hogs marketed each month varied from 232 hogs to 237 hogs with an additional 13 gilts held as replacements. Approximately 10-12 sows and gilts were also sold each month.

Cumulative net returns for the standard strategy were $174,781 with $20,815 obtained from breeding herd sales and ending inventory valuation (see Table 4) and $153,966 obtained from sale of 5,598 finishing hogs. Net returns from monthly sales closely followed relative trends in slaughter hog prices and feed costs.

Raising finishing hogs for sale from May 1975 through July 1976

Table 4. Selected summary statistics by management strategy.

			Management strategy				
			Standard	Semiflexible-forecasted prices	Semiflexible-actual prices	Flexible forecasted prices	Flexible actual prices
Net revenue[a]							
Sows and gilts		$	20,815	20,815	20,815	24,801	26,061
Raised pigs		$	153,966	174,153	199,853	144,046	138,950
Purchase feeder pigs		$	---	---	---	28,723	92,671
	TOTAL	$	174,781	194,968	220,668	197,570	257,682
Production volume[b]		cwt.	12,854	15,062	15,734	16,290	15,138
Inflow of pigs into nursery/ finishing[c]							
Beginning inventory		no.	980	980	980	980	980
Raised-26 lb (12 kg)		no.	5,916	5,916	5,916	5,906	5,524
Purchased-40 lb (18 kg)		no.	---	---	---	497	1,279
Purchased-56 lb (25 kg)		no.	---	---	---	2,309	1,466
Purchased-74 lb (34 kg)		no.	---	---	---	859	938
	TOTAL	no.	6,896	6,896	6,896	10,551	10,187
Sale of raised feeder pigs at:							
40 lb (18 kg)		no.				---	669
56 lb (25 kg)		no.				---	686
74 lb (34 kg)		no.				2,745	2,508
	TOTAL	no.				2,745	3,863
Sale of finishing Hogs at:							
187 lb (85 kg)		no.	---	---	---	206	---
212 lb (96 kg)		no.	5,598	467	232	755	453
237 lb (108 kg)		no.	---	2,478	699	2,602	1,331

Table 4. Concluded.

262 lb (119 kg)		no.	---	1,605	3,166	1,114	1,238
287 lb (130 kg)		no.	---	1,048	1,501	1,150	1,993
	TOTAL	no.	5,598	5,598	5,598	5,827	5,015
Average sale weight							
Finishing hogs		lb (kg)	212 (96)	251 (114)	263 (119)	256 (116)	261 (118)
Feeder pigs		lb (kg)	---	---	---	74 (34)	65 (29)
Average feeder pig							
Purchase weight		lb	---	---	---	58 (26)	55 (25)
Net revenue per:							
Cwt. (kg) of prod.		$	13.60 (.30)	12.94 (.29)	14.02 (.31)	12.13 (.27)	17.02 (.38)
Raised pig sold		$/c	27.24	30.89	35.33	26.20	27.27
Purchased feeder pig sold		$	---	---	---	7.84	25.16

[a]Net revenue is computed for each inventory group at time of sale.
Net revenue calculations for:
1) Raised pigs and gilts = Net sales revenue—Grow/Finish cost—Breeding Herd Cost
2) Purchased pigs = Net sales revenue—Grow/Finish cost—Purchase Cost
3) Sows = Net cull sales revenue—Past Carrying costs where:
Net Sales Revenue is gross sales revenue minus marketing charges and a two percent death loss charge.

Breeding Herd Cost is the total carrying cost of the breeding herd and pigs for the decision periods from breeding to weaning prorated by number of pigs weaned.

Purchase Cost includes marketing commission and transportation cost, preparatory labor and medical expense in addition to direct purchase expense.

Grow/Finish Cost is the feed and nonfeed carrying costs from the decision period pigs are weaned or purchased through the sale decision period. Cost of unused nursery-finishing space is included in the nonfeed costs and is prorated across the number of hogs inventoried in a given decision period.

Net cull sales revenue is gross sales revenue minus marketing charges and additional feed/nonfeed cost necessary to prepare sow for sale.

Past carrying costs refer to all costs associated with the sows prior to its first breeding. It excludes all carrying costs of sows in each production cycle. This latter cost is included in the carrying cost of pigs weaned from the breeding herd.

[b]Production volume is sales volume cwt. adjusted by differences in beginning inventory and ending inventory composition.

[c]Inflow of raised pigs includes future replacement gilts.

Table 5. Net returns and sale weight of finishing hog inventory groups, standard and semiflexible strategies.

Standard strategy				Semiflexible-forecasted prices			Semiflexible-actual prices		
Sale date Standard Strategy[a]	Sales	Sale weight	Net return per head sold	Sales	Sale weight	Net return per head sold	Sales	Sale weight	Net return per head sold
	No. of head	cwt. (kg)	$	No. of head	cwt. (kg)	$	No. of head	cwt. (kg)	$
Jan. 25	232	2.12 (96)	9.02	232	2.37 (108)	13.63	232	2.62 (119)	16.26
Feb. 22	232	2.12 (96)	12.79	232	2.12 (96)	12.08	232	2.87 (130)	16.28
April 5	232	2.12 (96)	12.70	201	2.62 (119)	23.52	232	2.62 (119)	24.63
				31	2.87 (130)	35.93			
May 3	232	2.12 (96)	23.94	201	2.37 (108)	37.04	201	2.62 (119)	38.67
				31	2.87 (130)	40.16	31	2.87 (130)	41.73
May 31	232	2.12 (96)	28.44	232	2.37 (108)	35.00	232	2.87 (130)	63.95
June 28	232	2.12 (96)	51.44	232	2.87 (130)	65.28	232	2.87 (130)	65.28
July 26	232	2.12 (96)	50.83	232	2.37 (108)	56.46	232	2.62 (119)	64.13
Aug. 23	232	2.12 (96)	50.22	232	2.37 (108)	58.79	232	2.87 (130)	83.97
Oct. 4	232	2.12 (96)	57.95	232	2.37 (108)	56.14	232	2.62 (119)	58.07
Nov. 1	232	2.12 (96)	41.03	232	2.62 (119)	45.68	232	2.62 (119)	45.58
Nov. 29	232	2.12 (96)	38..93	232	2.62 (119)	40.09	232	2.62 (119)	39.89
Dec. 27	232	2.12 (96)	35.41	232	2.87 (130)	44.18	232	2.87 (130)	43.51
Jan. 24	232	2.12 (96)	24.26	235	2.87 (130)	40.11	235	2.62 (119)	42.81
Feb. 21	232	2.12 (96)	31.90	232	2.37 (130)	34.43	232	2.87 (130)	34.21
April 3	237	2.12 (96)	25.68	208	2.37 (108)	36.57	212	2.62 (119)	38.41

Table 5. Concluded.

Sale date Standard Strategy[a]	Standard strategy			Semiflexible-forecasted prices			Semiflexible-actual prices		
	Sales	Sale weight	Net return per head sold	Sales	Sale weight	Net return per head sold	Sales	Sale weight	Net return per head sold
	No. of head	cwt. (kg)	$	No. of head	cwt. (kg)	$	No. of head	cwt. (kg)	$
				28	2.87 (130)	45.07	25	2.87 (130)	40.80
May 1	233	2.12 (96)	31.87	205	2.37 (108)	39.44	209	2.62 (119)	42.86
				28	2.87 (130)	45.07	24	2.87 (130)	45.47
May 29	235	2.12 (96)	35.04	235	2.37 (108)	40.17	235	2.62 (119)	44.79
June 26	232	2.12 (96)	34.63	232	2.87 (130)	22.67	232	2.37 (108)	35.47
July 24	237	2.12 (96)	25.33	237	2.37 (108)	21.29	236	2.62 (119)	24.73
Aug. 21	232	2.12 (96)	18.20	232	2.62 (119)	9.08	232	2.37 (108)	18.45
Oct. 2	237	2.12 (96)	-2.48	237	2.62 (119)	-13.95	237	2.62 (119)	-13.95
Oct. 30	235	2.12 (96)	-9.10	234	2.62 (119)	-3.24	204	2.62 (119)	-3.24
							29	2.87 (130)	-2.18
Nov. 27	237	2.12 (96)	1.50	237	2.62 (119)	11.85	237	2.62 (119)	11.85
Dec. 25	235	2.12 (96)	11.44	235	2.12 (96)	11.04	235	2.12 (96)	11.34
	No. of head		Net profit per head	No. of head		Net profit per head	No. of head		Net profit per head
Ending inventory	942		2.44	937		1.93	935		2.28

[a]Sale date is given for sale of finishing hogs at 212 pounds (96 kg).
Sale of this same inventory group at 237, 262 or 287 pounds (108, 119, or 130 kg) would be 2, 4 and 6 weeks later, respectively.
Sales at 187 pounds (85 kg) would be two weeks earlier.

was very profitable with net returns exceeding $20 per hog in each month (feed costs were relatively stable during this time). From the June 30 to October 4, 1975 decision periods, net returns exceeded $50 per 212 lb (96 kg) hog sold and slaughter hog prices were above $55 per hundredweight ($24.95 per kg).

Cumulative net returns to the standard strategy exceeded $170,000 by the end of July 1976 with only minor gains occurring thereafter. The last five months of 1976 were characterized by rapidly declining slaughter hog prices from July 1976 through October 1976 with some increase during November and December. Feed costs were also declining but at a much slower rate, while nonfeed costs and breeding herd costs were stable or increasing.

Solutions for the Semiflexible Strategies (II and III)

Both semiflexible strategy conditions performed better than the standard strategy. Relative to the standard strategy, cumulative net returns increased $20,187 or about 12% from adopting a semiflexible strategy using forecasted prices and a 26% increase, or $45,887, using actual prices for decision-making purposes. Most of the net return increases were based on hog sales from June 1975 through June 1976.

Net return increases were obtained from carrying finishing hogs to sale weights heavier than 212 lb (96 kg). Net returns, per hundredweight, were similar by management strategy but net return per hog sold increased substantially (Table 4). Relatively few raised hogs were sold at 212 lb (96 kg) in strategy II or III and none were sold at 187 lb (85 kg). Decisions based on forecasted prices usually resulted in sale of 237 lb (108 kg) or 262 lb (119 kg) hogs, while the optimal solution using actual prices resulted in hog sales at 262 lb (119 kg) or 287 lb (130 kg).

Hogs carried to heavier weights on a rising slaughter hog price trend during most of 1975 produced substantial net return increases above highly profitable sales at 212 lb (96 kg). For example, net returns were $50.22 for raised pigs sold during the August 23 decision period at 212 lb (96 kg) (Table 5). However, holding this same group of pigs for sale at 237 lb (108 kg) increased net returns by $8.57 per hog. Further holding of these hogs another four weeks for sale at 287 lb (130 kg) increased net returns an additional $25.18 per hog. These increases occurred despite high profitability of 212 lb (96 kg) hog sales, declining average feed efficiency in carrying hogs to heavier weights and the cost of additional finishing space. Differences in net returns from carrying hogs to heavier weights in December 1975 and all of 1976 were much smaller than gains in most earlier months of 1975.

There were several cases in both semiflexible strategies that a

group of hogs weaned on a common date were sold at two different time periods and weight levels. These results occurred when activities carrying hogs to heavier weights over one or more decision periods were selected by the LP model but were effectively constrained by available finishing space over these periods.

Overall, the semiflexible strategy using forecasted prices obtained about 44% of the potential net return gain over the standard strategy. This gain was usually accomplished by carrying hogs to sale weights of 237 lb (108 kg) or 262 lb (119 kg). Strategy II decisions only carried three groups of hogs to heavier than optimum strategy III weights for an opportunity loss of about $5,800. Further opportunity loss of about $14,400 occurred in strategy II from not carrying hogs to optimal heavier weights.

The semiflexible strategies obtained net return gains over a standard strategy from carrying hogs to heavier weights and from flexibility in selecting the specific market weight. If a revised strategy of selling all hogs at 237 lb (108 kg) had been adopted, net returns over the standard strategy would have increased about $19,800.

Solutions for the Flexible Strategies (IV and V)

The flexible strategies involved sale of hogs at five alternative finishing weight levels or three feeder pig weight levels, purchase of feeder pigs at three alternative weights for resale at finishing weights and considerable flexibility in breeding decisions with four age groups of sows and gilts.

Considerable differences in breeding decisions, breeding herd sale decisions, feeder pig purchases and sales and finishing hog sales were evident depending on the use of forecasted prices or actual prices for decision making purposes.

Flexible Strategy—Forecasted Prices

The flexible strategy using forecasted prices (strategy IV) increased net returns $22,789 or 13% above net returns of the standard strategy during the 1975-1976 performance period (Table 4). Relative net return gains approached $31,500 during July 1976 but declined to $22,789 by the end of 1976. This result coincided with rapidly declining hog prices and modest reductions in feed costs. Feeder pig purchases during June, July and August 1976 lost more than $10 per head when sold during September, October and November 1976 and accounted for most of the relative eecline in the last months of 1976.

Monthly breeding decisions were nearly identical to decisions made in the standard and semiflexible strategies. Net returns from breeding herd sales were increased $3,986 from the standard strategy because 189 additional replacement gilts were sold from strategy IV

decisions. These same gilts were sold as finishing animals in the standard and semiflexible strategy with net returns from these sales reflected in the nursery-finishing sales accounts. The opportunity loss to the firm from deferred gilt sales relative to sale as finishing animals was about $1,200-$1,600 during the performance period.

The general pattern of nursery-finishing activities was to sell raised pigs at feeder pig and finishing hog weight levels and continually purchase feeder pigs for resale at finishing weights. Feeder pigs were purchased in 20 of 52 decision periods and 17 of 24 months in the 1975-1976 performance period. Pigs were often purchased from more than one weight class in a decision period. Feeder pig purchases were a risky activity. Net return losses of $9,140 occurred from the sale of 1,200 purchased feeder pigs. Profits of $37,860 occurred from sale of the other 2,195 feeder pigs purchased. Overall profitability per purchased feeder pig was $7.84 compared to $26.20 per raised hog.

Forty-two percent of raised pigs produced were sold as feeder pigs, 49% were sold as finishing hogs and 9% were held back as replacement gilts. Raised feeder pigs were sold at 74 lb (34 kg). In most cases the solution indicated carrying raised pigs to finishing weights was more profitable than selling feeder pigs. However, finishing space was usually occupied by pigs purchased in earlier time periods. Furthermore, the combined expected net returns of feeder pig purchases for resale at finishing weights and selling raised pigs at feeder pig levels usually exceeded expected net returns from carrying raised pigs to finishing weights.

The average weight per finishing hog sold was about 256 lb (116 kg) with frequent sales at all finishing market weight levels. Continuous competition among numerous raised pig and feeder pig purchase activities for nursery-finishing space explains the tendency in the flexible strategy for sales at all possible finishing weight levels and split sales of inventory groups purchased or weaned on common dates.

Flexible Strategy—Actual Prices

The flexible strategy using actual prices for decision-making purposes (strategy V) increased net returns over the standard strategy by 47% or $82,900 over the 1975-1976 performance period. About $78,000 of the relative net return gains were achieved by the April 3, 1976 decision period with minimal relative gains during the remaining months of 1976. The major relative gains occurred from arranging raised pig sales and purchased feeder pig sales at finishing weight levels for the May 31, June 28 and October 4, 1975 decision periods. During the latter decision period, 924 slaughter hogs and 32 sows were sold with average net returns of $62.28 per hog sold.

A distinct pattern of nursery-finishing sales was evident in strategy

V. More than 75% of raised pigs produced were sold at feeder pig weight levels compared to 42% of raised feeder pigs sold in strategy IV. About the same number of feeder pigs were purchased in both flexible strategy conditions, but the timing and distribution of purchases varied. Most pigs were purchased in the first 15 months of the 1975-1976 performance period in strategy V compared to a relatively even purchase flow for both years in strategy IV. Forty-two percent of all strategy V feeder pigs purchased occurred in three decision periods and another 41% of feeder pigs purchased occurred in six additional decision periods. The remaining 17% of purchases occurred in 12 decision periods.

Feeder pigs of different weights were often purchased in the same decision period. Split sales of the same inventory groups were also common. Both of these patterns occurred due to continual competition among many activities for limited nursery-finishing space. Profitability of raised hogs and feeder pig purchases per animal were comparable, contrasting with low profitability of feeder pig purchases in strategy IV.

Finishing sale weights in the optimal strategy V exceeded 212 lb (96 kg) in most decision periods. Nine percent of finishing hogs were sold at 212 lb (96 kg), 52% were sold at 237 lb (108 kg) or 262 lb (119 kg) and 39% were sold at 287 lb (130 kg). Carrying finishing hogs to heavier weights were profitable in most months.

Breeding decisions through 1975 and the first three months of 1976 resulted in full utilization of farrowing facility space. The August 1975 breeding decision started a pattern of breeding 22-23 sows and gilts one month and 40-41 sows and gilts the following month until the April 1976 breeding decision. Consecutive breeding herd reduction decisions to the minimum breeding herd limit occurred during the April, May and June, 1976 decision periods. Breeding herd decisions in the last 6 months of 1976 resulted in rebuilding the breeding stock to over 90% of capacity by the end of 1976.

Overall, major gains, in order of importance of using actual prices instead of forecasted prices in the flexible strategy, were from:

1. Carrying finishing hogs to heavier weights.
2. Timing of feeder pig purchases.
3. Variation in breeding herd numbers.

Comparative Evaluation of Management Strategies

Figure 2 summarizes results for the 1975-1976 performance period by showing the cumulative net return paths for each of the five management strategies. The semiflexible and flexible strategies using forecasted prices for decisionmaking purposes increased net returns over the standard strategy by 12-13%. However, the same strategies under certainty conditions indicated net return increases over the

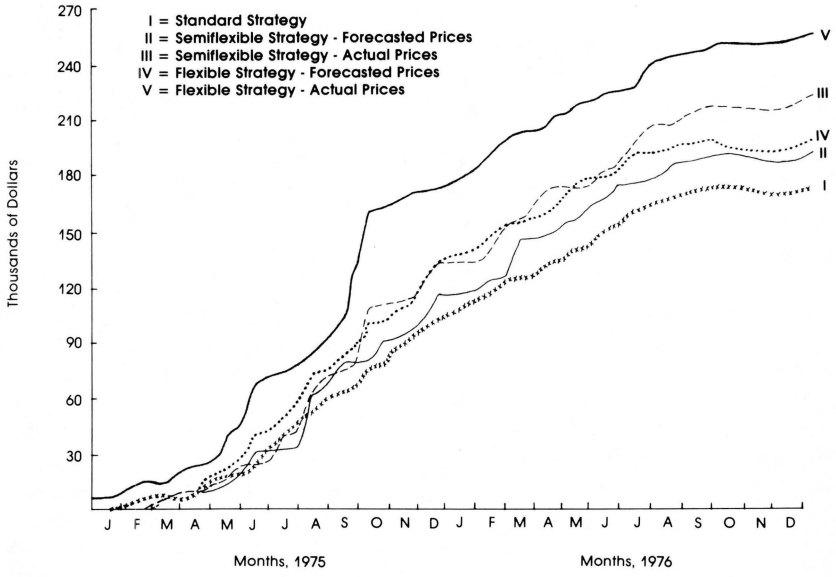

Figure 2. Cumulative net returns to model swine firm from five strategies, 1975-1976.

standard strategy of 26% and 47%, respectively.

The major opportunity for net return gains over the standard strategy was carrying finishing hogs to heavier sale weights and flexibility in selection of the specific sale weight. Average finishing hog sale weights in strategies II, III, IV and V exceeded 250 lb (113 kg) compared to the standard strategy sale weight of 212 lb (96 kg). The semi-flexible strategy was a relatively low risk approach for capturing some of the potential net return gain.

Net return increase potential of flexible breeding herd management decisions was not adequately tested over the 1975-1976 performance period. Relatively few breeding herd reduction decisions were made under certainty conditions because expected net returns from continued production were favorable, relative to other alternatives, in most planning horizons. Gilts were usually sold before sows when breeding herd sales were indicated.

Proper timing of feeder pig purchase and sale decisions under certainty conditions were the major reasons for increased net returns of the flexible strategy over the semiflexible strategy. However, the flexible strategy was unable to maintain consistent net return gains over the semiflexible strategy when forecasted prices were used for decision-making purposes. Results from strategy IV indicate the increased inventory turnover associated with numerous feeder pig purchase and sale decisions was not rewarded with increased net returns above strategy II decisions.

Feeder pig purchase and sale decisions were often based on relatively low expected net return increases over activities carrying raised pigs to finishing weights in both flexible strategy conditions. Comparison of strategies IV and V results suggests feeder pig sale and purchase strategies have high risk potential under forecast conditions even if the forecast models perform fairly well in the performance period. Management, under actual operating conditions, would probably limit activation of feeder pig purchase and sale decisions to cases when expected net return increases would be "substantial," the level depending on managers risk-preference functions.

IMPLICATIONS

The computerized decision model developed in this study represents a sophisticated and practical approach for inventory management decisions of modern swine firms operating over time with imperfect knowledge of future market conditions. The fundamental characteristics of this decision model are its capabilities for:

1. Revision of net revenue projections for all activities in a planning horizon as new forecasted price-cost information becomes available.
2. Application of the revised projections for making specific current period inventory management decisions.

This decision model has practical implications from several viewpoints:

1. It uses capabilities of existing computer program packages.
2. It uses readily available published information for forecast model development.
3. It provides comparisons of alternative inventory management strategies.
4. It can be applied to decision-making of individual firms or can be used as a public advisory service to the swine industry.

The decision model compared several inventory management alternatives in this study from which the following inferences can be obtained.

First, flexible inventory management associated with carrying finishing hogs to heavier weights provides the best potential, among alternatives examined, for increasing profits above the standard strategy.

Second, feeder pig purchase or sale decision options in a farrow-to-finish operation should be exercised only if expected net returns are substantially above finishing raised pigs. The precise level of "substantial increase in expected net returns" has to be determined by individual managers. Sensitivity analysis can provide information needed for this decision.

Results from this study suggested a minimum expected net return

increase of $5 per animal would have been needed during the 1975-1976 performance period to reduce the chaotic inventory flows in the flexible strategies and still provide opportunity to purchase feeder pigs when it was profitable.

Specific application of this decision model to individual swine firms or a group of firms would require detailed inventory flow records from each firm to obtain the current inventory flow records from each firm to obtain the current inventory status for each planning horizon. Breeding, placement, or sales activities not acceptable to an individual producer could be bounded at zero levels in the sequential LP model. Forecast equation coefficients should be re-estimated annually to account for possible changes in relative importance of explanatory variables.

The sequential decison model can also be used as a public advisory service to the swine industry. Management advisory reports could be made biweekly or monthly. These reports would provide detailed information on relative profit opportunities available for current inventory decisions in alternative management strategies. Related research by Schwarz and Hassler on a sequential decision model for beef feedlots indicates knowledge of specific inventory composition of individual firms is not necessary for providing information on relative profit opportunities of alternative decisions. It is only necessary for the model to evaluate all possible inventory decisions relative to unused space. The producer can then compare the profit potential for his set of possible inventory decisions and ignore information on infeasible inventory decision alternatives.

The advisory service approach has been extended to the swine industry by Hassler and Schwarz, in a pilot study, using an updated version of the sequential decision model reported in this study. Forecast equations have been revised and updated; nonfeed cost assumptions have also been updated. However, production coeficients and the LP matrix have not been changed except for RHS positions.

It is not possible within the scope of this study to estimate the probable macroeconomic impacts to the swine industry if an advisory service were adopted. However, the following ideas merit consideration for future examination.

First, it is important that information related to producers indicate relative profit opportunities and the change in slaughter hog prices, feeder pig prices or feed costs which would restore an equilibrium net return situation among decision alternatives.

Second, only some producers are needed to activate decisions in the indicated direction. Even if inventory management information was made available to all producers, differences in risk-aversion among producers would not make it likely that all producers would follow the recommendations.

A final evaluation of the sequential decison models' application to individual swine firms or as a management advisory service cannot be made unless the model is implemented. Preliminary results from this study indicated some of the potential benefits and problems of this approach to swine inventory management.

APPENDIX 1—SWINE PRODUCTION COEFFICIENTS[8]

Nursery-Finishing Swine Relationships

Swine growth rates and feed consumption assumptions for nursery pig and finishing hog inventory classes are shown in Appendix Table 1-1. Growth rate and feed consumption assumptions are based on results from animal science research as reported in Cooperative Extension Service publications, but arbitrarily revised upward 10% to reflect differences between above average actual management conditions and experimental research farm conditions. Feed conversion ration computations reflect declining feed efficiency as one carries hogs to heavier finishing weights.

Swine rations were developed which meet the protein level and other nutrition requirements recommended by the National Research Council. Corn and 44 percent soybean meal were the primary ingredients; other ingredients were added to balance the ration. Ration composition varied by inventory classes at various weight intervals with a finishing ration used by swine weighing more than 139 lb (63 kg). Ration composition was related to feed cost calculations through forecasts of per unit corn and soybean meal prices. Soybean meal and "other" ingredients were both priced on a per unit soybean meal basis.

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[8]The primary reference sources used to develop swine production coefficients were:

1. William T. Ahlschwede. 1976. Market Hogs—What Weight?, *Nebraska Swine Report—1976*, EC 76-219, Univ. of Nebr. Lincoln, Nebr.
2. William T. Ahlschwede, Ernest R. Peo, Jr., Murray Danielson, R. D. Fritschen and Bobby D. Moser. 1971. *Swine Ration Suggestions.* EC 71-210, Univ. of Nebr., Lincoln, Nebr.
3. William T. Ahlschwede, Dwane Zimmerman and Keith Gilster. 1971. *Breeding Herd Management*, EC 74-212, Univ. of Nebr., Lincoln, Nebr.
4. Larry L. Bitney and Bobby D. Moser. 1975. How to Determine Profitable Protein Levels for Swine. *Nebraska Farm, Ranch and Home Quarterly*, Univ. of Nebr., Lincoln, Nebr.
5. Palmer Holden, Vaughn C. Speer, Emmett J. Stevermer and Dean R. Zimmerman. 1980. *Life Cycle Swine Nutrition*, pM-489, Iowa State Univ., Ames, Iowa.
6. National Research Council. 1968. *Nutrient Requirements of Domestic Animals of Swine.* Sixth Revised Edition.

Table 1-1. Post-wean swine growth rates, rations fed and feed conversion assumptions.

Time from birth	Swine weight	Daily rate of gain	Ration description[a]	Daily feed consumption	Feed conversion ratio
weeks	lb (kg)	lb/day (kg/day)		lb/hog /day (kg/hog/day)	lb of feed/ lb of gain (Metric same)
6	26 (12)				
8	40 (18)	1.00 (.45)	Starter-18	2.49 (1.13)	2.49
10	56 (25)	1.14 (.52)	Grower-16	3.09 (1.40)	2.70
12	74 (34)	1.28 (.58)	Grower-16	3.75 (1.70)	2.92
14	94 (43)	1.42 (.64)	Grower-14	4.50 (2.04)	3.15
16	116 (53)	1.57 (.71)	Grower-14	5.36 (2.43)	3.41
18	139 (63)	1.64 (.74)	Grower-14	5.91 (2.68)	3.60
20	163 (74)	1.71 (.78)	Finish-12	6.43 (2.92)	3.75
22	187 (85)	1.71 (.78)	Finish-12	6.72 (3.05)	3.92
24	212 (96)	1.79 (.81)	Finish-12	7.32 (3.32)	4.10
26	237 (108)	1.79 (.81)	Finish-12	7.65 (3.47)	4.28
28	262 (119)	1.79 (.81)	Finish-12	8.02 (3.64)	4.49
30	287 (130)	1.79 (.81)	Finish-12	8.46 (3.84)	4.74

[a]Type of ration and minimum protein percentage is listed.

Breeding Herd Relationships

Breeding herd production activities are confined to four age groups. Selected breeding herd characteristics including animal weights, feed requirements, culling rates, production rates and feed efficiency assumption per age group are shown in Appendix Table 1-2. Replacement gilts are selected from finishing hogs at 187 lb (85 kg) and are held 10 weeks before a breeding decision is made. Gilts successfully bred are held in gestation facilities for 18 weeks before transfer to farrowing facilities. Gilts continue to make substantial weight gains, 0.94 lb (.43 kg) daily, during pregnancy. Seventy lb (32 kg) of weight gain, 250 to 320 lb (113-145 kg), from time of breeding is retained through the 8 week farrow-lactation period. Some of this weight gain reflects structural growth and development. Feed requirements during the farrow-lactation period increase relative to first litter sow feed requirements.

Table 1-2. Selected breeding herd characteristics by age group.

Breeding herd characteristic	Age group			
	Gilt-first litter	Sow-second litter	Sow-third litter	Sow-fourth litter
Weight range: (lb)[a] (kg)				
Breeding-gestation	250-369 (113-167)	320-402 (145-182)	352-428 (160-194)	378-448 (171-203)
Farrow-lactation	320 (145)	352 (154)	378 (171)	398 (181)
Sale weights (lb) (kg)				
Nonbreeding females	302 (137)	366 (166)	398 (181)	423 (192)
Post-wean sows	349 (158)	382 (173)	408 (185)	428 (194)
Feed requirement (lb/day) (kg/day)				
Bred-gestation	5.0 (2.3)	4.5 (2.0)	4.5 (2.0)	4.5 (2.0)
Farrow-lactation	10.0 (4.5)	12.0 (5.4)	12.0 (5.4)	12.0 (5.4)
Selling nonbreeding	10.0 (4.5)	11.0 (5.0)	12.0 (5.4)	12.0 (5.4)
Selling post-wean sows	11.0 (5.0)	12.0 (5.4)	12.0 (5.4)	12.0 (5.4)
Percent of culling of nonbreeding females exposed to boar	15.0	10.0	10.0	10.0
Percent culling of dry sows in farrowing house	6.0	6.0	6.0	6.0
Number of pigs weaned per sow weaning pigs	7.23	8.19	8.83	8.83
Amount of feed consumed by pig and bred sow-gilt per pig weaned (lb)[a](kg)	201 (91)	186 (84)	175 (79)	175 (79)

[a]Amount of feed consumed includes 30 lb (14 kg) of starter (18% protein) ration fed to each pig before weaning.

The culling rate assumptions are representative of medium to high breeding herd turnover rate policies. The pigs weaned assumptions are representative of actual conditions. Another dimension of breeding herd efficiency is the amount of feed consumed by the bred female and baby pigs per pig weaned. This measure represents 40-50% of the breeding herd carrying cost. It also represents 21-22% of total feed requirements in the standard strategy of the breeding herd carrying cost. It also represents 21-22% of total feed requirements in the standard strategy.

The implication of these production coefficients on selected annual production efficiency measures for a standard strategy provides a useful comparison with farm management enterprise budgets. For a standard strategy, overall feed efficiency averages 3.90 lb (1.77 kg) of feed fed per lb (.45 kg) of production. Average breeding herd efficiency is 16.34 pigs weaned annually per sow weaning pigs, pigs weaned annually per sow and gilt in breeding herd.

APPENDIX 2—SWINE PRICE FORECASTING MODELS[9]

Price Forecasting Models for Slaughter Hogs and Sows

Single equation forecasting models using Ordinary Least Squares estimation procedures were developed for biweekly average prices for U.S. Nos. 1 and 2 grade, 200-220 lb (91-100 kg) slaughter hogs (barrows and gilts) at Omaha, Nebraska, from 2 weeks to 68 weeks forward.

Prices were projected two weeks forward as a linear function of lagged hog prices (actual prices available for the weeks immediately preceding the current decision period) and monthly dummy variables for the forecast period. Prices projected 4 weeks to 30 weeks in adv-

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[9]Sources of data for swine price forecasting models:

1. Weekly price data for slaughter hog, slaughter sow and feeder pigs were obtained from *Livestock Meat Wool Market News—Weekly Summary and Statistics*, Livestock Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, D.C.

2. Monthly pork production data and quarterly data for hog inventories by weight class and pig crop estimates for ten major hog states were reported in:

A. *Livestock and Meat Statistics.* 1968. Stat. Bull. No. 333, Econ. Res. Ser., U.S. Dept. of Agric., Wash., D.C.

b. *Hogs and Pigs-Revised Estimates.* 1972. Stat. Bull. No. 496, Stat. Rep. Ser., U.S. Dept. of Agric., Wash., D.C.

c. *Livestock and Meat Statistics-Supplement for 1973.* 1974. Stat. Bull. No. 522, Econ. Res. Ser., U.S. Dept. of Agric., Wash., D.C.

d. *Livestock and Meat Statistics-Supplement for 1976*, Stat. Bull. No. 522, Econ. Res. Ser., U.S. Dept. of Agric., Wash., D.C.

3. Data for disposable income were obtained from *Survey of Current Business*, U.S. Dept. of Commerce, Wash., D.C., various years.

ance were a linear function of lagged hog prices, predicted U.S. per capita pork production for the forecast period, plus monthly dummy variables for the forecast period. Prices projected beyond 30 weeks were a linear function of predicted per capita disposable income in current dollars and predicted monthly U.S. per capita pork production for the forecast period plus monthly dummy variables for the forecast period.

Predicted per capita monthly pork production was estimated from predicted commercial dressed weight monthly pork production divided by annual U.S. Census civilian population projections. Population projections were interpolated on a quarterly basis. Pork production projections one to six months forward were estimated from appropriate pig crop inventory variables, hog and pig inventory variables for specific weight classes, and quarterly dummy variables. Pork production projections seven or more months forward were estimated from breeding herd inventories and quarterly dummy variables.

Predicted per capita disposable income was derived from predicted total disposable income divided by annual U.S. Census civilian population projections. Total disposable income was projected at annual rates on a quarterly basis from current disposable income and trend variables. All income and trend variables were estimated after converting data to natural logarithms.

Forecast equation coefficients for predicted 200-220 lb (91-100 kg) slaughter hog prices in the 1975-1976 performance period are shown in Appendix Table 2-1. Prices for all other slaughter hog and sow weight classes are related to predicted 200-220 lb (91-100 kg) slaughter hog prices using single variable linear regression models. Weight class price relationships for the 1975-1976 performance period are shown in Appendix Table 2-2.

Price Forecasting Models for Feeder Pigs

Single equation forecasting models using Ordinary Least Squares procedures were developed for biweekly average prices for 50-60 lb (23-27 kg) feeder pigs from 2 weeks to 48 weeks forward.

Prices are projected 2 weeks to 20 weeks forward as a linear function of lagged feeder pig prices, predicted slaughter hog prices in the forecast period for 200-220 lb (91-100 kg), U.S. Nos. 1 and 2 barrows and gilts at Omaha, predicted feed costs in the forecast period and quarterly dummy variables for the forecast period. Prices projected beyond 20 weeks forward are a linear function of the same variables except for deletion of the lagged feeder pig price variable.

Lagged feeder pig prices are actual prices available for the week immediately preceding the current decision period. The feed cost variable combines predicted corn and soybean meal costs per hun-

Table 2-1. Slaughter hog price forecasting equations from base week to forecast week for basic weight class, 200-220 lb (91-100 kg) (based on 1962-1974 Omaha data, $/cwt.).

Dependent variable[a,b]	Constant term	Independent variables[c]														Summary statistics[e]	
		HP_w	Pork meat, w+i	w+i	Monthly dummy variable, w+i[d]											R^2	Std. error[g] (C.V.)
					Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
HP_w+_2	0.586	0.989	---	---	-0.254	-1.199	-0.563	0.398	0.592	0.176	-0.318	-1.236	-0.519	-0.375	0.487	0.986	1.47
	(2.2)[f]	(133.2)			(-0.9)	(-4.2)	(-2.0)	(1.4)	(2.1)	(0.6)	(-.1)	(-4.3)	(-1.8)	(-1.3)	(1.7)		(6.1)
HP_w+_4	14.170	0.732	-2.751	0.267	-1.940	-1.551	-2.019	-1.027	-1.662	-1.886	-1.690	-3.189	-0.611	-1.150	0.468	0.937	2.06
	(9.3)	(30.3)	(-9.6)	(10.7)	(-4.3)	(-3.9)	(-5.0)	(-2.4)	(-3.6)	(-3.8)	(-3.9)	(-7.8)	(-1.5)	(-2.9)	(1.2)		(8.5)
HP_w+_6	20.041	0.626	-3.868	0.373	-2.794	-1.724	-3.102	-2.129	-2.475	-2.690	-2.336	-3.959	-1.292	-1.665	0.0734	0.916	2.37
	(11.9)	(23.3)	(-12.2)	(13.4)	(-5.4)	(-3.7)	(-6.7)	(-4.4)	(-4.6)	(-4.7)	(-4.7)	(-8.4)	(-2.8)	(-3.6)	(0.2)		(9.8)
HP_w+_8	24.643	0.549	-4.757	0.451	-3.443	-1.51	-3.714	-3.135	-3.223	-3.598	-2.491	-4.127	-1.922	-1.983	-0.350	0.904	2.53
	(14.3)	(20.0)	(-14.7)	(15.9)	(-6.3)	(-3.1)	(-7.5)	(-6.2)	(-5.7)	(-6.0)	(-4.7)	(-8.2)	(-3.8)	(-4.0)	(-0.7)		(10.5)
HP_w+_{10}	27.626	0.505	-5.368	0.497	-3.534	-1.232	-3.837	-3.843	-3.832	-3.920	-2.285	-4.049	-2.050	-2.249	-0.464	0.899	2.60
	(16.3)	(18.7)	(-17.0)	(18.0)	(-6.2)	(-2.4)	(-7.6)	(-7.5)	(-6.7)	(-6.4)	(-4.1)	(-8.0)	(-3.9)	(4.4)	(-0.9)		(10.7)
HP_w+_{12}	30.213	0.456	-5.925	0.549	-3.563	-0.834	-3.538	-4.213	-4.4350	-4.168	-2.307	-3.611	-1.510	-2.595	-0.405	0.892	2.69
	(17.7)	(16.9)	(-18.7)	(19.8)	(-6.1)	(-1.6)	(-6.8)	(-7.9)	(-7.6)	(-6.6)	(-4.0)	(-6.8)	(-2.8)	(-4.9)	(-0.8)		(11.1)
HP_w+_{14}	32.174	0.410	-6.360	0.592	-3.653	-0.347	-3.173	-4.239	-4.982	-4.548	-2.131	-3.014	-0.937	-2.646	-0.411	0.884	2.79
	(18.4)	(15.0)	(-19.8)	(21.1)	(-6.1)	(-0.6)	(-5.9)	(-7.7)	(-8.3)	(-7.0)	(-3.6)	(-5.4)	(-1.7)	(-4.8)	(-0.8)		(11.5)
HP_w+_{16}	33.841	0.366	-6.727	0.632	-3.871	0.066	-2.898	-4.028	-5.377	-5.024	-1.993	-2.758	-0.239	-2.258	-0.596	0.876	2.88
	(18.9)	(13.1)	(-20.6)	(22.2)	(-6.2)	(0.1)	(-5.2)	(-7.1)	(-8.7)	(-7.5)	(-3.2)	(-4.8)	(-0.4)	(-4.0)	(-1.1)		(11.9)
HP_w+_{18}	35.186	0.334	-7.032	0.662	-4.063	0.332	-2.604	-3.788	-5.519	-5.484	-2.045	-2.469	0.449	-1.869	-0.645	0.872	2.93
	(19.5)	(12.0)	(-21.6)	(23.2)	(-6.4)	(0.6)	(-4.6)	(-6.5)	(-8.8)	(-8.1)	(-3.2)	(-4.2)	(0.8)	(-3.2)	(-1.1)		(12.1)
HP_w+_{20}	36.086	0.322	-7.274	0.676	-4.040	0.597	-2.125	-3.447	-5.351	-5.674	-2.080	-2.014	1.072	-1.304	-0.264	0.871	2.94
	(20.3)	(11.8)	(-22.9)	(24.3)	(-6.4)	(1.0)	(-3.7)	(-5.9)	(-8.5)	(-8.4)	(-3.3)	(-3.4)	(1.9)	(-2.3)	(-0.5)		(12.2)
HP_w+_{22}	36.938	0.310	-7.496	0.689	-4.064	0.786	-1.774	-3.100	-5.094	-5.717	-2.197	-1.760	1.583	-0.599	0.156	0.870	2.95
	(21.1)	(11.6)	(-24.1)	(25.1)	(-6.4)	(1.4)	(-3.0)	(-5.2)	(-8.0)	(-8.6)	(-3.4)	(-2.9)	(2.7)	(-1.0)	(0.3)		(12.2)
HP_w+_{24}	38.301	0.283	-7.757	0.714	-4.538	0.643	-1.890	-3.053	-5.236	-6.059	-2.683	-2.027	1.776	-0.357	0.345	0.866	3.00
	(21.9)	(10.6)	(-25.0)	(26.1)	(-7.1)	(1.1)	(-3.2)	(-5.0)	(-8.0)	(-8.9)	(-4.2)	(-3.3)	(3.0)	(-0.6)	(0.6)		(12.4)

Table 2-1. (continued)

Dependent variable[a,b]	Constant term	Independent variables[c]													Summary statistics[e]	
		HP_w	Pork meat, w+i	w+i	Monthly dummy variable, w+i[d]										R^2	Std. error[g] (C.V.)
					Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
HP_w+_{26}	39.835	0.242	-8.023	0.749	-5.136	0.354	-2.254	-3.298	-5.552	-6.406	-3.195	-2.546	1.627	-0.426	0.528	0.860	3.06
	(22.5)	(9.0)	(-25.6)	(27.2)	(-7.9)	(0.6)	(-3.7)	(-5.3)	(-8.4)	(-9.2)	(-4.9)	(-4.1)	(2.7)	(-0.7)	(0.9)		(12.7)
HP_w+_{28}	41.341	0.195	-8.274	0.788	-5.490	0.007	-2.629	-3.679	-5.854	-6.826	-3.571	-3.073	1.298	-0.507	0.531	0.853	3.13
	(23.1)	(7.1)	(-26.0)	(28.2)	(-8.3)	(0.0)	(-4.3)	(-5.8)	(-8.6)	(-9.7)	(-5.4)	(-4.9)	(2.1)	(-0.8)	(0.9)		(13.0)
HP_w+_{30}	42.506	0.158	-8.459	0.817	-5.645	-0.277	-2.924	-4.017	-6.161	-7.153	-3.792	-3.420	-0.987	-0.658	0.418	0.849	3.18
	(23.7)	(5.7)	(-26.4)	(28.7)	(-8.5)	(-0.5)	(-4.7)	(-6.3)	(-9.0)	(-10.1)	(-5.7)	(-5.4)	(1.6)	(-1.1)	(0.7)		(13.1)
HP_w+_{32}-	45.880	---	-9.088	0.946	-5.896	-0.061	-3.185	-4.577	-7.074	-8.084	-4.389	-3.763	0.715	-1.153	0.137	0.841	3.26
HP_w+_{68}	(26.4)		(-29.5)	(53.4)	(-8.6)	(-0.1)	(-5.0)	(-7.1)	(-10.4)	(-11.4)	(-6.5)	(-5.9)	(1.1)	(-1.8)	(0.2)		(13.5)

[a]Subscript w+i refers to future forecast week where: w = base week; i = number of weeks forward from base week.

[b]Dependent variable HP_w+_i is the price ($/cwt.) of 200-220 lb (91-100 kg) barrows and gilts, Omaha market in future forecast weeks, price forecasts are made biweekly for two weeks to 68 weeks forward.

[c]Explanation of seledted independent variables:

HP_w—Price ($/cwt.) of 200-220 lb (91-100 kg) barrows and gilts, Omaha market in base week.

Pork meat, $_w+_i$—Monthly U.S. per capita pork production (lb/month).

Income, $_w+_i$—Annual U.S. per capita disposable income, current dollars, adjusted quarterly. Each income unit is one hundred dollars.

[d]Monthly dummy variables for the months of February through December are included to indicate seasonal price differences relative to January. A monthly variable has a value of one if the forecast week occurs within that month, zero otherwise.

[e]The number of observations is 625.

[f]The figures in parentheses below the coefficients are Student t-values.

[g]Standard error of the estimate and coefficient of variation.

Table 2-2. Relationships between prices of all other slaughter weight hog and sow classes and the price of base weight, 200-220 lb (91-100 kg) slaughter hogs at Omaha, 1963-1974 ($/cwt.)

Weight class[a]	Constant term	HP_w[b]	Summary statistics R^2	Std. error (C.V.)[c]	N	Observation years[d]
180-200 lb hog	-0.020	0.986	0.998	0.35	488	1963-1974
	(-0.4)	(436.7)		(1.6)		
220-240 lb hog	-0.111	1.002	0.999	0.15	625	1963-1974
	(-6.4)	(431.1)		(0.6)		
240-270 lb hog	-0.026	0.970	0.996	0.46	623	1963-1974
	(-0.5)	(443.5)		(2.0)		
270-300 lb hog	-1.259	0.972	0.992	0.76	308	1968-1974
	(-8.7)	(199.8)		(2.9)		
270-330 lb sow	0.046	0.892	0.974	0.90	394	1965-1974
	(0.3)	(122.0)		(4.8)		
330-400 lb sow	-0.275	0.869	0.973	1.17	625	1963-1974
	(-2.0)	(155.2)		(5.7)		
400-550 lb sow	-0.760	0.860	0.967	1.281	624	1963-1974
	(-4.9)	(139.7)		(6.5)		

[a]Weight classes for hogs and sows coincide with reported price information in *Livestock and Meat Statistics*, U.S. Department of agriculture, Economic Research Service.

[b]HP_w represents the price ($/cwt.) of 200-220 lb (91-100 kg) barrows and gilts, Omaha market.

[c]Standard error of the estimate and coefficient of variation.

[d]Number of weekly observations varies among weight classes because price reports were not available for selected years within the 1963-1974 period. The "Observation Years" column records the years when weekly price data were generally available.

dredweight for a ration composition of 80% corn and 20% soybean meal supplement. Per unit corn and soybean meal price forecasts were developed by Dr. Franz Schwarz and are published in Janssen (1978). Predicted slaughter hog prices are obtained from the forecast models shown in Appendix Table 2-1. The slaughter hog price and feed cost variables assume forecasted slaughter hog price-feed cost relationships are major explanations of expected feeder pig prices in the same forecast period.

Forecast equation coefficients for biweekly price prediction of 50-60 lb (23-27 kg) feeder pigs in the 1975-1976 performance period are shown in Appendix Table 2-3. Other weight classes were linked to the base weight class variable NP1G56 by the following relationships:

1. NP1G40 = 3.204 + 1.227 NP1G56
   (3.6) (78.2)
   R^2 = 0.966, Std. Error = $4.15
   C. V. = 6.0%, N = 240
2. NP1G74 = -1.056 + 0.885 NP1G56
   (-2.1) (61.0)
   R^2 = 0.979, Std. Error = $2.32
   C.V. = 5.0%, N = 240

Table 2-3. Feeder pig price forecasting equations from base week to forecast week for basic weight, 50-60 lb (23-27 kg), pigs (based on 1970-1974 data for Norfolk, Nebraska-Sioux Falls, South Dakota feeder pigs, $/cwt.).

Dependent variable[a,b]	Constant term	Independent variables[c]						Summary statistics		
		NP_w	HP_{w+i}	Ration, $_{w+i}$	Spring, $_{w+i}$	Summer, $_{w+i}$	Fall, $_{w+i}$	R^2	Std. error (C.V.)	N
NP_{w+2}	-0.658	0.618	1.070	-2.784	1.151	-3.941	-1.788	0.941	4.46	246
	(-0.6)	(16.2)	(9.7)	(-6.4)	(-1.3)	(-4.7)	(-2.2)		(8.5)	
NP_{w+4}	-1.470	0.459	1.574	-4.272	1.854	-5.969	-2.541	0.933	4.81	244
	(-1.2)	(13.9)	(16.2)	(-9.8)	(1.9)	(-6.7)	(-2.9)		(9.2)	
NP_{w+6}	-1.969	0.423	1.708	-4.724	2.333	-6.446	-2.550	0.932	4.83	242
	(-1.6)	(13.7)	(18.9)	(-11.0)	(2.4)	(-7.3)	(-2.9)		(9.2)	
NP_{w+8}	-3.060	0.353	1.945	-5.469	3.969	-7.358	-1.840	0.927	5.00	240
	(-2.4)	(12.8)	(23.2)	(-12.4)	(4.0)	(-7.9)	(-2.0)		(9.5)	
NP_{w+10}	-2.891	0.330	1.994	-5.574	4.500	-7.743	-1.846	0.923	5.15	238
	(-2.2)	(11.8)	(23.3)	(-12.3)	(4.4)	(-8.1)	(-1.9)		(9.8)	
NP_{w+12}	-2.890	0.260	2.158	-5.969	5.864	-8.650	-1.785	9.909	5.65	236
	(-2.0)	(8.8)	(23.7)	(-12.0)	(5.3)	(-8.1)	(-1.7)		(10.8)	
NP_{w+14}	-2.744	0.231	2.216	-6.120	6.308	-8.525	-1.612	0.902	5.87	234
	(-1.8)	(7.4)	(23.6)	(-11.8)	(5.5)	(-7.6)	(-1.5)		(11.3)	
NP_{w+16}	-2.425	0.190	2.313	-6.452	7.220	-8.750	-1.530	0.893	6.15	232
	(-1.5)	(5.8)	(24.2)	(-11.9)	(6.0)	(-7.4)	(-1.3)		(11.8)	
NP_{w+18}	-2.624	0.178	2.352	-6.581	7.469	-8.536	-1.594	0.890	6.24	230
	(-1.6)	(5.4)	(24.6)	(-11.9)	(6.1)	(-7.1)	(-1.4)		(12.0)	
NP_{w+20}	-1.680	0.128	2.425	-6.685	7.597	-8.488	-2.024	0.884	6.41	228
	(-1.0)	(3.8)	(25.3)	(-11.7)	(6.0)	(-6.9)	(-1.7)		(12.3)	
NP_{w+22}-NP_{w+48}	-1.367		2.584	-6.436	8.142	-7.168	-1.787	0.879	6.37	254
	(-0.9)		(31.9)	(-12.2)	(7.2)	(-6.3)	(-1.6)		(12.2)	

[a]Subscript w + i refers to future forecast week where: w = base week; i = number of weeks forward from base week.

[b]Dependent variable NP_{w+i} is the price ($/cwt.) of 50-50 lb (23-27 kg) Norfolk, Nebraska-Sioux Falls, South Dakota feeder pigs in future forecast weeks. Price forecasts are made biweekly for two weeks to 48 weeks forward.

[c]Explanation to independent variables:

NP_w—Price ($/cwt.) of 50-60 lb (23-27 kg) Norfolk, Nebraska-Sioux Falls, South Dakota feeder pigs in base week.

NP_{w+i}—Price ($/cwt.) of 200-220 lb (91-100 kg) Omaha market hogs for the i-th future forecast week.

Ration $_{w+i}$—Price ($/cwt.) of swine feed ration (80% corn and 20% soybeen meal supplement) for the i-th future forecast week.

Spring, $_{w+i}$—Dummy variable for March-May.

Summer, $_{w+i}$—Dummy variable for June-August.

Fall, $_{w+i}$—Dummy variable for September-November.

[d]Standard error of the estimate and coefficient of variation.

[e]The figures in parentheses below the coefficients are Student t-values.

where all variables are previously defined and numbers enclosed in parentheses are Student t-values for the null hypothesis Bi = 0.

APPENDIX 3—LABOR AND CAPITAL REQUIREMENTS

Table 3-1. Summary of variable labor requirements by major activity in model farrow-finish swine operation.

Activity	Labor requirements
	(Hours per animal unit per two-week decision period)
Feed and care of replacement gilts	0.10 hour/replacement gilts
Feed and care of sow or gilt during breeding and gestation	0.17 hour/bred sow or gilt
Feed and care of sow and litter of pigs from farrowing to weaning	1.48 hour/sow farrowed
Feed and prepare sow or gilt for sale	0.20 hour/sow or gilt/sales period
Feed and care of nursery pigs	0.13 hour/nursery pig
Prepare purchased feeder pigs for nursery[a]	0.10 hour purchased pig/purchase period
Prepare nursery pigs for sale or transfer to finishing space[a]	0.08 hour/nursery pig
Feed and care of finishing hogs	0.03 hour/finishing hog
Prepare finishing hogs for sale[a]	0.08 hour/finishing hog/sale period

[a]Labor requirement includes preparation (loading or unloading hogs and vaccination) time exceeding normal labor requirement for care and feeding of hogs.

Table 3-2. Initial capital investment in land, buildings and equipment for a 192 sow farrow-to-finish swine confinement unit, standard and flexible operations, 1975-1976.

Description	Investment cost per unit	Standard operation		Flexible operation[a]	
		No. of units	Total investment cost	No. of units	Total investment cost
	(Dollars/ unit		(Dollars)		(Dollars)
Land	$600/acre	8	4,800	9	5,400
Gestation and replacement gilt facilities[b]	$59/ space	220	12,980	250	14,750
Farrowing Facilities[b]	$965/ space	65	62,725	65	62,725
Nursery facilities[b]	$60/ space	500	30,050	500	30,050
Finishing facilities[b]	$72.70/ space	750	54,524	1,000	72,700
General equipment[c]	----	----	24,600	----	27,660
Total investment cost			$189,679		$213,285

[a]Flexible operation requires additional finishing facilities to permit holding finishing hogs to heavier weights. The flexible operation requires a higher number of replacement gilts which are held in the additional gestation facilities.

[b]Facilities include buildings and associated equipment such as pens, crates, feeders, waterers, heaters, fans, plumbing and wiring. Specific facilities assumed were:

1) Two environmentally-regulated farrowing houses with farrowing crates and slotted floor.
2) Two environmentally-regulated nursery houses with slotted floor and 4.65 square feet of space (including alleys) per pig for 250 pig ..jox
3) Three (four) modified open front finishing facilities for the standard (flexible) operation consisting of 250 spaces averaging 9.0 square feet (including alleys).
4) Practical sow shelters and breeding pens.

[c]General equipment is used by all facilities in a farrow-to-finish swine confinement unit. This equipment includes feed storage bins, electric mill, feed delivery system, water delivery system, manure handling equipment, standby generator sprayer cleaner, sales, loading and sorting equipment, office equipment and miscellaneous equipment. The ratio of general equipment and land investment cost to building facility investment cost is assumed to remain constant from the standard operation to the flexible operation.

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