ECONOMIC REPLACEMENT OF A HETEROGENEOUS HERD

by
K. Boys, N. Li, P.V. Preckel,
A.P. Schinckel, and K.A. Foster*
Dept. of Agricultural Economics, Purdue University
West Lafayette, Indiana 47907-1145
preckel@purdue.edu
Staff Paper #05-05
May 2005

Abstract

A model was developed and used to determine the optimal slaughter weights of pigs with heterogeneous growth raised in a 1,000 head barn and marketed in truckload groups. Explicitly recognizing the heterogeneity of pig weights and marketing the herd over time in truckload batches can substantially increase profit.

Keywords: livestock economics, livestock replacement, herd modeling

* Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005. Assistance in generating simulated heterogeneous herd growth results by Mark Einstein and feed cost information provided by Dr. Brian Richert are gratefully acknowledged.

ECONOMIC REPLACEMENT OF A HETEROGENEOUS HERD

by
K. Boys, N. Li, P.V. Preckel,
A.P. Schinckel, and K.A. Foster

Introduction

In the traditional analysis of the livestock replacement problem, a representative animal or the mean of a group of animals is used as the unit of analysis. Although recent research has sought to widen the scope of such problems (e.g., to include analysis of nutrition strategies, split-sex feeding, and the use of growth supplements), within-herd heterogeneity of animal growth has been largely ignored in the production literature. This omission is particularly important in the swine industry where packer payment programs frequently include significant price discounts for over- and under-weight animals, and where the majority of producers clear out an entire production unit for cleaning before replacing the animals with a new herd (All-In/All-Out production).

The goal of this paper is to assess the importance of considering heterogeneity of animal growth in making herd replacement decisions. The analysis proceeds in two steps. As a first step the economic results of basing the optimal slaughter age on the herd average growth curve are compared with the results basing the optimal slaughter age on the heterogeneous growth curves in the herd. For comparability, the entire herd is marketed at once in both the average growth and heterogeneous growth cases. In addition, revenues in both cases are calculated on the basis of the true heterogeneous weights of the animals at slaughter. As a second step, it is demonstrated that marketing animals in truckload batches over time rather than all at once can further increase profit. The potential advantage of this approach is that faster growing animals can be marketed earlier than slower growing animals, potentially avoiding some discounts for overweight and underweight animals that occur with marketing on a single day.

The present analysis focuses upon the replacement decision for a hog producer using an All-In/All-Out grow/finish production system (AIAO). Thus, animals are fed from age 50 days to slaughter in a barn with a capacity of 1,000 head. Per the AIAO system, all pigs must be marketed and the barn cleaned and disinfected before the next group of animals can be brought in. It is further assumed that animals are marketed through a “Cash Market”. In this channel, producers set prices that are transparent and known prior to delivery. As is common in practice, this study assumes that the packer applies price discounts to animals whose weight is not within what is deemed to be an optimal range with larger discounts for weights further from the optimal range.

This paper proceeds in the following manner. In the next section, details of the models used for the assessment, and assumptions underlying these models are presented. Subsequent sections present the research, draw conclusions from the study, and suggest avenues for further research.

Models

A deterministic spreadsheet model was developed and used to determine the optimal slaughter weights of pigs that are raised in a large (1000 head) barn, and are marketed in truckload groups. The purpose of this analysis is to consider herd replacement in a fixed capacity facility, and consequently the objective function is to maximize average daily returns to the facility and operator labor. In order to assess the economic outcomes of the alternative approaches to analyzing marketing decisions, three variants of the model are developed. Each of these models is presented below, followed by a discussion of the model parameters.

Model One: Homogeneous Herd, Single Shipping Decision

In this model, the producer bases his/her shipping decision upon a "mean animal" – an animal whose growth curve is equal to the average of the growth curves of all animals in the herd. It is assumed that all animals will be shipped on one day, and that the selected day will be the one for which the discounted average daily profit generated by this mean animal is maximized (Burt, 1963). As actual profits received by the producer are based on actual weights rather than on the mean animal's weight, the heterogeneous herd information is used to determine actual profits on the selected shipping date.

This model can be written as:

$$\max_t \ \mathrm{E}[\pi(t)] = \frac{1}{t} n \left[\beta^t \overline{W}_t \times \left(P - d(\overline{W}_t) \right) - \overline{VC}_t \right] \tag{1}$$

where:

i = the i^{th} pig

t = number of days the production facility is in use by the herd (animal growth/finishing plus turnover time)

β = discount factor used to convert future revenue to present value

$\overline{W}_t$ = the herd average hot carcass weight on day t

n = total number of individual pigs (n=1000)

$\overline{VC}_t$ = present value of average variable production costs per pig on day t

P = Base hot carcass weight price ($/kg)

$d(\overline{W}_t)$ = Discounted price for the herd average hot carcass weight ($/kg)

Model Two: Heterogeneous Herd, Single Shipping Decision

Similar to Model One, this model optimizes the day on which all animals are marketed. This analysis differs, however, in that Model Two explicitly recognizes herd heterogeneity; the shipping decision independently considers each animal weight and its associated discounted price. This model can thus be specified as:

$$\max_{t} \ \pi(t) = \frac{1}{t}\sum_{i=1}^{n}\left(\beta^{t} W_{it} \times [P - d(W_{it})] - VC_{it}\right) \qquad (2)$$

where:

W_{It} = the hot carcass weight of pig *i* on day *t*

VC_{it} = present value of variable production costs for pig *i* on day *t*

$d(W_{it})$ = price discount for the hot carcass weight of pig *i* on day *t* ($/kg)

Assumptions concerning producer information and prices are the same as those described in Model One above. In addition to selecting an optimal shipping date, this model can be directly used to determine the daily profit that will be realized by the production facility. (The economic results for Model One are calculated as in (2) despite (1) being used as the objective function for the optimization. Thus, the problem with Model One is that the optimization is performed with respect to the wrong objective.)

Model Three: Heterogeneous Herd, Multiple Shipping Decisions

Model Three also treats the herd as a heterogeneous group, but in this model truckload batches of animals may be shipped on multiple shipping dates. However, more than on batch may be shipped on any given day. For each herd of 1,000 animals, it is assumed that truckloads are shipped full (170 head), with the exception of the final, sixth load which contains the remaining 150 head. Because the primary reason for early shipments is to reduce overweight discounts (we do not consider issues related to crowding in the barn), the heaviest animals are shipped first. Following this shipment, animals remaining in the herd are evaluated to determine the date at which the next shipment should be made. Profits from all shipments are combined with the shipping date of the last load to determine the average daily returns to the facility. Returns to the facility are optimized per unit of time that the facility is in use, and are thus based on the shipping date of the final load corresponding to the barn turn-over period.

$$\max_{s_1, s_2, \ldots, s_6} \ \pi(t) = \frac{1}{s_6}\sum_{l=1}^{6}\sum_{i \in L_1(s_l)}\left[\beta^{t} W_{ls_l} \times [P - d(W_{is_l})] - VC_{is_l}\right]$$

where:

s_l = the marketing day for load *l*

$L_l(s_l)$ = subset of size 170 (150 for l = 6) of the remaining animals that are heaviest on day s_l

With this set-up, truckloads marketed prior to s_6 are not marketed until maximum profit for that batch is achieved (marginal revenue equal to marginal cost assuming differentiability). However, the final truckload(s) marketed on s_6 are shipped when the average profit per unit of time is maximized (including revenues and costs for all truckloads), thereby accounting for the opportunity cost of the fixed facilities.

Production Characteristics and Assumptions

The following discussion provides details concerning the parameters and assumptions that were used in the developing this model.

Swine Herd

This analysis uses a stochastic model of swine herd compositional growth that has been estimated as a random effects model based on animal feeding trials (Schinckel *et al.*, 2003a). The portion of the model focused on live weight growth is briefly described below as a function of time:

$$BW_{it} = (C + c_i)(1 - \exp(-\exp(M + m_i)t^A)) + b + e_{it}$$

where:

BW_{it} = body weight of i^{th} pig at time t

C, M, A = fixed population parameters

c_i, m_i = random effects for the i^{th} pig

t = age of the pig

b = body weight at birth (a constant equal to 1.4kg)

The portion of the model focused on feed consumption is as follows:

$$PA_{it} = (E + e_i)[1 - \exp(\delta_0 + \delta_1 BW_{it} + \delta_2 BW_{it}^2)]$$
$$FA_{it} = [(BW_{it} - \alpha_1 PA_{it}^{\gamma_1}) / \alpha_2]^{1/\gamma_2}$$
$$FI_{it} = \phi BW_{it}^{\eta} + \varphi PA_{it} + \psi FA_{it}$$

where:

PA_{it} = protein accretion for i^{th} pig at time t

FA_{it} = fat accretion for i^{th} pig at time t

FI_{it}	= feed intake for i^{th} pig at time t
$E, \delta_0, \delta_1, \delta_2$	= fixed population parameters for protein accretion
e_i	= random effect parameter for i^{th} pig protein accretion
$\alpha_1, \alpha_2, \gamma_1, \gamma_2$	= parameters for fat accretion
ϕ, φ, ψ	= parameters for feed intake

Because this model focuses on the growth of individual animals in the herd, and reflects the most important determinant of revenue (body weight) and costs (feed intake), it is ideal for the evaluation of the impacts of heterogeneity on optimal marketing decisions. (Details of the model may be found in Schinckel *et al.*, 2003a,b.)

Using this model, 100 herds of 1,000 gilts were generated, and body weight and feed intake were recorded daily from the age of 50 to 200 days (a time span sufficiently large to cover any reasonable length for the grow-finish stage of production). Descriptive herd statistics are provided in the Results section. The alternative marketing models were applied to each of the 100 herds.

Production System

As previously described, the present analysis assumes the use of an AIAO production system. This widely used system accounts for 80% of pigs currently produced in the United States, and has been the focus of work by several authors including Conner and Lowe (2002). Briefly, under this system, all pigs have to be marketed and the barn must be cleaned and disinfected before the next group of young feeder pigs is brought in to refill the barn. It is assumed that this cleaning and herd restocking process takes seven (7) days. This analysis further assumes that the production facilities are a sunk expense, and have no alternative uses. Labor to operate the production facility is subsumed in the production facility cost and is assumed not to vary with either the herd or herd size. As such, both the facility and associated operator labor are considered fixed expenses and thus, the objective is returns to these fixed facilities and operator labor. Given low interest rates and the relatively short period (less than four months) to cycle a herd through a barn, the discount rate reflecting the time value of money was set to zero.

Production Inputs

Feeder pigs, feed, transportation costs, and a small number of other inputs are explicitly taken into account in calculating the return to fixed facilities and operator labor. Each of these inputs and their costs are detailed below:

Feeder Pigs: It was assumed that pigs were purchased from another (nursery) site at 50 days of age. Descriptive statistics concerning the herd averages at purchase are presented in the discussion of Results. A ten year average (1991-2000) feeder pig price of $42.00 (Li, 2003) was used in this analysis.

Feed: As feed is the largest-cost input in the swine grower-finisher production process, this topic deserves special attention. To approximate an economically optimal nutrition program, this analysis assumed that pigs would be fed a total of five diets over their growth and finishing phases. For the purpose of this analysis, animals were fed diets 1-3 during the growth phase, and diets 4-5 during the finishing phase. Decisions concerning the day on which each diet was started were based on Li (2003; p. 177), and Schinckel (2005). Optimized content for each of these diets is presented in Table 2 below. In addition to feed, the cost per kg of each diet included a $12/ton grinding, mixing and feed transportation cost.

Feed composition was based on a standard corn-soybean meal diet that included synthetic lysine, a vitamin-mineral premix. Calculation of feed composition and feed cost followed a cost minimization research work by Hill *et al.* (1998). Synthetic lysine was added at 0.117% of the available lysine level, and the proportion of corn and soybean meal was adjusted to achieve the desired dietary lysine percentage. A simple feed-mix model was developed and used for this optimization process. Desired diet levels for ingredients other than corn and soybean meal were adopted from the "Purdue University Standard Swine Diets for the Research and Teaching Center" (Purdue University, 2003). A summary of the major diet components, their energy availability and price are provided in Table 1 below. In this study, dietary rather than digestible energy levels are used.

<u>Corn</u>: As is commonly done, this analysis assumed that a bushel of corn weighed 56 lbs. Industry standard nutrient values were used for the corn used in this analysis (yellow grain, NRC, 1998). Corn prices were calculated by Li (2003) and were based on a ten-year price average (1991-2003).

<u>Soybean Meal</u>: Industry standard nutrient values were used for the soybean meal used in this analysis (dehulled 48% crude protein soybean meal, NRC, 1998). The soybean meal price uses in this analysis was similarly based upon the same ten-year price average (Li, 2003).

<u>Lysine</u>: As dietary lysine is available to hogs through a number of common feeds, producers may mix feed ingredients to obtain the lowest cost of desired lysine levels. Lysine is the first limiting essential amino acid in corn-soybean meal based swine diets(NRC, 1998). In this instance, corn and soybean meal provided the major sources of lysine and other essiential animo acids. Low lysine diets contain relatively more corn and less soybean meal, have greater net energy content, and result in an increased ratio of lipid to protein accretion in the animal than low lysine diets. As corn is relatively less expensive, low lysine diets have a lower cost per pound. Alternatively, high lysine diets, contain relatively more soybean meal, provide a lower amount of net energy, and contribute to an increased rate of protein accretion relative to lipid accretion (Schinckel *et al.*, 2003b; Li, 2003). Following the Purdue recommended swine diets (Purdue University, 2003), it was assumed that 0.15% synthetic Lysine-HCL contianing 78 % L-Lysine was added throughout the duration of the feeding period.

<u>Other Feed Ingredients</u>: While the soybean meal and corn content of the diets is adjusted to meet minimum lysine requirements and varies with the relative prices of these ingredients, other feed ingredients were assumed to be included in fixed quantities. The quantity and composition of other diet ingredients were based upon the Purdue University recommended standard swine diets (Purdue University, 2003). These diet formulations contain, in small quantities, a number of

ingredients that help ensure that the swine nutrient requirements are met at each growth/finishing stage. All feed ingredients, their percentages, and the feed analysis are displayed in Table 2. It is assumed that the nutrient requirements for "Grower 1" were used for Diet 1, and Diet 2; the ingredients in Grower 2 were assumed for swine on Diet 3. Diets 4 and 5 correspond to diets for Finisher I and Finisher II, respectively. It is assumed that no metabolizable energy is obtained from base mixes (Schinckel, 2005).

Transportation: Transportation costs of feeder pigs to the production facility are assumed to be included in the feeder pig purchase price. Transportation costs at the point of marketing are based upon ten-year transportation cost averages (1991-2000), and were determined to be $2.00/head (Li, 2003). It is assumed that transportation costs are the same whether the entire barn is marketed at once or truckload batches are marketed over time.

In order to most efficiently market a herd, it is assumed that, where possible, animals are shipped in full-truckload batches. Shipping in this manner requires 5 full truckloads of (170 head/truck), and one partial truckload (remaining 150 head). It is further assumed that, in shipping, animals are ordered by weight at the time the load is shipped.

Other Inputs: For the purposes of this analysis, a variety of other, relatively small inputs and expenses are combined under this heading. Veterinary expenses, medication, and death loss are among the expenses captured here. It is estimated that the cost of these other items are $0.09/day (Li, 2003).

Marketing

To encourage the delivery of more homogeneous animals, swine processors discount base prices for those animals that are outside an ideal weight range. Hog base price and discount schedules are based on the individual animal's hot carcass weight (head and skin removed) rather than their live weight. This model assumes that the producer has perfect knowledge of the individual pig's live-weight. Hot carcass weight is a function of live weight, and it is assumed that the producer has perfect knowledge of each animal's hot carcass weight and can sort animals without error.

In practice, two types of carcass based payment schemes are widely used in industry. The first scheme assigns payments based on animal weight for over- and under- weight carcasses. The second scheme bases payments first upon the animal weight, and then provides further premiums or discounts on the basis of carcass leanness. The present study considers only the first payment scheme. This analysis uses the discount schedule from Farmland America's "Best Pork Carcass Merit Program" which is presented in Table 3. A ten-year average live weight price (1991-2000) of $43.00/cwt was used to as the base price (Li, 2003). It is assumed that the market for live hogs is competitive and that the producer in question cannot influence the price or discount schedule for either finished hogs or feeder pigs, and that producers face no price risk.

<u>Results</u>

Swine shipping decisions have historically been based on consideration of herds as homogeneous groups of animals; where decisions were based on the state of an average or representative animal. In this analysis, Models One and Two were used to determine if there was a difference in the optimal shipping decision should herds be considered as a heterogeneous rather than a homogeneous (average) group, as well as the impact on returns to facilities and labor. The results of this analysis are displayed in the first two columns of Table 4.

The first column in Table 4 displays the results when the analysis is based on the representative animal, but revenues are calculated based on the true, heterogeneous animal weights. Based on 100 randomly drawn herds, the expected annual return for a 1,000 head barn was $91,048 with a standard deviation of $613, and the observed range is from about two percent below the mean to about one and a half percent above the mean. The average number of days on feed was quite stable with a range of 113 to 114 days.

The explicit recognition that the herd is heterogeneous has a substantial effect on both the optimal shipping date and the level of returns to fixed facilities and operator labor. (These results are displayed in the second column of Table 4.) The average number of days on feed with the improved analysis is reduced by five, and returns to fixed facilities and operator labor increase by over 1.3 percent. In addition, the standard deviation of returns is reduced by about 8.3 percent. The range of optimal shipping dates is slightly wider with this approach to analysis – four days as opposed to two days with the analysis based on the representative animal.

The results for the analysis that explicitly recognizes that the herd is heterogeneous and allows truckload shipments on multiple dates are displayed in columns three through five in Table 4. Because multiple shipment dates are permitted, but not required, one feasible strategy is to market all animals on the same day. This was not optimal for any of the 100 randomly generated herds. It was optimal in some cases (52 percent of the time) to ship one truckload of animals on one day and ship the rest of the animals on another day. These cases are summarized in the fourth column of Table 4. It was optimal the rest of the time (48 percent of the herds) to ship two single truckloads on different days followed by a shipment of all remaining animals on a single day. These cases are summarized in the fifth column of Table 4. Column four of Table 4 summarizes both of these cases. Overall, the strategy of multiple shipments increases returns to fixed facilities and operator labor by slightly under 0.2 percent. However, this strategy also reduces the standard deviation of returns, thus increasing the benefit from a risk management perspective. The optimal date for shipping the final load is only slightly changed by the multiple shipment strategy. It increases by one day on average, reflecting the fact that the marketing of an early truckload or two removes the heaviest animals from the herd, thereby reducing the incidence of discounts for heavy animals in the final shipment. However, the fact that the increase in the shipping date for the final load is so small indicates that the opportunity of facility costs continues to dominate that decision.

Conclusions and Future Work

This study adapts the standard approach to the livestock replacement model to the situation where the unit of analysis is a herd, and the growth of animals within the herd is heterogeneous. Based on simulation results for a swine production unit, we find that ignoring heterogeneity within the herd distorts decisions regarding the optimal timing of marketing, and in the presence of discounts for over- and under-weight pigs overstates the returns to facilities and operator labor. Explicit recognition of heterogeneous animal growth also allows us to analyze the potential earnings associated with the strategy of multiple marketing. In the context of a swine producing unit where marketing is restricted to truckload batches, but permitted to occur over time, we found that multiple marketing resulted in a modest increase in expected return to facilities and operator labor, but also resulted in a decrease in variability of returns. While the return per pig may appear small it should be noted that in some cases producers or production contractors may reap the benefits of a more sophisticated marketing strategy for many thousands of pigs making the sum total benefit of the strategy potentially quite large.

The results presented here are based on an estimated herd-level swine growth model where the original data comes from herds with good genetics, above average growth rates, and above average health status. Thus, the variability of live weight within the herd was at the low end of what is normal for a producer. Pigs with lower health status can have depressed growth and increased variation in growth (Schinckel and Craig, 2003). Additional work should focus on evaluating the multiple marketing strategy under greater within herd variability. In addition, the assessment should also be made for alternative packer payment programs.

This type of approach to analysis may also be useful for evaluating production strategies such as nutrition management. A herd level model is also essential for the evaluation of technologies such as ractopamine that are known to affect not only the mean growth performance, but also the variation of growth performance within the herd. In addition, this type of model is needed for the evaluation of the benefits of production facilities that incorporate automatic sorting technology. This type of analysis could be extended to reflect the affects that marketing over time would have on growth performance for animals remaining after the first and subsequent truckloads have been shipped due to reduced crowding. In general, this type of model is a prerequisite for determining the value of production and marketing strategies that influence the variability of growth within the herd.

References

Burt, O. 1963. "Economic Replacement," *SIAM Review*, 5(3): 203-208.

Conner, J. and J. Lowe. 2002. "Economic Analysis and the Discussion of Automatic Sorting Technology," Carthage Veterinary Service, Ltd. Carthage, IL. Copyright by Farmweld, Inc., Teutopolis, IL.

Farmland Co. 1999. "America's Best Pork Carcass Merit Program," Kansas City, MO.

Hill, G., D. Roxeboom, N. Trottier, D. Mahan, L. Adeoli, T. Cline, D. Forsyth, and B. Richert. 1998. "Tri-State Swine Nutrition Guide," The Ohio State University Bulletin 869-98, Department of Animal Sciences, Ohio State University, Columbus, Ohio.

Kirstein, D. 2001. "Tools to Evaluate the Use of Animal Fats in Livestock and Poultry Rations," AMENA CONGRESS. Puerto Vallarta, Jalisca, Mexico. Available Online.

Kendall, D., B. Richert, A. Sutton, J. Frank, S, DeCamp, K. Bowers, D. Kelly, M. Cobb, and D. Bundy. 1999. "Effects of fiber addition (10% soybean hulls) to a reduced crude protein diet supplemented with synthetic amino acid verses a standard commercial diet on pig performance, pit composition, odor, and ammonia levels in swine buildings," Purdue University 1999 Swine Day Report, Department of Animal Science.

Li, N. 2003. Economic analysis of optimal production and marketing management strategies for swine production operations with Paylean. Ph.D Thesis. Purdue University, Department of Agricultural Economics.

National Research Council (NRC). 1998. Nutrient Requirements of Swine, 10th Revised Edition. National Academic Press, Washington, DC, USA.

Purdue University. 2003. "Purdue University Standard Swine Diets for the Research and Teaching Center."

Richert, B. 2005. Personal Communication.

Schinkel, A. and B. Craig. 2003. Evaluation of alternative nonlinear mixed effects models of swine growth. *The Professional Animal Scientist*, 18:219-226.

Schinckel, A., P. Preckel, M. Einstein, and D. Miller. 2003a. Development of a Stochastic Pig Compositional Growth Model. *The Professional Animal Scientist*, 19 (3): 255-260.

Schinckel, A. P., N. Li, B. Richert, P. Preckel, and M. Einstein. 2003b. Development of a model to describe the compositional growth and dietary lysine requirements of pigs fed ractopamine. J. Anim. Sci. 81:1106-1119.

Schinckel, A. 2005. Personal Communication.

Table 1: Summary of Swine Diet Ingredient Energy Availability and Price

Diet Component	Metabolizable Energy (kcal/kg)	Price ($)/kg	Information Source	
			Energy Content	Price
Corn (Yellow grain)	3420	0.0992	NRC, 1998	Li 2003
Soybean Meal	3380	0.2106	NRC, 1998	Li 2003
Lysine (Lysine-HCl)	701	1.2125	Kirstein, 2001	Kendall *et al.*, 1999
Diets 1- Supplementary Ingredients	0	0.012907	Assume no dietary energy; Schinkel 2005	Richert, 2005
Diets 2- Supplementary Ingredients	0	0.012907	Assumes no dietary energy: Schinckel, 2005	Richert, 2005
Diets 3- Supplementary Ingredients	0	0.012343	Assumes no dietary energy: Schinckel, 2005	Richert, 2005
Diets 4- Supplementary Ingredients	0	0.011438	Assumes no dietary energy: Schinckel, 2005	Richert, 2005
Diets 5- Supplementary Ingredients	0	0.013561	Assumes no dietary energy: Schinckel, 2005	Richert, 2005

Table 2. Composition of Phase Feeding Diets Used During the Growth and Finishing Stages

Diet	1	2	3	4	5
Diet Phase	Grower 1	Grower 1	Grower 2	Finisher 1	Finisher 2
Days Diet Fed (start-finish)	50-75	76-102	102-116	117-129	130-market
Days on Diet	25	26	14	13	Variable
Ingredient %					
Corn	71.60	77.10	80.80	83.80	86.90
Soybean Meal, 48%	24.70	19.30	15.70	13.10	10.20
Dical. Phosphate	1.08	1.08	0.92	0.74	.54
Limestone	0.75	0.75	0.78	0.81	.83
Salt	0.35	0.35	0.35	0.25	0.25
Choice white grease	1.00	1.00	1.00	1.00	1.00
Lysine -HCl	0.15	0.15	0.15	0.15	0.15
Swine Vit. Premix	0.15	0.15	0.15	0.10	0.10
Swine TM Premix	0.0875	0.0875	0.0875	0.05	0.05
Selinium 600 premix	0.05	0.05	0.05	0.025	0.025
OTC or CTC (50 g/lb)	0.10	0.10	0.10	0.10	0.00
Tylan 40	0.00	0.00	0.00	0.00	0.05
Phytase (600 PU/g)	.075	.075	.075	.075	0.05
Calculated Analysis					
Crude Protein, %	17.0	17.0	14.9	12.9	11.5
Lysine, %	1.00	1.00	.85	.70	.60
Threonine, %	.68	.68	.60	.53	.47
Tryptophan, %	.22	.22	.19	.16	.14
Methionine, %	.29	.29	.26	.23	.22
Total Sulfurs, %	.60	.60	.55	.50	.47
Ca, %	.65	.65	.60	.55	.50
P, %	.55	.55	.50	.45	.40
Avail. P, %	.29	.29	.25	.21	.16

Notes:
Percentage content of Corn and Soybean Meal was optimized based upon market prices and lysine dietary requirements. Percentage content of all other ingredients was based upon the Purdue University Standard Swine Diets for the Research and Teaching Center (Revised 11.18.2003)

Table 3: Carcass Weight Discount Grids for Under- and Over- weight Carcasses in all Payment Schemes

Estimated Live Weight Range (lbs)	Hot Carcass Weight Range (lbs)	Discount (per cwt of scalded carcass)
Under 190	Under 140	-$9.46
191-200	141-148	-$9.46
201-210	149-155	-$6.76
211-220	156-163	-$4.05
221-229	164-169	-$1.35
230-240	170-177	0
241-250	178-185	0
251-260	186-192	0
261-270	193-200	0
271-280	201-207	0
281-290	208-214	-$0.68
291-300	215-222	-$2.03
301-310	223-229	-$3.38
311-320	230-237	-$6.08
Over 320	Over 237	-$8.76

Notes:
Discount schedule based upon Farmland America's Best Pork Carcass Merit Program, effective 9/20/99.
Source: Li, 2003.

Table 4. Annual Return to Fixed Facilities and Operator Labor[1]

Model Type	Homogeneous (Average) Herd	Heterogeneous Herd			
	Single Shipping Date	Single Shipping Date	Multiple Shipping Dates		
			Overall	Market Once	Market Twice
Expected Return	91,048	92,270	92,435	92,539	92,323
Standard Deviation of Return	613	562	552	530	558
Minimum Return	89,670	91,088	91,240	91,406	91,240
Maximum Return	92,688	92,890	93,973	93,973	93,631
Average Days on Feed	114	109	110	Load 1:105 Rest: 110	Load 1:104 Load 2: 108 Rest: 110
Std. Dev. Days on Feed	0.487	0.677	0.674	Load 1:1.256 Rest: 0.727	Load 1: 1.148 Load 2: 0.616 Rest: 0.555
Minimum Days on Feed	113	108	108	Load 1:102 Rest: 108	Load 1: 102 Load 2: 107 Rest: 109
Maximum Days on Feed	114	111	111	Load 1:107 Rest: 111	Load 1: 107 Load 2: 109 Rest: 111
Number of Cases	100	100	100	52	48

Notes:
[1]These results are based on 100 randomly generated herds of 1,000 animals for a finishing operation. Calculations include a seven day period for marketing animals, cleaning and restocking the facility.