1972

Optimum swine production and marketing strategies with limited farrowing and finishing space

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by

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A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Department: Economics
Major: Agricultural Economics

Iowa State University
Ames, Iowa

1972

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ACKNOWLEDGEMENTS

The author wishes to acknowledge the help of several individuals who contributed significantly to the completion of his task.

Thanks are due Professor Raymond R. Beneke, who was patient.

Thanks are due Charlotte Latta and Shu Huang, who were friendly and cooperative.

Very special thanks are due Carol A. Hanrahan, who continually showers the author with unselfish love.

INTRODUCTION

Many observers have noted an increasing move toward swine confinement production systems. The most common reasons given for this trend are that land is becoming more and more expensive and that hired labor is becoming both scarce and expensive.[1] It is usually claimed that confinement swine production requires considerably less labor per animal produced than swine on pasture. Confinement production also allows the operator to devote more time to managing his animals because less of his labor is required to tend them. Therefore, on the production side there has been a steady substitution of capital in the form of buildings and equipment for labor and for land.

The move to confinement has been associated with increasing scale. Table 1 shows that the percentage of Iowa swine producing farms spring farrowing 31 sows or more has risen from 8.1% of the total in 1961 to 21.8% in 1970. The table also shows that 36.6% of all pigs marketed in 1969 came from producers marketing 500 or more pigs yearly. This means that the dollar cost of non-optimal production and marketing decisions to these larger producers is greatly magnified.

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[1]The average daily wage in Iowa increased from $10.30 in 1961 to $15.80 in 1970, while the average price of farmland increased from $237 to $385 per acre during the same period (6,8).

Table 1. Size distribution of Iowa swine producers, 1961-1970[a]

Year	Total number of farms reporting farrowings[b]	Farms farrowing 1 to 10 sows as % of total	Farms farrowing 11 to 30 sows as % of total	Farms farrowing 31 sows or more as % of total	Pigs marketed from herds of 500 pigs or more as % of all pigs marketed
1961	91829	32.4	59.5	8.1	-
1962	87508	30.3	60.2	9.5	-
1963	84131	28.4	60.7	10.9	-
1964	77795	27.8	60.8	11.4	-
1965	71593	27.1	60.4	12.5	-
1966	71193	24.7	60.4	14.9	-
1967	68959	24.1	60.3	15.6	-
1968	65000	22.8	60.3	16.9	33.6
1969	58969	21.3	60.5	18.2	36.6
1970	58638	19.3	58.9	21.8	-

[a]Source: (12, 13).

[b]All farrowing figures are for spring farrowings only.

The historic instability in swine production has generated sharply fluctuating prices. From 1961 through 1970 live weight pork prices fluctuated from a low of $13.00 to a high of $28.00 per hundredweight. Movements of one to two dollars per hundredweight per month are common, and on one occasion prices fell five dollars per hundred in less than five weeks. Price relationships also vary among pigs of different weights and grades at time of sale. Appendix Table I.1 shows biweekly variation in prices for different weight pigs from 1961 to 1970.

The use of confinement farrowing and finishing facilities attaches new importance to the resource of space. A given set of facilities can house pigs only up to its capacity.

As the industry becomes more complex, with costs and prices continuing to vary with the whims of the market, efficient use of heretofore non-limiting resources becomes paramount.

Theoretically a swine producer will try to maximize profits by equating the value of the marginal product obtained from an additional unit of input to the price of the last unit of the input. The value of the marginal product depends on pork prices and on production technology. It is well known that swine marketing weights affect prices through grading, discounts, and premiums, and affect

production through variations in rates of gain and feed conversion. Thus, as more of a given input is used to add weight to live pigs, the value of the marginal product will change because of varying prices and varying physical returns to inputs. The theoretical conclusion is that the optimum combination of inputs and optimum market weight of swine depends on production technology, input prices, and pork prices. A decision to always market pigs at a given weight regardless of the prices of inputs or of outputs may greatly simplify management decisions, but is also likely to result in lower profits than might be possible through efficient utilization of all factors.

This study deals with the relationship between the efficient use of scarce space and varying market prices.

OBJECTIVE AND METHODS

Objective

The objective of the study is to compare the difference in net profit between two production and marketing strategies:

a. always market pigs at the arbitrarily predetermined weights of 210 or 220 pounds, regardless of pork prices; or

b. market pigs at optimal weights between 180 and 260 pounds.

If the optimum weight does not occur at either 210 or 220 pounds, we will calculate the reduced profit per hundredweight that would have occurred had pigs been sold at 210 or 220 pounds.

There are a number of popular maxims in commercial pork production and marketing. Among these are to try to "top the market," to market pork carcasses in the highest value weight ranges, to aim for the highest grading and yielding pigs, and to avoid heavier, fatter weights. This sort of advice is heard from packers and extension personnel alike. To achieve these aims it is commonly recommended that pigs be marketed at 200 to 220 pounds. This weight range is closely associated with highest value per pound, highest grade and yield, and with carcasses of top quality. How consistent are these criteria with the objective of profit maximization? What is

the cost to the pork production industry of following a constant weight strategy? The difference in net profit between the constant weight strategy and the most profitable weight strategy will provide a quantitative measure of the income foregone by marketing pigs at arbitrarily selected weights.

Methods

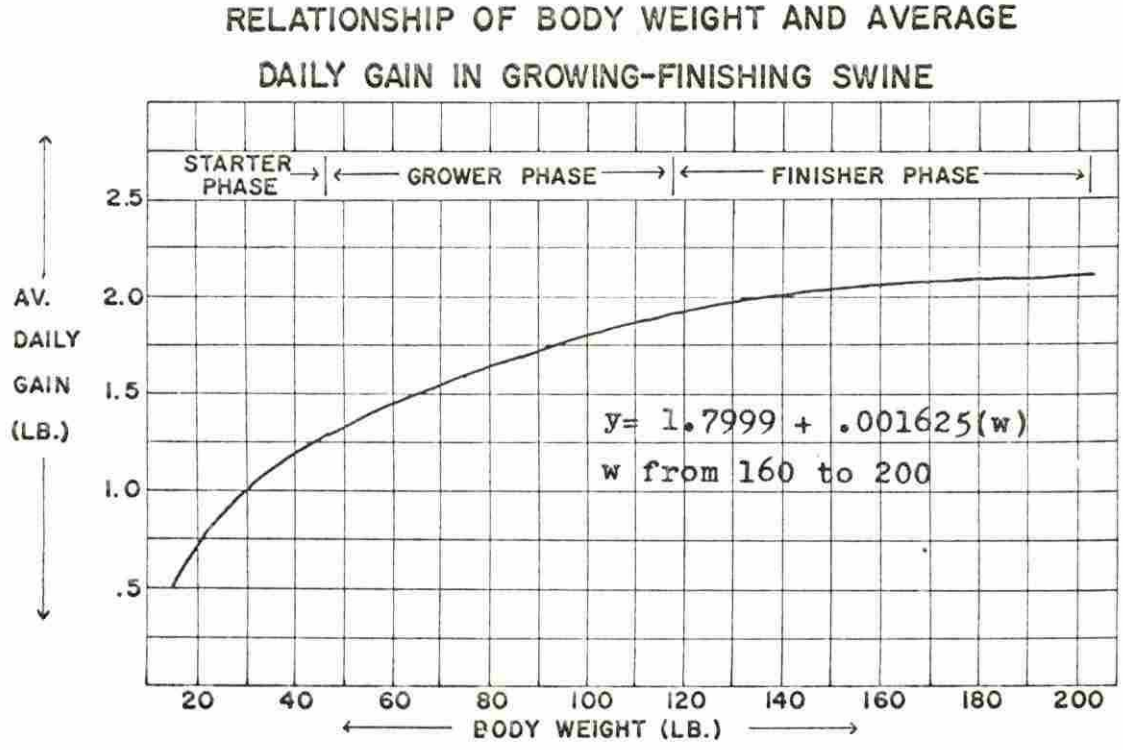
The model uses linear programming to simulate ten years of operation of a total confinement, farrow-to-finish, commercial pork production farm.

The ten years are divided into successive two week periods, with the first two-week period starting on August 23, 1960. On the first day of every two weeks, the producer decides whether to sell any pigs on hand, how much weight to add to pigs kept on hand, and how many sows to farrow four months hence. Each ten pounds added beyond 180 pounds is a separate weight-adding activity requiring differing amounts of feed and time to make a ten-pound weight gain. Under the optimum strategy, option b., page 5, pigs may be sold at 180, 190, 200, 210, 220, 230, 240, 250, or 260 pounds. Pigs are farrowed and raised to 180, and gain from 180 to 190, from 190 to 200, 200 to 210, 210 - 220, 220 - 230, 230 - 240, 240 - 250, and 250 - 260. Under the arbitrary strategy, option a., page 5, pigs are farrowed and raised in exactly the same way, but are always marketed at either 210 or 220 pounds.

In general, coefficients for labor, facility design, building and pen size, and for their related costs, were taken from the Brenton Hog Farm at Dallas Center, Iowa. These data are based on three years of operation of a facility marketing 8,000 pigs yearly. Ration composition and performance characteristics, that is, pounds of feed per pound of gain, pounds of feed per day, average daily gain, and weight per day of age, were taken from several experiments done at the Iowa Agricultural Experiment Station in 1960-61 (4,7, Figure 1). These data are based on performance records from three groups totaling 324 pigs. The pigs were reared in confinement. Equations describing performance characteristics were all calculated with body weight as the independent variables, so that all coefficients are functions of body weight. The data and equations are shown in Figure 1.

Such other coefficients as space requirements and live pigs farrowed and weaned were taken from a combination of Brenton and Iowa State experience. All resources and charges necessary to produce and market hogs were included in the model and are shown in Appendix Tables I.2, I.3, and I.4.

All prices used are market prices received or paid by producers in Central Iowa and were taken from either United States Department of Agriculture publications or from local and area newspapers. The price series used covers the period from 8/23/60 to 7/31/71 (1, 3, 10, 11, Appendix Table I.1).



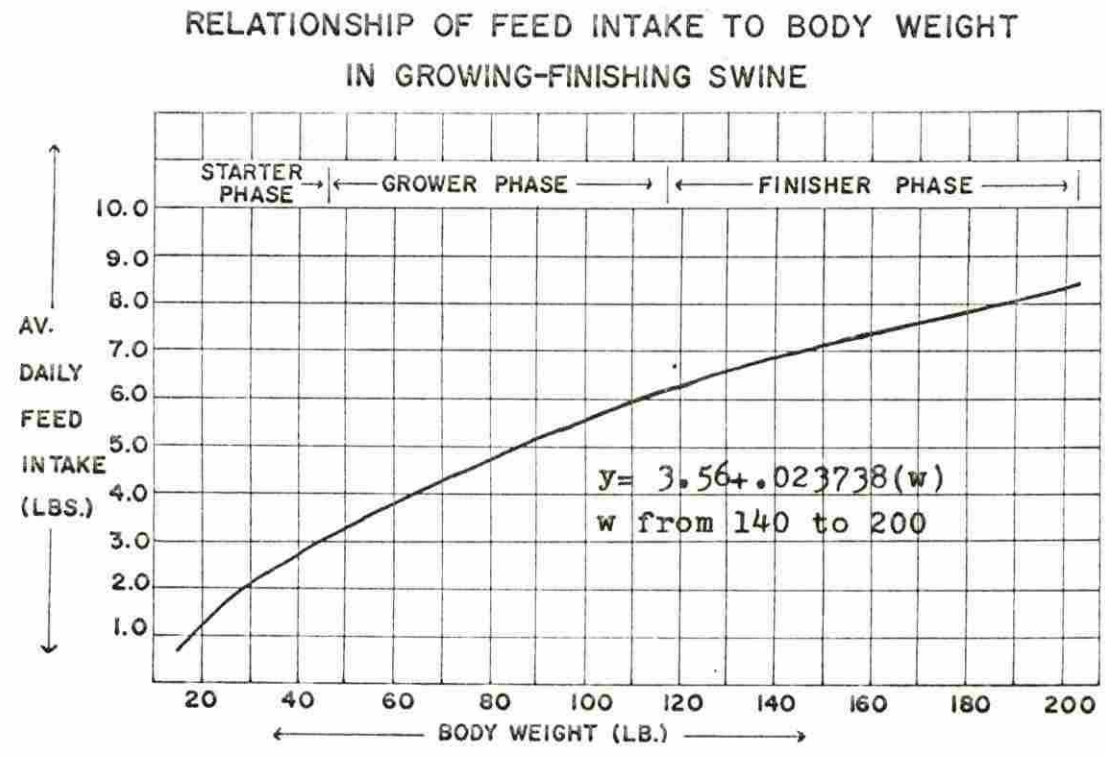
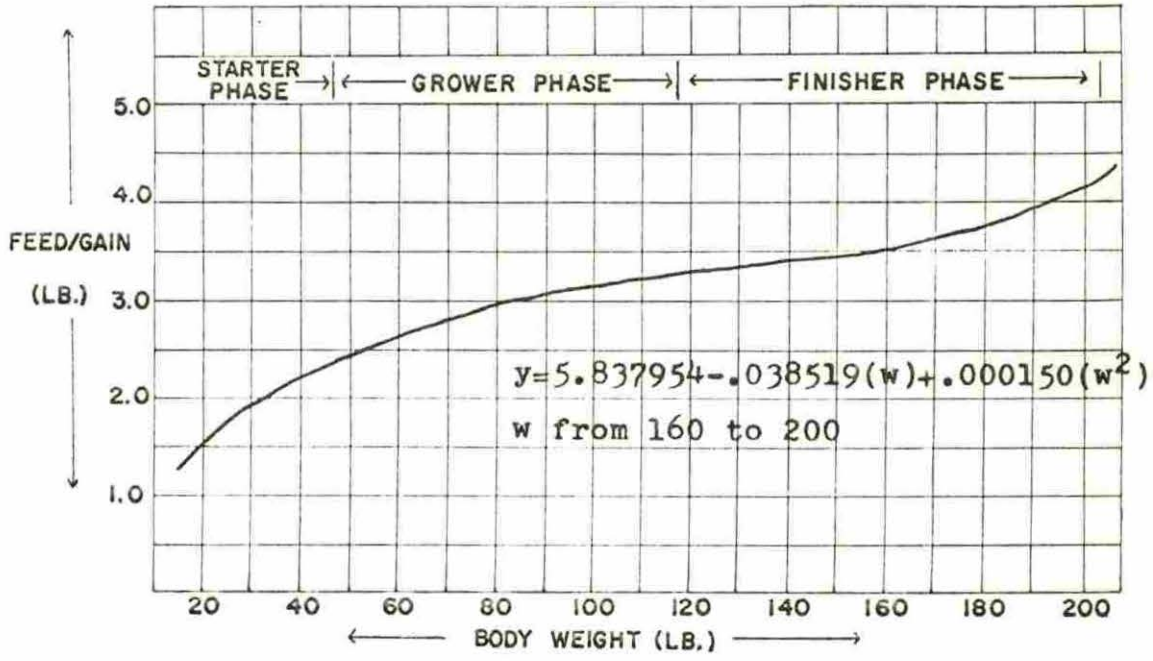


Figure 1. Performance characteristics as functions of body weight, w (4)

RELATIONSHIP OF FEED REQUIRED PER POUND OF GAIN AND BODY WEIGHT IN GROWING-FINISHING SWINE



RELATIONSHIP OF AGE TO BODY WEIGHT IN GROWING-FINISHING SWINE

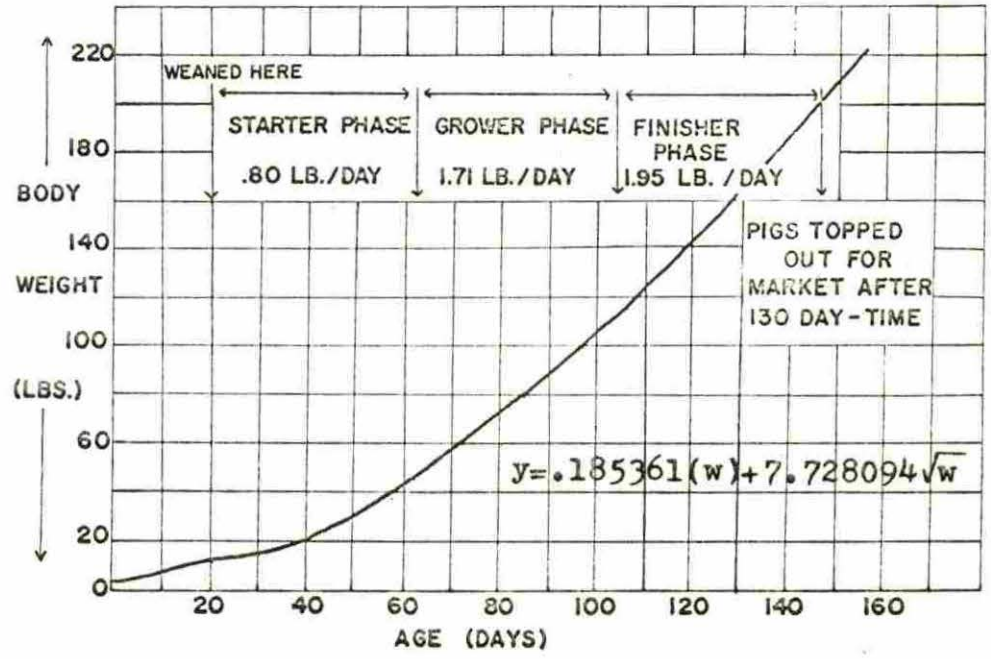


Figure 1. (continued)

Appendix II shows the layout of the Brenton farm, while Appendix III contains a discussion of the optimization procedure.

Advantages of the Model

Linear programming routines calculate "shadow prices." Estimation of these prices is one important reason for using linear programming in this study. In our case, these prices indicate the profit per hundredweight that would have been lost if a pig marketed at a given weight had instead been marketed at 210 or 220 pounds.

The size and detail of the model also permit exact calculation of the net income from the most profitable combination of the thousands of revenue generating options available.

Shortcomings of the Model

Had the model been precise, it would have offered sales, weight adding, and farrowing options daily. This would have increased the size of the matrix to nearly 9,000 columns and 6,000 rows. Therefore, to make the model manageable, we chose to work with two-week periods. This introduced a major shortcoming. It requires between four and five days to add ten pounds to any pig weighing between 180 and 260 pounds. Prices quoted for different weight pigs during any two weeks

were the prices on the first day of the two-week period. This means that the model sold pigs of a given weight at the price prevailing for that weight on the first day of the two weeks, regardless of what day during the two weeks the pig reached market weight and was sold. However, for any given pig, there were four successive two-week periods during which he could be sold at steadily increasing weights.

A second shortcoming was that the model had perfect foresight with respect to price fluctuations. The reason for selling a pig at a given weight on a given date often had as much to do with the model's having perfectly foreseen the direction of price movements as with that weight being the profit maximizing weight for the pig. We note, however, that this flaw is common to both sales at arbitrarily predetermined weights and sales at optimum weights, and does not affect the comparison of the two production strategies.

ANALYSIS

Introductory Discussion

Production efficiency criteria from the theory of the firm require that the marginal physical product of the last unit of input used to produce a commodity times the price of the commodity be equal to the unit price of the input. That is, if product y is a function of input x,

$$y = f(x),$$

then the marginal physical product of x times the price of y must be equated to the price of x,

$$P_y \frac{\partial y}{\partial x} = P_x.$$

Input and output prices are taken as exogenous parameters. By varying the use of one input in relation to fixed quantities of one or more other inputs, the marginal product of the variable input changes. This variation leads toward efficiency, the equation of marginal value product and marginal cost. Where several inputs are used, the marginal value product of each must be equated to marginal cost of each of the inputs. If product y is a function of two inputs, x and z, then the price of y times the marginal physical product of the input must be equal to the price of the input for each input

$$P_y \frac{\partial y}{\partial x} = P_x$$

and $P_y \frac{\partial y}{\partial x} = P_z$.

Our model uses linear programming and therefore assumes constant returns to scale production functions. Marginal products are constant and do not vary with levels of use of the inputs. It becomes impossible to equate marginal value product to marginal cost unless prices vary. The effects of linearity in the production functions can be partially offset by dividing a production activity into several parts. Returns to inputs remain constant within each of the segmented activities, but different activities may be made to require inputs in differing intensities.

In swine production, rates of use of feed (pounds of feed per day or per pound of weight added) and of space (average daily gain) vary for pigs between 180 and 260 pounds. This was taken into account by using eight separate activities to carry pigs from 180 to 260 pounds, one activity for each ten-pound increment. These different weight adding activities, or different weight ranges, required differing quantities of feed and space.

Our functions are of the order of

$$y_{190}^{260} = a_{190}^{260}(\text{feed}) + b_{190}^{260}(\text{space}) + \ldots .$$

We have eight functions by increments of ten pounds, with eight values of y (pork), a, and b. For each of these functions we need

$$P_y a_{190}^{260} = P_{feed}$$

$$P_y b_{190}^{260} = P_{space}$$

Our problem was to come as close to satisfying the last two equations for each pound of pork marketed as we could. All prices were continually varying. a, feed, and b, space, were fixed parameters, but did take different values for different ten-pound weight intervals (activities).

What can be concluded from this discussion? If feed, space, and pork prices remained fairly constant, it would be possible to select closest-to-optimal market weights for any set of those prices. It would be possible to approach the optimum point on the pork production function. If some accurate method were available to form price expectations in the face of price uncertainty, then optimality might again be approached. One conclusion, however, is certain. Since pork, feed, and space prices do vary, optimal market weights also vary. Therefore, marketing pigs at predetermined, fixed weights is almost certainly not the best production strategy. The following analysis provides ten years quantitative measure of the difference between optimal and arbitrary marketing strategies.

Results and Analysis

Tables 2 and 3 show dates, weights, and prices of pork

Table 2. Biweekly weight, price, and shadow price distribution of pork marketed under the optimum plan

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
			1961			
2/4	220	17.78	16.99	1.08	17.78	--
2/18	250	17.24	16.99	1.08	17.78	--
2/18	260	16.99	16.99	1.08	17.78	--
3/4	240	17.10	18.02	.20	17.48	.35
4/15	210	17.06	--	--	16.22	.47
4/15	240	16.67	16.72	.91	17.05	.29
4/15	260	16.17	17.15	.19	16.72	.28
5/13	240	15.61	16.26	.21	16.07	.06
5/27	230	15.73	16.13	.20	15.99	.03
6/24	220	16.25	16.09	.24	16.25	--
6/24	250	15.60	16.08	.26	15.97	.09
7/8	240	16.92	16.36	1.29	17.38	.23
7/8	260	16.42	16.09	.24	16.25	--
8/5	250	16.80	17.40	.48	17.12	.39
8/19	240	17.63	17.31	1.37	17.89	.37
8/19	250	17.38	17.12	1.80	17.31	1.16
8/19	260	17.13	17.12	1.80	17.31	1.16
9/2	240	17.54	17.89	.78	17.79	.49
9/16	240	17.34	17.79	.20	17.64	.01
9/30	210	17.43	--	--	16.31	.35
9/30	240	17.19	17.64	.52	17.43	.47
10/28	240	15.66	16.31	.00	15.87	.14
11/11	210	15.49	--	--	15.30	--
11/25	220	15.30	--	--	15.30	--
11/11	240	15.26	15.87	.05	15.49	.22
12/9	220	15.73	15.32	.43	15.73	--
12/9	250	15.16	--	--	15.30	--
12/23	220	16.68	15.76	.93	16.68	--
12/23	230	16.48	15.76	.93	16.68	--
12/23	250	16.03	15.32	.43	15.73	--

[a]Pigs not marketed at 210 or 220 would have been marketed at 210 or 220 at the prices in these columns.

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
			1962			
1/20	220	16.76	16.32	.76	--	--
1/20	250	16.06	16.69	.55	16.31	.65
2/3	240	16.22	16.78	.18	16.62	.02
2/3	210	16.67	--	--	16.31	.11
2/17	240	15.96	16.67	--	16.31	.11
3/3	210	16.15	--	--	15.79	.07
3/17	240	15.51	16.15	--	15.79	.07
3/3	240	15.82	16.32	.37	16.12	.28
3/17	210	15.82	--	--	15.53	.08
3/31	240	15.23	15.82	--	15.53	.08
4/28	210	15.69	--	--	15.01	.38
4/28	240	15.28	15.52	.61	15.64	.17
4/28	250	15.03	15.55	.51	15.48	.31
5/26	220	15.17	15.08	.34	--	.31
6/9	220	15.30	15.20	.04	--	--
6/23	250	16.66	15.20	.04	15.30	--
6/23	240	16.91	15.30	1.81	17.15	.20
7/21	250	17.23	17.15	.66	17.26	.31
7/21	220	17.76	17.27	.55	--	--
8/4	250	18.06	17.27	.55	17.76	--
8/4	210	18.58	--	--	17.42	.74
8/4	240	18.31	17.76	1.79	18.58	.51
9/1	220	17.54	17.42	.39	--	--
9/15	230	17.81	17.54	.50	17.95	--
9/15	250	17.43	17.42	.39	17.54	--
9/29	210	17.35	--	--	16.56	.43
9/29	240	17.08	17.95	.01	17.35	.39
10/27	220	16.31	16.56	.01	--	--
11/10	210	16.27	--	--	16.06	.00
11/10	220	16.27	16.32	.11	--	--

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
11/10	240	15.91	16.32	.11	16.27	--
11/24	230	15.87	--	--	16.06	.00
12/8	220	15.90	16.08	.01	--	--
12/22	210	15.96	--	--	15.51	.16
12/22	220	15.91	15.93	.18	--	--
			1963			
1/19	220	15.51	15.55	.24	--	--
1/19	210	15.56	--	--	15.15	.30
2/16	210	15.04	--	--	14.10	--
2/16	220	14.98	15.22	.01	--	--
3/2	210	14.15	--	--	13.68	.59
3/16	210	13.69	--	--	13.36	.15
4/13	220	13.56	13.36	.38	--	--
5/11	220	13.70	13.28	.35	--	--
5/11	250	13.19	13.56	.14	13.29	.24
5/25	220	15.24	13.70	1.05	--	--
6/8	250	16.04	13.70	1.05	15.24	--
7/6	250	16.87	16.55	.42	16.72	.03
7/20	240	17.47	17.60	.90	17.98	.16
7/20	210	17.99	--	--	17.58	.14
8/3	210	17.59	--	--	16.82	.16
8/17	210	16.88	--	--	16.26	.88
8/31	200	16.33	--	--	15.48	.03
8/31	210	16.29	--	--	15.48	.03
9/14	210	15.48	--	--	14.81	.44
10/12	210	15.11	--	--	14.80	.16
10/12	220	15.11	14.81	.49	--	--
10/12	230	15.01	14.81	.49	15.11	--
10/26	210	14.81	--	--	14.26	.05
11/9	210	14.26	--	--	13.53	.55
12/7	220	13.50	13.53	.07	--	--
12/21	220	13.91	13.50	.45	--	--

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
			1964			
1/4	220	14.10	13.92	.26	--	--
1/18	220	14.80	14.12	.79	--	--
2/1	210	14.74	--	--	14.49	.09
2/1	220	14.73	14.82	.12	--	--
2/29	220	14.37	14.53	.03	--	--
3/14	220	14.19	14.37	.01	--	--
3/28	210	14.13	--	--	13.90	.09
3/28	220	14.10	14.24	.04	--	--
5/9	220	14.07	13.92	.20	--	--
5/23	210	15.21	--	--	14.83	.15
5/23	220	15.16	14.11	1.00	--	--
6/20	220	15.08	14.88	.20	--	--
7/4	250	16.27	14.88	.20	15.08	--
7/4	220	17.01	15.14	1.66	--	--
7/4	210	17.04	--	--	16.77	.00
7/18	230	16.49	--	--	16.77	.00
7/18	210	16.82	--	--	16.22	--
8/29	210	17.08	--	--	16.36	.62
8/29	220	17.08	16.06	1.20	--	--
8/29	250	16.30	16.26	.85	16.02	.87
9/26	210	15.88	--	--	15.40	--
10/24	210	14.96	--	--	14.30	--
12/5	220	14.43	14.08	.28	--	--
12/19	220	15.36	14.48	.74	--	--
			1965			
1/2	220	15.88	15.41	.64	--	--
1/2	230	15.62	15.41	.64	15.88	--
1/2	250	15.11	14.48	.74	15.36	--
1/16	220	15.74	15.93	.08	--	--
1/30	250	15.14	15.93	.08	15.74	--

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price [a]	210 lb. shadow price	220 lb. live price [a]	220 lb. shadow price
1/30	220	15.97	15.79	.47	--	--
2/13	210	16.83	--	--	16.64	--
2/13	220	16.78	16.02	1.09	--	--
2/27	210	16.69	--	--	16.46	.03
2/27	220	16.64	--	--	--	--
3/13	200	16.51	16.48	.04	16.50	00
3/27	220	16.50	16.48	.04	--	--
4/10	220	16.87	16.56	.42	--	--
4/24	220	17.54	16.92	.62	--	--
4/24	250	16.79	16.56	.42	16.87	--
5/8	250	17.95	16.92	.62	17.54	--
5/22	220	20.29	18.82	1.36	--	--
5/22	250	19.49	17.58	1.21	18.77	.15
6/19	210	23.90	--	--	23.39	.29
6/19	240	23.48	21.08	2.85	23.86	.09
6/19	250	23.23	20.35	2.42	21.02	1.72
7/17	230	23.93	23.40	1.01	24.20	.02
7/17	240	23.66	23.40	1.01	24.20	.02
7/17	250	23.41	--	--	23.39	.29
8/14	210	24.27	--	--	23.90	.77
8/14	220	24.27	23.61	.90	--	--
8/14	250	23.62	24.21	.00	23.59	.17
8/28	210	23.90	--	--	21.85	1.60
8/28	240	23.54	--	--	23.90	.77
9/25	220	22.52	21.81	.77	--	--
10/9	250	22.26	21.81	.71	22.52	--
10/9	230	22.68	22.52	.50	22.86	.00
10/9	240	22.51	22.52	.50	22.86	.00
11/6	220	23.37	22.59	1.08	--	--
11/20	250	23.06	22.59	1.08	23.06	--
11/6	250	22.70	22.86	1.05	22.59	1.04
11/20	220	23.73	23.37	.33	--	--
12/4	250	24.83	23.37	.33	23.73	--
12/4	220	25.62	23.73	1.43	--	--
12/18	240	27.26	25.65	2.68	27.69	.83
12/18	260	26.76	23.73	1.43	25.62	--

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
			1966			
1/1	250	26.75	25.65	2.68	27.69	.83
1/15	260	26.88	27.70	1.21	27.42	.81
1/15	240	27.38	27.43	1.64	27.96	.66
1/29	250	26.87	27.43	1.64	27.96	.66
1/29	260	26.62	27.43	1.64	27.96	.66
2/12	230	27.58	27.86	1.51	27.88	.65
2/12	240	27.28	27.86	1.51	27.88	.65
2/12	260	26.78	28.01	2.54	27.79	1.83
2/26	210	27.31	--	--	24.04	2.51
2/26	240	26.65	27.96	.84	27.22	.86
3/26	210	23.49	--	--	22.48	.42
3/26	240	22.96	24.11	.58	23.46	.59
4/9	240	21.90	--	--	22.48	.42
5/7	190	22.19	22.38	.74	23.42	--
5/7	220	22.33	21.66	.73	--	--
5/21	220	23.42	22.38	.74	--	--
6/4	220	24.58	23.53	1.19	--	--
6/4	260	23.18	22.38	.74	23.42	--
7/2	220	24.42	24.48	.42	--	--
7/2	250	23.31	24.67	.44	24.37	.27
7/2	260	23.06	24.67	.44	24.37	.27
7/16	220	24.23	24.49	.00	--	--
7/30	250	24.08	24.49	.00	24.23	--
7/30	260	23.83	24.49	.00	24.23	--
8/13	220	25.40	25.18	.69	--	--
8/13	250	24.56	24.29	2.82	25.12	1.23
8/27	210	25.06	--	--	23.50	1.01
8/27	240	24.46	25.42	.08	25.06	.35
9/10	210	23.50	--	--	22.46	.38
9/24	210	22.46	--	--	21.96	.05

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
10/8	210	21.96	--	--	20.54	1.06
10/8	240	21.46	--	--	21.96	.05
11/5	210	20.43	--	--	19.40	.70
11/5	220	20.40	20.54	.23	--	--
11/5	230	20.12	20.54	.23	20.12	--
12/3	220	19.40	19.48	.21	--	--
12/17	220	19.58	19.46	.25	--	--
12/31	220	19.78	19.77	.21	--	--
12/31	210	19.97	--	--	19.54	.05
			1967			
1/28	210	19.84	--	--	19.40	--
1/28	220	19.75	19.78	.35	--	--
2/25	210	19.37	--	--	18.52	.49
2/25	220	19.27	19.50	.13	--	--
3/11	210	18.67	--	--	17.94	--
3/25	210	18.09	--	--	17.36	--
4/8	210	17.49	--	--	17.33	.01
5/6	250	17.83	--	--	17.33	.01
5/20	210	23.23	--	--	22.50	.31
5/20	240	22.56	18.97	3.66	23.15	.04
5/20	250	22.31	17.52	1.69	18.81	.78
6/3	240	21.88	--	--	22.50	.31
6/17	220	22.25	22.59	.11	--	--
7/15	230	22.31	22.06	1.06	22.38	.27
7/15	250	21.56	22.31	.91	22.00	.83
7/15	260	21.31	22.31	.91	22.00	.83
7/29	210	21.94	--	--	21.00	.36
7/29	240	21.50	22.46	.06	21.85	.21
8/26	210	20.38	--	--	19.20	.74
8/26	240	20.00	21.06	.17	20.32	.48

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price[a]	210 lb. shadow price	220 lb. live price[a]	220 lb. shadow price
9/23	240	18.63	19.28	.43	18.92	.39
10/7	210	18.52	--	--	17.82	.35
10/7	240	18.10	18.98	.13	18.45	.28
10/21	210	17.90	--	--	17.10	.08
11/18	230	17.02	17.29	.30	17.20	.09
12/2	220	17.31	17.38	.22	--	--
12/16	240	16.96	17.50	.20	17.40	.09
			1968			
1/13	220	18.16	17.78	.45	--	--
1/27	250	18.01	17.78	.45	18.16	--
1/27	230	18.88	18.35	1.38	18.99	.29
2/24	240	19.33	18.72	1.59	19.74	.42
2/24	260	18.80	19.10	.24	18.61	.44
3/9	210	19.18	--	--	18.61	.20
3/9	240	18.70	19.85	.08	19.05	.42
4/6	220	18.97	18.72	.45	--	--
4/6	230	18.88	18.72	.45	--	--
4/6	250	18.25	--	--	18.61	.20
4/20	190	18.83	19.08	.33	19.19	.26
5/4	230	19.08	19.08	.33	19.19	.26
5/4	240	18.74	19.08	.33	19.19	.26
5/18	230	18.90	19.30	.42	19.05	.25
6/1	220	18.98	19.20	.03	--	--
6/15	220	20.07	19.09	.91	--	--
6/15	250	19.22	19.20	.03	--	--
6/29	220	21.09	20.18	.79	--	--
6/29	250	20.38	19.09	.91	--	--
7/13	240	21.77	21.18	1.43	22.18	.38

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price [a]	210 lb. shadow price	220 lb. live price [a]	220 lb. shadow price
7/13	260	21.20	20.18	.79	--	--
7/13	210	22.28	--	--	20.65	.41
7/27	210	20.82	--	--	19.81	.45
8/24	230	19.90	19.92	.91	19.90	.44
9/7	230	19.62	19.90	.10	19.67	--
9/21	210	19.75	--	--	19.01	.29
9/21	240	19.36	19.72	.68	19.75	.44
10/5	210	19.12	--	--	17.75	.97
10/5	240	18.60	--	--	19.01	.29
11/2	210	18.08	--	--	17.67	.08
11/2	230	17.80	17.88	.65	17.94	.20
11/30	220	18.00	17.80	.34	--	--
11/30	250	17.22	--	--	17.76	.08
12/28	220	19.88	18.28	1.50	--	--
12/28	250	18.84	18.12	.09	18.22	.11
			1969			
1/25	250	19.15	19.88	.55	18.89	1.38
1/25	260	18.90	19.88	.55	18.89	1.38
2/8	230	19.75	19.78	1.31	19.80	.79
2/8	250	19.25	18.95	2.14	19.72	.83
2/22	210	20.38	--	--	19.76	.36
2/22	240	19.87	19.85	1.02	20.25	.25
2/22	250	19.62	19.78	1.31	19.80	.79
2/22	260	19.37	19.78	1.31	19.80	.79
3/22	210	20.62	--	--	19.97	.24
3/22	240	20.15	19.78	1.38	20.51	.45
3/22	260	19.65	--	--	19.76	.36
4/5	230	19.94	--	--	19.97	.24
4/5	240	19.69	--	--	19.97	.24
5/3	220	20.42	19.95	.31	--	--
5/3	250	19.80	20.00	.27	19.88	.14

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live[a] price	210 lb. shadow price	220 lb. live[a] price	220 lb. shadow price
5/17	220	22.97	20.55	1.80	--	--
5/17	250	22.40	19.95	.31	--	--
5/31	230	24.44	23.05	1.52	24.51	.20
5/31	240	24.19	23.05	1.52	24.51	.20
5/31	250	23.94	20.55	1.80	--	--
6/28	220	24.90	24.52	.65	--	--
6/28	250	24.35	24.59	1.10	24.43	.90
7/12	230	25.32	24.95	.63	25.40	.09
7/26	250	25.00	24.95	.63	25.40	.09
7/26	260	24.75	24.95	.63	25.40	.09
8/9	220	26.47	25.62	3.15	--	--
8/9	250	25.90	25.48	3.29	25.56	2.38
8/23	210	26.85	--	--	25.45	.70
8/23	240	26.50	26.55	1.98	26.80	1.10
8/23	260	26.00	25.62	3.15	--	--
9/20	230	25.18	25.56	.11	25.21	.04
9/20	250	24.68	--	--	25.45	.70
10/4	210	25.65	--	--	24.70	.77
10/4	220	25.60	25.25	.44	--	--
10/4	230	25.55	25.25	.44		
10/4	250	25.05	25.56	.11	25.04	.04
11/1	220	24.98	24.75	.54	--	--
11/1	250	24.38	--	--	24.70	.77
11/15	220	25.47	25.08	.40	--	--
11/29	220	26.33	25.60	.72	--	--
11/29	230	26.22	25.60	.72	--	--
11/29	250	25.72	25.08	.40	--	--
12/27	220	27.65	26.72	1.08	--	--
12/27	250	27.03	26.44	1.16	26.61	.82
			1970			
1/24	250	27.40	--	--	27.06	.60
1/24	260	27.15	--	--	27.06	.60
2/7	240	27.90	28.15	2.72	28.27	1.66

Table 2. (continued)

Date	Live weight	Sale price (cwt)	210 lb. live price [a]	210 lb. shadow price	220 lb. live price [a]	220 lb. shadow price
2/7	250	27.65	27.12	3.81	28.02	1.97
2/21	210	28.40	--	--	27.22	.78
2/21	230	28.18	28.38	.74	28.29	.16
2/21	250	27.68	28.15	2.72	28.27	1.66
3/7	240	26.90	--	--	27.22	.78
3/21	210	25.80	--	--	23.95	1.17
3/21	240	25.43	27.28	.10	25.74	1.00
4/18	200	24.22	--	--	24.06	--
4/18	210	24.22	--	--	24.06	--
4/18	220	24.15	23.98	.58	--	--
4/18	250	23.58	--	--	23.95	1.17
5/2	210	24.12	--	--	23.47	.28
5/30	220	23.60	23.60	.14	--	--
6/13	220	24.22	23.68	.38	--	--
6/27	220	24.97	24.35	.63	--	--
6/27	250	24.35	23.68	.38	--	--
7/11	230	25.20	25.08	.56	25.25	.22
7/11	250	24.70	24.35	.63	--	--
7/11	210	25.30	--	--	24.72	1.00
7/25	210	24.72	--	--	22.76	.81
7/25	240	24.47	--	--	24.72	1.00
8/8	210	22.78	--	--	21.63	.63
8/22	210	21.58	--	--	20.07	1.19
8/22	240	21.43	--	--	21.63	.63
9/19	230	20.18	20.10	.44	20.18	.27
10/3	210	19.80	--	--	18.18	.33
10/3	230	19.80	20.18	.20	19.80	.27
10/3	240	19.55	20.18	.20	19.80	.27
10/17	180	17.43	15.95	.18	15.79	.12
10/17	210	18.18	--	--	15.89	.12
11/14	210	15.85	--	--	15.58	.04
12/12	190	15.65	15.90	.44	16.44	.07
12/12	220	15.82	15.64	.16	--	--
12/26	210	16.50	--	--	15.94	.39
12/26	230	16.38	15.90	.44	16.44	.07

Table 3. Biweekly weight and price distribution of pork marketed under the arbitrary plan

Date	Live weight	Sale price (cwt.)
	1961	
2/4	220	17.78
2/18	210	18.02
3/18	210	17.15
4/15	210	17.06
4/15	220	17.05
5/13	220	16.07
5/27	220	15.99
6/10	220	15.97
7/8	220	18.12
8/5	220	17.31
8/19	220	17.89
9/2	220	17.79
9/16	220	17.64
9/30	210	17.43
9/30	220	17.43
10/14	210	16.31
10/28	210	15.87
11/25	220	15.30
12/9	220	15.73
12/23	210	16.69
12/23	220	16.68
	1962	
1/20	220	16.76
2/3	210	16.67
2/3	220	16.62
3/3	210	16.15
3/31	220	15.53

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
4/14	220	15.48
4/28	210	15.69
4/28	220	15.64
5/26	220	15.17
6/23	220	17.15
7/7	220	17.26
7/21	220	17.76
8/4	210	18.58
8/4	220	18.58
9/1	220	17.54
9/15	210	17.95
9/15	220	17.95
9/29	210	17.35
10/27	220	16.31
11/10	220	16.27
11/24	220	16.06
12/22	210	15.96
12/27	220	15.91
	1963	
1/19	220	15.51
1/19	210	15.56
2/16	210	15.04
2/16	220	14.98
3/2	210	14.15
4/13	210	13.56
4/13	220	13.56
5/11	220	13.70
5/25	220	15.24
6/8	220	16.55
6/22	220	16.72
7/6	220	17.60
7/20	220	17.98
7/20	210	17.99
8/3	210	17.59

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
8/17	210	16.88
8/31	210	16.29
9/14	210	15.48
10/12	210	15.11
10/12	220	15.11
10/26	210	14.81
11/9	210	14.26
12/21	220	13.91
	1964	
1/4	220	14.10
1/18	220	14.80
2/1	210	14.74
2/1	220	14.73
2/29	220	14.37
3/14	220	14.19
3/28	220	14.10
4/11	210	14.13
4/25	220	13.88
5/9	220	14.07
5/23	210	15.21
5/23	220	15.16
6/20	220	15.08
7/4	220	17.01
7/18	220	16.77
7/18	210	16.82
8/1	210	16.26
8/29	210	17.08
8/29	220	17.08
9/12	210	16.39
9/26	210	15.88
10/10	210	15.44
10/24	210	14.96
12/5	220	14.43
12/19	220	15.36

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
	1965	
1/2	210	15.93
1/16	220	15.74
1/2	220	15.88
2/13	210	16.78
2/27	220	16.64
3/13	220	16.46
3/27	220	16.50
4/7	220	16.87
5/8	220	18.77
5/22	220	20.29
6/5	220	21.02
6/19	210	23.90
6/19	220	23.86
7/17	220	24.20
7/17	210	24.21
8/14	220	24.27
8/28	210	23.90
8/28	220	23.90
9/25	220	22.52
10/9	220	22.86
10/23	220	22.59
11/6	220	23.37
11/20	220	23.73
12/4	220	25.62
12/18	220	27.69
	1966	
1/1	220	27.42
1/15	220	27.96
1/29	220	27.79
2/12	220	27.88
2/26	210	27.31

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
2/26	220	27.22
3/12	210	24.11
3/26	210	23.49
4/9	210	22.55
5/7	220	22.33
5/21	220	23.42
6/4	220	24.58
6/18	220	24.37
7/2	220	24.42
7/16	220	24.23
7/30	220	25.12
8/13	220	25.40
8/27	210	25.06
8/27	220	25.06
9/10	210	23.05
9/24	210	22.46
10/8	210	21.96
11/5	210	20.43
11/5	220	20.40
12/3	220	19.40
12/17	220	19.58
12/31	210	19.97
12/31	220	19.78
	1967	
1/28	210	19.84
2/25	210	19.37
1/28	220	19.75
2/25	220	19.27
3/25	220	18.67
4/22	220	17.33
5/6	220	18.81
5/20	210	23.23
5/20	220	23.15
6/17	220	22.25

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
7/1	220	22.00
7/15	220	22.38
7/15	210	22.46
7/29	210	21.94
8/12	210	21.06
8/26	210	20.38
9/23	210	18.98
9/23	220	18.92
10/7	210	18.52
10/21	210	17.90
11/18	220	17.20
12/2	220	17.31
12/16	220	17.40
12/30	220	17.54
	1968	
1/13	220	18.16
1/27	210	19.10
1/27	220	18.99
2/24	210	19.85
2/24	220	19.74
3/9	210	19.18
4/6	220	18.97
4/20	220	18.97
5/4	220	19.19
5/18	220	19.05
6/11	220	18.98
6/15	220	20.07
6/29	220	21.09
7/13	220	22/18
7/13	210	22.28
7/27	210	20.82
8/24	220	19.90
9/7	220	19.67
9/21	210	19.75

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
9/21	220	19.75
10/5	210	19.12
11/2	220	17.94
11/30	220	18.00
12/14	220	18.22
12/28	210	19.88
12/28	220	19.88
	1969	
1/25	220	19.72
2/8	220	19.80
2/22	210	20.38
2/22	220	20.25
3/22	210	20.62
3/22	220	20.51
5/3	220	20.42
5/17	220	22.97
5/31	220	24.51
6/14	220	24.43
6/28	220	24.90
7/12	220	25.40
7/26	220	25.56
8/9	220	26.47
8/23	210	26.85
8/23	220	26.80
9/20	220	25.21
10/4	210	25.65
10/4	220	25.60
11/1	220	24.98
11/15	220	25.47
11/29	220	26.33
12/13	220	26.61
12/27	220	27.65

Table 3. (continued)

Date	Live weight	Sale price (cwt.)
	1970	
1/10	220	27.06
1/24	220	28.02
2/7	220	28.27
2/21	210	28.40
2/21	220	28.29
3/7	210	27.28
3/21	210	25.80
4/18	220	24.15
5/2	210	24.12
5/2	220	24.06
5/30	220	23.60
6/13	220	24.22
6/27	220	24.97
7/11	220	25.25
7/25	210	24.72
7/25	220	24.72
8/8	210	22.78
8/22	210	21.58
10/3	210	19.80
10/3	220	19.80
10/17	210	18.18
11/14	210	15.85
11/14	220	15.79
12/19	220	15.82
12/26	210	16.50
12/26	220	16.44

marketed under the two plans. The tables cover the entire ten-year period. Table 2 also shows the shadow prices for 210 and 220 pound pigs marketed under the optimum plan.

Shadow prices should be interpreted as follows: If one unit of the activity corresponding to the shadow price were forced into the optimum plan, then the value of the program (profit) would be reduced by the amount of the shadow price. In our case, requiring the program to sell one hundredweight of any 210- or 220-pound pig for which a positive shadow price is shown would result in profit being decreased by the amount of the shadow price. When the program chooses to include an activity, e.g., to sell a 210- or 220-pound pig, no shadow price results.

The range of shadow prices is from less than one cent to $3.81, with most estimates falling between one and forty cents. About sixty percent of the prices were less than fifty cents. Many of the higher shadow prices were associated with periods of sharply fluctuating market prices. This was particularly true of shadow prices in excess of $1.00 per hundred, and is only one of many instances where price movements clouded the significance of our results.

The overall results of the model indicate a difference in profit between the two strategies of about $18,500, or a gross average of about $.60 per head marketed. This indicates that there was frequently a significant penalty attached

to marketing pigs at the arbitrarily selected weights of 210 or 220 pounds. This gross average also indicates that the higher shadow prices shown should be interpreted with care. Price fluctuations and not technical production relationships probably contributed substantially to the magnitude of these higher shadow prices.

Tables 4 and 5 show quarterly and yearly results under the two plans. Quarterly average market weights under the optimum plan varied from 212.9 to 245.1 pounds, while under the arbitrary plan these weights varied from 212.1 to 220 pounds. Quarterly average prices varied from $14.41 to $27.26 per hundred under the optimum plan, and from $14.48 to $27.87 per hundred under the arbitrary plan. The lowest average price occurred in the same quarter for both strategies, as did the highest average price. Looking at the ten-year totals, we see that the optimum plan marketed pigs at an overall average weight of 230 pounds and an overall average price of $19.50 per hundred, while the arbitrary plan marketed pigs at an overall average weight of 217 pounds and an overall average price of $19.77. Both plans marketed the same number of pigs, the difference of 24 pigs shown in the totals being due to rounding errors. However, the optimum plan marketed 70,587 hundredweights of pork, while the arbitrary plan marketed only 66,644 hundredweights, a difference of 394,300 pounds.

Table 4. Quarterly and yearly results under the optimum production and marketing strategy

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price	Range in marketed weights[a]
1/1961	568	1390	244.7	17.16	220-260
2/1961	667	1544	231.5	16.17	210-260
3/1961	1011	2471	244.3	17.10	210-260
4/1961	627	1437	229.1	15.88	210-250
1961	2873	6842	239	16.65	220-260
1/1962	855	2002	234.0	15.96	210-250
2/1962	682	1609	236.0	15.92	210-250
3/1962	910	2131	234.0	17.63	210-250
4/1962	694	1532	220.8	16.03	210-240
1962	3141	7274	232	16.45	210-250
1/1963	628	1338	212.9	15.17	210-220
2/1963	568	1335	235.0	14.59	220-250
3/1963	920	2102	228.5	16.96	200-250
4/1963	853	1861	218.2	14.56	210-230
1963	2969	6636	223	15.45	210-240

[a]Totals exclude the three highest and three lowest observations.

Table 4. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price	Range in marketed weights[a]
1/1964	959	2096	218.6	14.41	210-220
2/1964	352	769	218.3	14.80	210-220
3/1964	1184	2639	222.8	16.50	210-250
4/1964	499	1071	214.6	14.97	210-220
1964	2994	6575	220	15.38	210-220
1/1965	872	1941	222.6	16.15	200-250
2/1965	796	1899	238.6	20.20	210-250
3/1965	689	1642	238.2	23.55	210-250
4/1965	766	1870	244.0	24.30	220-260
1965	3123	7352	235	20.92	210-250
1/1966	889	2094	235.5	26.24	210-260
2/1966	505	1172	232.2	23.04	190-260
3/1966	1040	2375	228.2	24.11	210-260
4/1966	921	2010	218.2	20.22	210-240
1966	3355	7651	228	23.51	210-260

Table 4. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price	Range in marketed weights[a]
1/1967	710	1524	214.7	19.24	210-220
2/1967	626	1458	232.7	21.71	210-250
3/1967	903	2157	238.7	20.27	210-260
4/1967	632	1432	226.5	17.35	210-240
1967	2871	6571	229	19.71	210-250
1/1968	642	1575	245.2	18.66	210-260
2/1968	907	2091	230.6	19.38	190-250
3/1968	759	1734	228.4	20.57	210-260
4/1968	783	1831	233.7	18.53	210-250
1968	3091	7231	234	19.30	210-250
1/1969	772	1788	231.6	19.81	210-260
2/1969	763	1817	238.2	22.93	220-250
3/1969	636	1474	231.8	25.93	210-260
4/1969	899	2131	236.9	26.03	210-250
1969	3070	7210	235	23.69	210-260

Table 4. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price	Range in marketed weights[a]
1/1970	827	1896	229.2	27.26	210-260
2/1970	705	1558	221.1	24.11	200-250
3/1970	760	1723	226.	23.2	210-250
4/1970	972	2068	212.7	17.71	180-240
1970	3264	7245	222	22.90	210-250
Ten year totals	30751	70587	230	19.48	190-260

Table 5. Quarterly and yearly results under the arbitrary production and marketing strategy

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price
1/1961	626	1344	214.5	17.82
2/1961	618	1339	216.7	16.48
3/1961	993	2177	219.1	17.79
4/1961	712	1526	214.2	16.26
1961	2949	6386	216.5	17.16
1/1962	683	1473	215.7	16.35
2/1962	738	1609	218.0	16.09
3/1962	940	2034	216.2	17.85
4/1962	824	1768	214.6	16.11
1962	3185	6884	216.1	16.67
1/1963	572	1214	212.1	14.99
2/1963	685	1507	219.9	14.96
3/1963	906	1931	213.1	17.17
4/1963	670	1426	212.8	14.64
1963	2833	6078	214.5	15.59

Table 5. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price
1/1964	900	1961	217.8	14.48
2/1964	598	1305	218.2	14.83
3/1964	993	2133	214.7	16.74
4/1964	544	1169	214.8	15.20
1964	3035	6568	216.4	15.41
1/1965	718	1565	217.8	16.29
2/1965	908	1991	219.3	20.17
3/1965	735	1602	218.0	23.84
4/1965	718	1581	220.0	24.24
1965	3079	6739	218.8	21.10
1/1966	993	2147	216.2	27.08
2/1966	543	1195	219.9	23.56
3/1966	993	2147	216.2	24.60
4/1966	827	1776	214.7	20.40
1966	3356	7265	216.4	24.14

Table 5. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price
1/1967	703	1541	219.2	19.35
2/1967	634	1390	219.3	21.90
3/1967	903	1942	215.0	20.85
4/1967	637	1372	215.5	17.81
1967	2877	6245	217.0	20.05
1/1968	642	1401	218.1	19.09
2/1968	894	1967	220.0	19.43
3/1968	901	1945	215.7	20.75
4/1968	827	1799	217.4	18.90
1968	3264	7112	217.8	19.59
1/1969	710	1544	217.6	20.28
2/1969	636	1400	220.0	23.45
3/1969	796	1742	218.7	26.00
4/1969	892	1960	219.6	26.27
1969	3034	6646	219.0	24.21

Table 5. (continued)

Quarter and year	Total pigs marketed	Total pounds marketed (cwt.)	Average weight pigs marketed	Weighted average price
1/1970	750	1612	215.0	27.87
2/1970	793	1723	217.2	24.33
3/1970	603	1294	214.7	23.79
4/1970	969	2092	215.8	17.50
1970	3115	6721	215.7	22.95
Ten year totals	30727	66644	216.9	19.77

There is a different in net profit between the two plans of $18,624.67.

The results indicate that a profit maximizing producer would market heavier pigs and receive lower average prices, but would sell more total pounds of pork. A producer always marketing pigs in the 210-220 pound range would sell lighter than optimal pigs, receive higher than optimal prices, and would sell fewer than optimal total pounds of pork. Specifically, we conclude that between 1961 and 1970 swine confinement operators with facilities and performance similar to ours and with the ability to predict price changes would have profited from accepting a $.27 per hundred discount and selling hogs at an average 230 weight instead of at the 217 pound weight.

These results indicate that trying to "top the market" is not always the most profitable plan. Nor is it necessarily wise to attempt to sell in the weight range with the highest price. Rather, for each pig, the producer should attempt to find that market weight and price maximizing the difference between total revenue and total cost. This difference, that is, the greatest profit, does not always occur with 210 or 220 pound pigs.

It is not correct to conclude from this discussion that when market prices are high, e.g., $24.00 instead of $19.00 per hundred, pigs should be carried to heavier weights. To

test the hypothesis that hogs should be marketed at heavier weights during periods of higher prices we made a least squares fit of the equation

$$Y = a + bx + cx^2$$

where Y was the observed optimum market weight and x was the observed market price. The regression gave the equations

$$\hat{Y} = 151.795 + 7.142(\bar{x}) - .155(\bar{x}^2)$$

or, with the variables at their means,

$$229.502 = 151.795 + 7.142(19.350) - .155(388.561)$$

The observed F-value from the analysis of variance from this fit was 3.55, significant at the 5% level. The partial correlation coefficients of .339 and .321 were significant at between five and ten percent. The t-values of the regression coefficients were 1.59 and -1.41, significant at about 20%(9). However, the R^2 was only .16. These results indicate that while price level was correlated with optimum market weights, one or more other factors of great importance were left out of the equation. We point to varying input prices as partial explanation, but, once again, the great likelihood is that the model's perfect foresight with respect to price fluctuations played the major role in determining marketing weight.

Table 6 compares net profit resulting from the two plans. The arbitrary plan showed a net profit of $262,325.32, while the optimum plan showed $280,949.99. This is a difference of $18,624.67. The optimum plan was 7.1% more

Table 6. Net profit from the two strategies

Year	Net profit from the arbitrary plan	Net profit from the optimum plan
1961	9,390.41	10,893.72
1962	4,828.90	6,351.46
1963	-4,912.67	-4,619.32
1964	-7,306.96	-6,816.75
1965	38,946.61	44,333.98
1966	47,739.70	47,078.72
1967	17,110.28	18,426.29
1968	24,584.23	27,449.64
1969	57,289.70	63,666.88
1970	44,655.12	44,185.37
Subtotals	232,325.32	250,949.99
Scrap value of buildings	30,000.00	30,000.00
Totals	262,325.32	280,949.99

profitable than the arbitrary plan, and was more profitable in all years but 1966 and 1970.[1] In these two years the arbitrary plan was slightly more profitable.[2]

This result is as we expected. The 210-220 pound weight range is optimal for some price and technical production relationships, but not for all such relationships. For many sets of input and output prices, market weights heavier than 220 pounds are optimal.

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[1]Profit for any year was equal to the computed profit (objective function) - feed costs - labor* - repairs and maintenance* - depreciation* - interest on investment* - veterinary charge. Stared items were constant for both plans.

[2]There are two reasons why the arbitrary plan, a subset of the whole plan, might have been more profitable during any single year. First, all decisions in the model were inextricably tied together. Production decisions taken in 1961 determined the path of resource availability (space) leading to production decisions in later years. The two plans farrowed and sold pigs at different times during any year. It may have been that the optimal plan was unable to concentrate marketings at the most favorable times during 1966 and 1970 because of the way the plan allocated resources (space) in earlier years. Second, the model did not cover whole years. It covered 182-day periods. The first period started on 1/7/61. It was necessary to establish the date of each activity in the plan and then to convert results into quarterly and yearly figures. Activities from two 180-day periods are frequently included in quarterly totals. It is possible that less profitable activities ended up in one quarter and more profitable activities in another quarter. See for example the last quarter of 1965 and the first quarter of 1966 (Tables 4 and 5).

Additional Findings

When the quantity of available finishing space was reduced to the point where some farrowing capacity went unused, the model sold 180-pound pigs exclusively. This indicates that the foremost decision rule in confinement swine production should be to use farrowing capacity as fully as possible. It is apparently more profitable to farrow to capacity and sell 180-pound pigs than to farrow fewer total pigs and use scarce finishing space to carry pigs to heavier weights. In other words, the rate of profit on 180-pound pigs is greater than the rate of profit on weight added past 180 pounds.

This introduces the question of disease. Our farrowing house was left empty one-sixth of the time for disease prevention. Shadow prices on the farrowing restraints used to keep the farrowing house partly empty ranged from $50.00 when pork was at $13.00 to well over $150.00 when pork was at $27.00. This suggests that disease problems associated with confinement are a substantial added cost. Confinement producers must pay this (opportunity) cost. Other producers may not have to.

We would also suggest that producers with no binding limit on finishing space should consider carrying pigs past 220 pounds whenever feed and pork price relationships are favorable. If all inputs are essentially costless save feed,

the profit maximizing criteria is

Pork Price (Marginal Physical Product of Feed) =

price of feed,

$$MPP_F = \frac{\text{feed price}}{\text{pork price}}.$$

Let pork be at \$16.00, and feed at \$.04 per pound.

$$MPP_F = \frac{.04}{.16} = .25.$$

That is, it is profitable at these prices to carry pigs to where their feed conversion ratio is four pounds of feed per pound of gain. If pork prices are higher or if feed prices are lower, then it is profitable to add weight past a 4:1 ratio. However, immediate conclusions as to optimal weight-feed-price relationships cannot be drawn when additional constraints, such as space, are added.

Conclusions

1. A consistent pattern of marketing pigs at 210 to 220 pounds is frequently not the optimum marketing strategy. Between 1961 and 1970, a producer with facilities similar to those assumed in this study following such a strategy would have realized an opportunity loss of \$18,600 compared to the optimum strategy. However, whether a producer could improve upon the results of a fixed weight marketing strategy is a function of his capacity to forecast future price relationships.

2. Aiming for the highest value per pound of pork

marketed is not the best marketing strategy to follow.

3. The best marketing strategy is to equate the marginal value product of each input to the marginal cost of each input for each input used in production, regardless of final marketing weight.

4. From a given number of pigs, a profit maximizing producer would often market more total pounds of pork at a lower average price than would a producer always marketing at 210 or 220 pounds.

5. The single most important decision rule for confinement swine producers with facilities comparable to those studied is to use farrowing space to capacity.

SUMMARY

This study compares two pork production and marketing strategies. The strategies are

a. always market pigs at the arbitrarily predetermined weights of 210 or 220 pounds; or

b. market pigs at optimal weights between 180 and 260 pounds.

The study spans a period of ten years.

The optimal plan showed $280,949.99 total profit for the ten years, while the arbitrary plan showed $262,325.32. The optimal plan was 7.1% more profitable than the arbitrary plan. Both plans sold the same number of pigs, but the optimal plan sold 394,300 more pounds of pork and averaged $.27 less per hundredweight.

The optimal plan was more nearly able to satisfy the marginal-value-product-equal-marginal-cost criteria than was the arbitrary plan.

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APPENDIX I. TABLES

Appendix Table I.1. Biweekly market prices for pork, 1961 - 1970[a]

Weight	Date	Price	Date	Price	Date	Price
180	1/7/61	$16.30	1/21/61	$16.30	2/4/61	$17.03
190		16.64		16.80		17.53
200		16.98		17.05		17.78
210		16.84		16.99		17.78
220		16.70		16.93		17.78
230		16.41		16.63		17.46
240		16.12		16.33		17.14
250		15.87		16.08		16.89
260		15.62		15.83		16.64
180	2/18/61	17.30	3/4/61	16.75	3/18/61	16.40
190		17.80		17.25		16.90
200		18.05		17.50		17.15
210		18.02		17.49		17.15
220		17.99		17.48		17.15
230		17.74		17.29		16.95
240		17.49		17.10		16.70
250		17.24		17.85		16.45
260		16.99		17.60		16.20
180	4/1/61	15.97	4/15/61	16.33	4/29/61	15.56
190		16.47		16.83		16.06
200		16.72		17.08		16.31
210		16.72		17.06		16.26
220		16.72		17.05		16.22
230		16.52		16.81		15.99
240		16.33		16.67		15.75
250		16.08		16.42		15.50
260		15.83		16.17		15.25
180	5/13/61	15.44	5/27/61	15.42	6/10/61	15.45
190		15.94		15.92		15.95
200		16.19		16.17		16.20
210		16.13		16.08		16.09
220		16.07		15.99		15.97
230		16.84		15.73		15.74
240		15.61		15.47		15.51
250		15.36		15.23		15.26
260		15.11		14.98		15.01

[a]Source: (10).

Appendix Table L.L (continued)

Weight	Date	Price	Date	Price	Date	Price
180	6/24/61	$15.71	7/8/61	$16.76	7/22/61	$16.37
190		16.21		17.09		16.87
200		16.46		17.42		17.12
210		16.36		17.40		17.12
220		16.25		17.38		17.12
230		16.05		17.15		16.97
240		15.85		16.92		16.81
250		15.60		16.67		16.56
260		15.35		16.67		16.31
180	8/5/61	16.56	8/19/61	17.14	9/2/61	17.04
190		16.06		17.64		17.54
200		17.31		17.89		17.79
210		17.31		17.89		17.79
220		17.31		17.89		17.79
230		17.18		17.76		17.66
240		16.80		17.63		17.54
250		16.80		17.29		17.09
260		16.55		17.13		17.04
180	9/16/61	16.89	9/30/61	16.68	10/14/61	15.56
190		17.39		17.18		16.06
200		17.64		17.43		16.31
210		17.64		17.43		16.31
220		17.64		17.43		16.31
230		17.49		17.31		16.18
240		17.34		17.19		16.06
250		17.09		16.94		15.81
260		16.84		16.69		15.56
180	10/28/61	15.12	11/11/61	14.75	11/25/61	14.59
190		15.62		15.25		15.09
200		15.87		15.50		15.34
210		15.87		15.49		15.32
220		15.87		15.49		15.30
230		15.76		15.37		15.17
240		15.66		15.26		15.05
250		15.41		15.01		14.80
260		15.16		14.76		14.55

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	12/9/61	$15.04	12/23/61	$15.96	1/6/62	$15.59
190		15.54		16.46		16.09
200		15.79		16.71		16.34
210		15.76		16.69		16.32
220		15.73		16.68		16.31
230		15.57		16.48		16.14
240		15.41		16.28		15.96
250		15.16		16.03		15.71
260		14.91		15.78		15.46
180	1/20/62	16.05	2/3/62	15.97	2/17/62	15.58
190		16.55		16.47		16.08
200		16.80		16.72		16.33
210		16.78		16.67		16.32
220		16.76		16.62		16.31
230		16.53		16.42		16.14
240		16.31		16.22		15.96
250		16.06		15.97		15.71
260		15.81		15.72		15.46
180	3/3/62	15.44	3/17/62	15.10	3/31/62	14.82
190		15.94		15.60		15.32
200		16.19		15.85		15.57
210		16.15		15.82		15.55
220		16.12		15.79		15.53
230		15.97		15.65		15.38
240		15.82		15.51		15.23
250		15.57		15.26		14.98
260		15.32		15.01		14.73
180	4/14/62	14.82	4/28/62	14.99	5/12/62	14.40
190		15.32		15.49		14.90
200		15.57		15.74		15.15
210		15.52		15.69		15.08
220		15.48		15.64		15.01
230		15.29		15.46		14.85
240		15.10		15.28		14.70
250		14.85		15.03		14.45
260		14.60		14.78		14.20

Appendix Table I.L. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	5/26/62	$14.49	6/9/62	$14.56	6/23/62	$16.41
190		14.99		15.06		16.91
200		15.24		15.31		17.16
210		15.20		15.30		17.15
220		15.17		15.30		17.15
230		14.99		15.15		17.03
240		14.80		15.01		16.91
250		14.55		14.76		16.66
260		14.30		14.51		16.41
180	7/7/62	16.53	7/21/62	17.01	8/4/62	17.83
190		17.03		17.51		18.33
200		17.28		17.76		18.58
210		17.27		17.76		18.58
220		17.26		17.76		18.58
230		17.12		17.62		18.45
240		16.98		17.48		18.31
250		16.73		17.23		18.06
260		16.48		16.98		17.81
180	8/18/62	16.67	9/1/62	16.79	9/15/62	17.21
190		17.17		17.29		17.71
200		17.42		17.54		17.96
210		17.42		17.54		17.95
220		17.42		17.54		17.95
230		17.28		17.43		17.81
240		17.14		17.32		17.68
250		16.89		17.07		17.43
260		16.64		16.82		17.18
180	9/29/62	16.61	10/13/62	15.81	10/27/62	15.58
190		16.11		16.31		16.08
200		17.36		16.56		16.33
210		17.35		16.56		16.32
220		17.35		16.56		16.31
230		17.21		16.42		16.18
240		17.08		16.28		16.06
250		16.83		16.03		15.81
260		16.58		15.78		15.56

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	11/10/62	$15.53	11/24/62	$15.36	12/8/62	$15.21
190		16.03		15.86		15.71
200		16.28		16.11		15.96
210		16.27		16.08		15.93
220		16.26		16.06		15.90
230		16.08		15.87		15.62
240		15.91		15.68		15.35
250		15.66		15.43		15.10
260		15.41		15.18		14.85
180	12/22/62	15.25	1/5/63	14.85	1/19/63	14.87
190		15.75		15.35		15.37
200		16.00		15.60		15.62
210		15.96		15.55		15.56
220		15.91		15.51		15.51
230		15.53		15.20		15.18
240		15.14		15.90		14.85
250		14.89		14.65		14.60
260		14.64		14.40		14.35
180	2/2/63	14.54	2/16/63	14.35	3/2/63	13.45
190		15.04		14.85		13.95
200		15.29		15.10		14.20
210		15.22		15.04		14.15
220		15.15		14.98		14.10
230		14.84		14.67		13.83
240		14.54		14.36		13.57
250		14.29		14.11		13.32
260		14.04		13.86		13.07
180	3/16/63	12.96	3/30/63	12.61	4/13/63	12.81
190		13.46		13.11		13.31
200		13.71		13.36		13.56
210		13.69		13.36		13.56
220		13.68		13.36		13.56
230		13.48		13.14		13.39
240		13.28		12.93		13.22
250		13.03		12.68		12.97
260		12.78		12.43		12.72

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	4/27/63	$12.53	5/11/63	$12.95	5/25/63	$14.49
190		13.03		13.45		14.99
200		13.28		13.70		15.24
210		13.28		13.70		15.24
220		13.28		13.70		15.24
230		13.13		13.57		15.13
240		12.99		13.44		15.03
250		12.74		13.19		14.78
260		12.49		12.94		14.53
180	6/8/63	15.80	6/22/63	15.97	7/6/63	16.85
190		16.30		16.47		17.35
200		16.55		16.72		17.60
210		16.55		16.72		17.60
220		16.55		16.72		17.60
230		16.42		16.53		17.36
240		16.29		16.35		17.12
250		16.04		16.10		16.87
260		15.89		15.85		16.62
180	7/20/63	17.25	8/3/63	16.86	8/17/63	16.19
190		17.75		17.36		16.69
200		18.00		17.61		16.94
210		17.99		17.59		16.88
220		17.98		17.58		16.82
230		17.72		17.32		16.61
240		17.47		17.08		16.40
250		17.22		16.83		16.15
260		16.97		16.58		15.90
180	8/31/63	15.58	9/14/63	14.73	9/28/63	14.06
190		16.08		15.23		14.56
200		16.33		15.48		14.81
210		16.29		15.48		14.81
220		16.26		15.48		14.81
230		16.10		15.29		14.69
240		15.94		15.11		14.58
250		15.69		14.86		14.33
260		15.44		14.61		14.08

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	10/12/63	$14.35	10/26/63	$14.07	11/9/63	$13.51
190		14.85		14.57		14.01
200		15.10		14.82		14.26
210		15.11		14.81		14.26
220		15.11		14.80		14.26
230		15.01		14.69		14.13
240		14.91		14.58		14.01
250		14.66		14.33		13.76
260		14.41		14.08		13.51
180	11/23/63	12.78	12/7/63	12.75	12/21/63	13.19
190		12.78		13.25		13.69
200		13.53		13.50		13.94
210		13.53		13.50		13.92
220		13.53		13.50		13.91
230		13.37		13.32		13.72
240		13.21		13.15		13.53
250		12.96		12.90		13.28
260		12.71		12.65		13.03
180	1/4/64	13.40	1/18/64	14.10	2/1/64	14.01
190		13.90		14.60		14.51
200		14.15		14.85		14.76
210		14.12		14.82		14.74
220		14.10		14.80		14.73
230		13.85		14.53		14.44
240		13.60		14.27		14.16
250		13.35		14.02		13.91
260		13.10		13.77		13.66
180	2/15/64	13.82	2/29/64	13.62	3/14/64	13.55
190		14.32		14.12		14.05
200		14.57		14.37		14.30
210		14.53		14.37		14.24
220		14.49		14.37		14.19
230		14.20		14.08		13.90
240		13.92		13.79		13.62
250		13.67		13.54		13.37
260		13.42		13.29		13.12

Appendix Table I.1 (continued)

Weight	Date	Price	Date	Price	Date	Price
180	3/28/64	$13.42	4/11/64	$13.25	4/25/64	$13.21
190		13.92		13.75		13.71
200		14.17		14.00		13.96
210		14.13		13.95		13.92
220		14.10		13.90		13.88
230		13.81		13.63		13.65
240		13.52		13.37		13.41
250		13.27		13.12		13.16
260		13.02		12.87		13.91
180	5/19/64	13.41	5/23/64	14.51	6/6/64	14.17
190		13.91		15.01		14.67
200		14.16		15.26		14.92
210		14.11		15.21		14.88
220		14.07		15.16		14.83
230		13.81		14.93		14.59
240		13.55		14.71		14.34
250		13.30		14.46		14.09
260		13.05		14.21		13.84
180	6/20/64	14.45	7/4/64	16.33	7/18/64	16.12
190		14.95		16.83		16.62
200		15.20		17.08		16.87
210		15.14		17.04		16.82
220		15.08		17.01		16.77
230		14.83		16.76		16.49
240		14.58		16.52		16.22
250		14.33		16.27		15.97
260		14.08		16.02		15.72
180	8/1/64	15.55	8/15/64	15.35	8/29/64	16.33
190		16.05		15.85		16.83
200		16.30		16.10		17.08
210		16.26		16.06		17.08
220		16.22		16.02		17.08
230		15.98		15.79		16.81
240		15.73		15.56		16.55
250		15.48		15.31		16.30
260		15.23		15.06		16.05

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	9/12/64	$15.67	9/26/64	$15.15	10/10/64	$14.74
190		16.17		15.65		15.24
200		16.42		15.90		15.49
210		16.39		15.88		15.44
220		16.36		15.87		15.40
230		16.09		15.61		15.11
240		15.81		15.36		14.81
250		15.56		15.11		14.56
260		15.31		14.86		14.31
180	10/24/64	14.27	11/7/64	13.67	11/21/64	13.39
190		14.77		14.17		13.89
200		15.02		14.42		14.14
210		14.96		14.36		14.08
220		14.90		14.30		14.02
230		14.59		14.00		13.70
240		14.28		13.70		13.39
250		14.03		13.45		13.14
260		13.78		13.20		12.89
180	12/5/64	13.78	12/19/64	14.72	1/2/65	15.23
190		14.28		15.22		15.73
200		14.53		15.47		15.98
210		14.48		15.41		15.93
220		14.43		15.36		15.88
230		14.14		15.07		15.62
240		13.85		14.78		15.36
250		13.60		14.53		15.11
260		13.35		14.28		14.86
180	1/16/65	15.08	1/30/65	15.33	2/13/65	16.13
190		15.58		15.83		16.63
200		15.83		16.08		16.88
210		15.79		16.02		16.83
220		15.74		15.97		16.78
230		15.48		15.68		16.50
240		15.23		15.39		16.21
250		14.98		15.14		15.96
260		14.73		14.89		15.71

Appendix Table L1.(continued)

Weight	Date	Price	Date	Price	Date	Price
180	2/27/65	$15.99	3/13/65	$15.76	3/27/65	$15.86
190		16.49		16.26		16.36
200		16.74		16.51		16.61
210		16.69		16.48		16.56
220		16.64		16.50		16.87
230		16.38		16.22		16.23
240		16.12		15.97		15.96
250		15.87		15.72		15.71
260		15.62		15.47		15.46
180	4/10/65	16.21	4/24/65	16.87	5/8/65	18.11
190		16.71		17.37		18.61
200		16.96		17.62		18.86
210		16.92		17.58		18.82
220		16.87		17.54		18.77
230		16.63		17.29		18.49
240		16.38		17.04		18.20
250		16.13		16.79		17.95
260		15.88		16.54		17.70
180	5/22/65	19.66	6/5/65	20.39	6/19/65	23.19
190		20.16		20.89		23.69
200		20.41		21.14		23.94
210		20.35		21.08		23.90
220		20.29		21.02		23.86
230		20.01		20.72		23.67
240		19.74		20.42		23.48
250		19.49		20.17		23.23
260		19.24		19.92		22.98
180	7/3/65	22.67	7/17/65	23.48	7/31/65	22.88
190		23.17		23.98		23.38
200		23.42		24.23		23.63
210		23.40		24.21		23.61
220		23.39		24.20		23.59
230		23.15		23.93		23.36
240		22.90		23.66		23.14
250		22.65		23.41		22.89
260		22.40		23.16		22.64

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	8/14/65	$23.52	8/28/65	$23.15	9/11/65	$21.03
190		24.02		23.65		21.53
200		24.27		23.90		21.78
210		24.27		23.90		21.81
220		24.27		23.90		21.85
230		24.07		23.72		21.64
240		23.87		23.54		21.44
250		23.62		23.29		21.19
260		23.37		23.04		20.94
180	9/25/65	21.77	10/9/65	22.11	10/23/65	21.84
190		22.27		22.61		22.34
200		22.52		22.86		22.59
210		22.52		22.86		22.59
220		22.52		22.86		22.59
230		22.34		22.68		22.59
240		22.17		22.51		22.21
250		21.92		22.26		22.70
260		21.67		22.01		21.71
180	11/6/65	22.63	11/20/65	22.98	12/4/65	24.93
190		22.13		23.48		25.43
200		23.38		23.73		25.68
210		23.37		23.73		25.65
220		23.37		23.73		25.62
230		23.16		23.52		25.35
240		22.95		23.31		25.08
250		22.70		23.06		24.83
260		22.45		22.81		24.58
180	12/18/65	26.96	1/1/66	26.70	1/15/66	27.31
190		27.46		27.20		27.81
200		27.71		27.45		28.06
210		27.70		27.43		28.01
220		27.69		27.42		27.96
230		27.47		27.21		27.67
240		27.26		27.00		27.38
250		27.01		26.75		27.13
260		26.76		26.50		26.88

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	1/29/66	$27.19	2/12/66	$27.29	2/26/66	$26.65
190		27.69		27.79		27.15
200		27.94		28.04		27.40
210		27.86		27.96		27.31
220		27.79		27.88		27.22
230		27.45		27.58		26.93
240		27.12		27.28		26.65
250		26.87		27.03		26.40
260		26.62		26.88		26.15
180	3/12/66	23.44	3/26/66	22.77	4/9/66	21.87
190		23.94		23.27		22.37
200		24.19		23.52		22.62
210		24.11		23.49		22.55
220		24.04		23.46		22.48
230		23.70		23.21		22.19
240		23.35		22.96		21.90
250		23.10		22.71		21.65
260		22.85		22.46		21.40
180	4/23/66	21.00	5/7/66	21.69	5/21/66	22.89
190		21.50		22.19		23.39
200		21.75		22.44		23.64
210		21.66		22.38		23.53
220		21.56		22.33		23.42
230		21.23		21.95		22.95
240		20.90		21.56		22.48
250		20.65		21.31		22.23
260		20.40		21.06		21.98
180	6/4/66	24.00	6/18/66	23.85	7/2/66	23.82
190		24.50		24.35		24.32
200		24.75		24.60		24.57
210		24.67		24.48		24.49
220		24.58		24.37		24.42
230		24.13		23.94		23.99
240		23.68		23.50		23.56
250		23.43		23.25		23.31
260		23.18		23.00		23.06

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	7/16/66	$23.60	7/30/66	$24.50	8/13/66	$24.69
190		24.10		25.00		25.19
200		24.35		25.25		25.44
210		24.29		25.18		25.42
220		24.23		25.12		25.40
230		23.78		24.73		25.10
240		23.33		24.33		24.81
250		23.08		24.08		24.56
260		22.83		23.83		24.31
180	8/27/66	24.31	9/10/66	22.75	9/24/66	21.71
190		24.81		23.25		22.21
200		25.06		23.50		22.46
210		25.06		23.50		22.46
220		25.06		23.50		22.46
230		24.76		23.25		22.20
240		24.46		23.00		21.94
250		24.21		22.75		21.69
260		23.96		22.50		21.44
180	10/8/66	21.21	10/22/66	19.79	11/5/66	19.71
190		21.71		20.29		20.21
200		21.96		20.54		20.46
210		21.96		20.54		20.43
220		21.96		20.54		20.40
230		21.71		20.28		20.12
240		21.46		20.02		19.83
250		21.21		19.77		19.58
260		20.96		19.52		19.33
180	11/19/66	18.81	12/3/66	18.77	12/17/66	19.21
190		19.31		19.27		19.71
200		19.56		19.52		19.96
210		19.48		19.46		19.77
220		19.40		19.40		19.58
230		19.10		19.01		19.10
240		18.81		18.62		18.61
250		18.56		18.37		18.36
260		18.31		18.12		18.28

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	12/31/66	$19.41	1/14/67	$19.17	1/28/67	$19.17
190		19.91		19.67		19.67
200		20.16		19.92		19.92
210		19.97		19.70		19.84
220		19.78		19.54		19.75
230		19.28		19.09		19.33
240		18.78		18.64		18.90
250		18.53		18.39		18.65
260		18.28		18.14		18.40
180	2/11/67	18.85	2/25/67	18.73	3/11/67	18.08
190		19.35		19.23		18.58
200		19.60		19.48		18.83
210		19.50		19.37		18.67
220		19.40		19.27		18.52
230		18.99		18.88		18.18
240		18.58		18.48		17.83
250		18.33		18.23		17.58
260		18.08		17.98		17.33
180	3/25/67	17.52	4/8/67	16.88	4/22/67	16.96
190		18.02		17.38		17.46
200		18.27		17.63		17.71
210		18.09		17.49		17.52
220		17.94		17.36		17.33
230		17.60		17.05		17.02
240		17.27		16.73		16.71
250		17.02		16.48		16.46
260		16.77		16.23		16.21
180	5/6/67	18.37	5/20/67	22/56	6/3/67	21.93
190		18.87		23.06		22.43
200		19.12		23.31		22.68
210		18.97		23.23		22.59
220		18.81		23.15		22.50
230		18.44		22.86		22.19
240		18.08		22.86		21.88
250		17.83		22.31		21.63
260		17.58		22.06		21.38

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	6/17/67	$21.63	7/1/67	$21.31	7/15/67	$21.71
190		22.13		21.81		22.21
200		22.38		22.06		22.46
210		22.31		22.06		22.46
220		22.25		22.00		22.38
230		21.94		21.94		22.31
240		21.62		21.63		21.93
250		21.37		21.31		21.56
260		21.12		21.06		21.31
180	7/29/67	21.19	8/12/67	20.31	8/26/67	19.63
190		21.69		20.81		20.13
200		21.94		21.06		20.38
210		21.94		21.06		20.38
220		21.85		21.00		20.32
230		21.77		20.94		20.25
240		21.50		20.65		20.00
250		21.23		20.35		19.75
260		20.98		20.10		19.50
180	9/23/67	18.23	10/7/67	17.77	10/21/67	17.15
190		18.73		18.27		17.65
200		18.98		18.52		17.90
210		18.98		18.52		17.90
220		18.92		18.45		17.82
230		18.85		18.38		17.75
240		18.63		18.10		17.42
250		18.42		17.83		17.10
260		18.17		17.58		16.85
180	11/4/67	16.54	11/18/67	16.63	12/2/67	16.75
190		17.04		17.13		17.25
200		17.29		17.38		17.50
210		17.29		17.38		17.50
220		17.10		17.20		17.31
230		16.92		17.02		17.12
240		16.61		16.72		16.80
250		16.31		16.42		16.48
260		16.06		16.17		16.23

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	12/16/67	$16.83	12/30/67	$17.03	1/13/68	$17.60
190		17.33		17.53		18.10
200		17.58		17.78		18.35
210		17.58		17.78		18.35
220		17.40		17.54		18.16
230		17.21		17.31		17.98
240		16.96		16.89		17.58
250		16.71		16.48		17.18
260		16.46		16.23		16.93
180	1/27/68	18.35	2/10/68	17.97	2/24/68	19.10
190		18.85		18.47		19.60
200		19.10		18.72		19.85
210		19.10		18.72		19.85
220		18.99		18.61		19.74
230		18.88		18.50		19.62
240		18.45		18.11		19.33
250		18.01		17.72		19.05
260		17.76		17.47		18.80
180	3/9/68	18.43	3/23/68	17.97	4/6/68	18.30
190		18.93		18.47		18.80
200		19.18		18.72		19.05
210		19.18		18.72		19.05
220		19.05		18.61		18.97
230		18.92		18.50		18.88
240		18.70		18.25		18.56
250		18.48		18.00		18.25
260		18.23		17.75		18.00
180	4/20/68	18.33	5/4/68	18.55	5/18/68	18.45
190		18.83		19.05		18.95
200		19.08		19.30		19.20
210		19.08		19.30		19.20
220		18.97		19.19		19.05
230		18.85		19.08		18.90
240		18.56		18.74		18.53
250		18.28		18.42		18.17
260		18.03		18.17		17.92

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	6/1/68	$18.34	6/15/68	$19.43	6/29/68	$20.43
190		18.84		19.93		20.93
200		19.09		20.18		21.18
210		19.09		20.18		21.18
220		18.98		20.07		21.09
230		18.88		19.95		21.00
240		18.46		19.58		20.69
250		18.04		19.22		20.38
260		17.79		18.97		20.13
180	7/13/69	21.53	7/27/68	20.07	8/10/68	19.17
190		22.03		20.57		19.67
200		22.28		20.87		19.92
210		22.28		20.82		19.92
220		22.18		20.65		19.81
230		22.08		20.48		19.70
240		21.77		20.17		19.31
250		21.45		19.85		18.92
260		21.20		19.60		18.67
180	8/24/68	19.15	9/7/68	18.97	9/21/68	19.00
190		19.65		19.47		19.50
200		19.90		19.72		19.75
210		19.90		19.72		19.75
220		19.90		19.67		19.75
230		19.90		19.62		19.75
240		19.45		19.23		19.36
250		19.00		18.84		18.98
260		18.75		18.59		18.73
180	10/5/68	18.37	10/19/68	17.13	11/2/68	17.33
190		18.87		17.63		17.83
200		19.12		17.88		18.08
210		19.12		17.88		18.08
220		19.01		17.75		17.94
230		18.90		17.62		17.80
240		18.60		17.32		17.47
250		18.30		17.02		17.15
260		18.05		16.77		16.90

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	11/16/68	$17.05	11/30/68	$17.37	12/14/68	$17.53
190		17.55		17.87		18.03
200		17.80		18.12		18.28
210		17.80		18.12		18.28
220		17.67		18.00		18.22
230		17.55		17.88		18.15
240		17.27		17.55		17.72
250		16.98		17.22		17.30
260		16.73		16.97		17.05
180	12/28/68	19.13	1/11/69	18.20	1/25/69	19.03
190		19.63		18.70		19.53
200		19.88		18.95		19.78
210		19.88		18.95		19.78
220		19.88		18.89		19.72
230		19.88		18.82		19.65
240		19.36		18.57		19.40
250		18.84		18.32		19.15
260		18.59		18.07		18.90
180	2/8/69	19.10	2/22/69	19.63	3/8/69	19.03
190		19.60		20.13		19.53
200		19.85		20.38		19.78
210		19.85		20.38		19.78
220		19.80		20.25		19.76
230		19.75		20.12		19.75
240		19.50		19.87		19.50
250		19.25		19.62		19.25
260		19.00		19.37		19.00
180	3/22/69	19.87	4/5/69	19.25	4/19/69	19.20
190		20.37		19.75		19.70
200		20.62		20.00		19.95
210		20.62		20.00		19.95
220		20.51		19.97		19.88
230		20.40		19.94		19.82
240		20.15		19.69		19.57
250		19.90		19.44		19.32
260		19.65		19.19		19.07

Appendix Table L.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	5/3/69	$19.80	5/17/69	$22.30	5/31/69	$23.84
190		20.30		22.80		24.34
200		20.55		23.05		24.59
210		20.55		23.05		24.59
220		20.42		22.97		24.51
230		20.30		22.90		24.44
240		20.05		22.65		24.19
250		19.80		22.40		23.94
260		19.55		22.15		23.69
180	6/14/69	23.77	6/28/69	24.20	7/12/69	24.73
190		24.27		24.70		25.23
200		24.52		24.95		25.48
210		24.52		24.95		25.48
220		24.43		24.90		25.40
230		24.35		24.85		25.32
240		24.10		24.60		25.07
250		23.85		24.35		24.82
260		23.60		24.10		24.57
180	7/26/69	24.87	8/9/69	25.80	8/23/69	26.10
190		25.37		26.30		26.60
200		25.62		26.55		26.85
210		25.62		26.55		26.85
220		25.56		26.47		26.80
230		25.50		26.40		26.75
240		25.25		26.15		26.50
250		25.00		25.90		26.25
250		24.75		25.65		26.00
180	9/6/69	24.81	9/20/69	24.50	10/4/69	24.90
190		25.31		25.00		25.40
200		25.56		25.25		25.65
210		25.56		25.25		25.65
220		25.45		25.21		25.60
230		25.34		25.18		25.55
240		25.09		24.93		25.30
250		24.84		24.68		25.30
260		24.59		24.43		24.80

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	10/18/69	$24.00	11/1/69	$24.33	11/15/69	$24.85
190		24.50		24.83		25.35
200		24.75		25.08		25.60
210		24.75		25.08		25.60
220		24.70		24.98		25.47
230		24.65		24.88		25.35
240		24.40		24.63		25.10
250		24.15		24.38		24.85
260		23.90		24.13		24.60
180	11/29/69	25.69	12/13/69	25.97	1/10/70	26.37
190		26.19		26.47		26.87
200		26.44		26.72		27.12
210		26.44		26.72		27.12
220		26.33		26.61		27.06
230		26.22		26.50		27.00
240		25.97		26.25		26.75
250		25.72		26.00		26.50
260		25.47		25.75		26.25
180	1/24/70	27.40	2/7/70	27.63	2/21/70	27.65
190		27.90		28.13		28.15
200		28.15		28.38		28.40
210		28.15		28.38		28.40
220		28.02		28.27		28.29
230		27.90		28.15		28.18
240		27.65		27.90		27.93
250		27.40		27.65		27.68
260		27.15		27.40		27.43
180	3/7/70	26.53	3/21/70	25.05	4/4/70	23.23
190		27.03		25.55		23.73
200		27.28		25.80		23.98
210		27.28		25.80		23.98
220		27.22		25.74		23.95
230		27.15		25.68		23.92
240		26.90		25.43		23.67
250		26.65		25.18		23.42
260		26.40		24.93		23.17

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	4/18/70	$23.47	5/2/70	$23.37	5/16/70	$22.85
190		23.97		23.87		23.35
200		24.22		24.12		23.60
210		24.22		24.12		23.60
220		24.15		24.06		23.47
230		24.08		24.00		23.35
240		23.83		23.75		23.10
250		23.58		23.50		22.85
260		23.33		23.25		22.60
180	5/30/70	22.93	6/13/70	23.60	6/27/70	24.33
190		23.43		24.10		24.83
200		23.68		24.35		25.08
210		23.68		24.35		25.08
220		23.60		24.22		24.97
230		23.52		24.10		24.85
240		23.27		23.85		24.60
250		23.02		23.60		24.35
260		22.77		23.35		24.10
180	7/11/70	24.55	7/25/70	23.97	8/8/70	22.03
190		25.05		24.47		22.53
200		25.30		24.72		22.78
210		25.30		24.72		22.78
220		25.25		24.72		22.76
230		25.20		24.72		22.75
240		24.95		24.47		22.50
250		24.70		24.22		22.25
260		24.45		23.97		22.00
180	8/22/70	20.83	9/5/70	19.35	9/19/70	19.43
190		21.33		19.85		19.93
200		21.58		20.10		20.18
210		21.58		20.10		20.18
220		21.63		20.07		20.18
230		21.68		20.05		20.18
240		21.43		19.80		19.93
250		21.18		19.55		19.68
260		20.93		19.30		19.43

Appendix Table I.1. (continued)

Weight	Date	Price	Date	Price	Date	Price
180	10/3/70	$19.05	10/17/70	$17.43	10/31/70	$15.20
190		19.55		17.93		15.70
200		19.80		18.18		15.95
210		19.80		18.18		15.95
220		19.80		18.18		15.89
230		19.80		18.18		15.82
240		19.55		17.93		15.57
250		19.30		17.68		15.32
260		19.05		17.43		15.07
180	11/14/70	15.10	11/28/70	14.89	12/19/70	15.15
190		15.60		15.39		15.65
200		15.85		15.64		15.90
210		15.85		15.64		15.90
220		15.79		15.58		15.82
230		15.72		15.52		15.75
240		15.47		15.27		15.50
250		15.22		15.02		15.25
260		14.97		14.77		15.00
180	12/26/70	15.75				
190		16.25				
200		16.50				
210		16.50				
220		16.44				
230		16.38				
240		16.13				
250		15.88				
260		15.63				

Appendix Table I.2. Farrowing activity[a]

Name of restraint	Restraint level	Activity coefficient
Available days of farrowing space per first two weeks	560	14
Available days of farrowing space per second two weeks	560	14
Available days of nursery space per third two weeks[b]	4480	100.8
Available days of nursery space per fourth two weeks	4480	100.8
Available days of grower space per fifth two weeks[c]	8064	99.4
Available days of grower space per sixth two weeks	8064	99.4
Available days of finisher space per seventh two weeks	6048	99.4
Available days of finisher space per eighth two weeks	6048	99.4
Available days of finisher space per ninth two weeks	6048	99.4
Available days of finisher space per tenth two weeks	6048	
Transfer pounds of 180-pound pigs		-1278
Transfer pounds of 12% feed		2258

[a]These activities farrow, grow, and finish to 180 pounds one litter of 7.1 live pigs.

[b]7.2 live pigs per litter use the nursery.

[c]7.1 live pigs per litter use the grower and finisher pens.

Appendix Table I.2. (continued)

Name of restraint	Restraint level	Activity coefficient
Transfer pounds of 14% feed		736
Transfer pounds of 18% feed		343
Bred sow requirement		1
Available days of general labor per six months	1283	.83
Pig accounting		7.1
Limit on total farrowings per quarter	99.924	1

Appendix Table I.3. Weight adding activities

Name of restraint	Restraint level	180 to 190 lb.	190 to 200 lb.	200 to 210 lb.	210 to 220 lb.
Available days of finisher space per two weeks	6048	2.952	4.620	4.553	2.084
Pig requirement[a]		180	190	200	210
Pig finished[a]			-200	-210	
Available days of finisher space in next two weeks[a,b]		1.743			1.405
Pig finished during next two weeks[a]		-190			-220
Transfer 12% feed		37.33	37.83	38.36	38.89
Weight gain time paying transfer[c]		4.7	4.6	4.6	4.5
Available hours of general labor per six months	1283	.0166	.0166	.0166	.0166

[a]There are nine separate transfer rows requiring and supplying pigs of differing weights (nine per two weeks).

[b]These pigs did not complete the ten pound gain within one two-week period. This was due to our assumptions about timing (4).

[c]All pigs adding weight past 180 pounds were required to pay interest on the revenue foregone by not being sold at 180.

Appendix Table I.3. (continued)

Name of restraint	220 to 230 lb.	230 to 240 lb.	240 to 250 lb.	250 to 260 lb.
Available days of finisher space per two weeks	4.430	4.374	3.791	4.273
Pig requirement[a]	220	230	240	250
Pig finished[a]	-230	-240		-260
Available days of finisher space in next two weeks[a,b]			.532	
Pig finished during next two weeks[a]			-250	
Transfer 12% feed	39.43	39.97	40.53	41.07
Weight gain time paying transfer[c]	4.4	4.4	4.3	4.3
Available hours of general labor per six months	.0166	.0166	.0166	.0166

Appendix Table I.4. Sales activities

Name of restraint	Restraint level	Activity coefficient
Objective function	maximum	_b
Pig requirement[a]		100
Marketing charge		1
Available hours of general labor	1283	_c
Profit accounting	No restraint	_b

[a]There are nine separate transfer rows requiring and supplying pigs of differing weights (nine per two weeks). Sales activities sell hundredweights of pigs of specific weights.

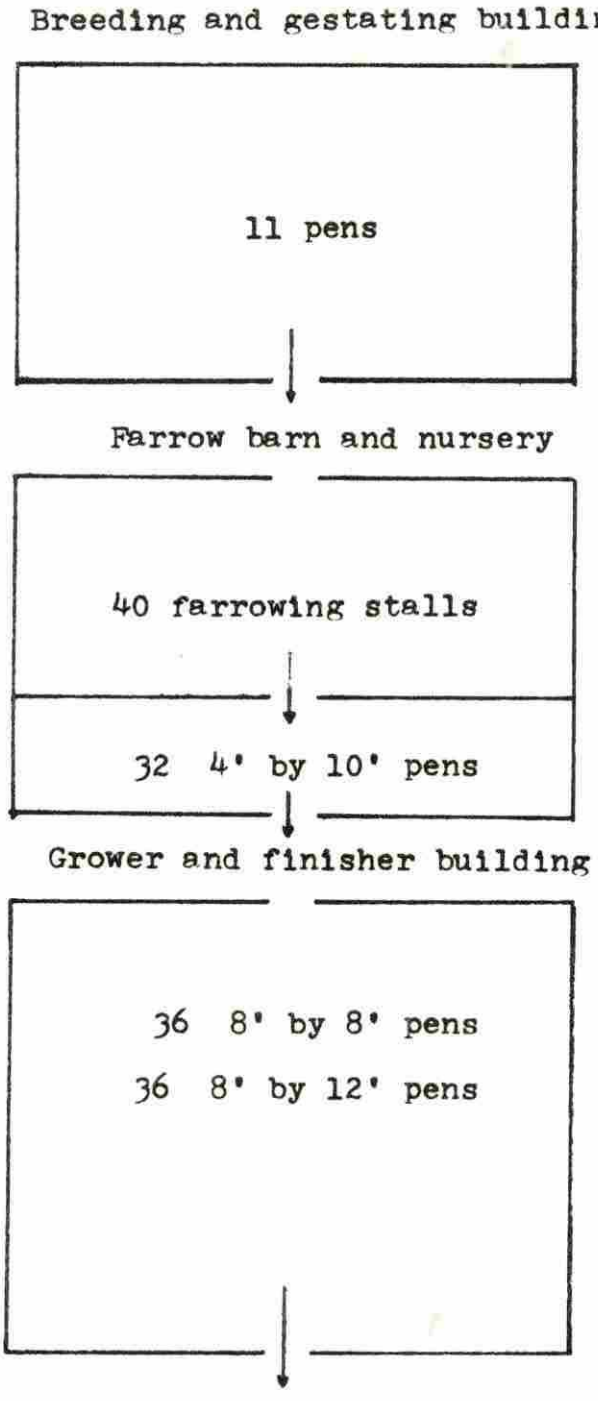
[b]This coefficient is equal to the hundredweight market price reported on the date of the sale.

[c]The model assumed the same labor requirement per pig sold, but, since the sales activities sold hundredweights, labor required per sale varied with the weight of the pig. Hundredweight requirements were:

180 pounds	.0131 hours
190 pounds	.0124 hours
200 pounds	.0118 hours
210 pounds	.0112 hours
220 pounds	.0107 hours
230 pounds	.0103 hours
240 pounds	.0098 hours
250 pounds	.0094 hours
260 pounds	.0091 hours

APPENDIX II

The Brenton Facility



Additional Comments

The Brenton facility is located in Dallas County, near Dallas Center, Iowa. It is not an integrated farming operation, but raises pork almost exclusively.

The farrow barn contains 40 farrowing stalls, or 560 days of available space every two weeks.

The nursery contains thirty-two 4 by 10 foot pens. This is room for 320 pigs, or 4460 available days of nursery space every two weeks.

The grower and finisher barn contains thirty-six 8 by 8 foot pens and thirty-six 8 by 12 foot pens. There are 8064 available days of grower space and 6048 available days of finisher space every two weeks. Grower and finisher space are perfect substitutes, although market weight pigs require more square feet of space than growers.

All buildings have totally slatted floors except the breeding and gestating building. It has partial slats. All feeding is automatic, via overhead coreless augers.

APPENDIX III

The Optimization Procedure

Optimizing for a ten-year period at once would have involved a matrix of the order of 7,000 by 5,000. This was both too large and too costly given the resources available for the project. It was decided arbitrarily to build the model to provide for step-by-step optimization with each optimization focusing on a one-year period. The basic model contained 711 columns and 499 rows. It was optimized twenty times with appropriate changes in coefficients made between each optimization. To provide for activities in process, each optimization covered 64 weeks. The 64 weeks were further divided into two-week periods. During each two weeks, farrowing, weight adding, and selling activities were formulated. Optimum results were taken for one year's time.

The model was recursive in that each optimization provided results used in the following optimization. Optimizations proceeded in chronological order. The first began on 8/24/60 with a farrowing activity.

Appendix Table III.1 shows the exact number of days required by each weight adding activity in the model (4).

Farrowing activities occurred at 12:01 a.m. on the first day of every two-week period. Sales activities occurred at the exact moment the optimum market weight was reached.

Appendix Table III.1. Elapsed time required by various weight-adding activities[a]

Activity name	Days required	Days accumulated
Farrow and add weight to 180 pounds	137	137
Add weight from 180 to 190 pounds	4.7	141.7
190 to 200	4.6	146.3
200 to 210	4.6	150.9
210 to 220	4.5	155.4
220 to 230	4.4	159.8
230 to 240	4.4	164.2
240 to 250	4.3	168.5
250 to 260	4.3	172.8

[a]Source: (4).

Weight-adding activities proceeded continuously according to Appendix Table III.1.

The Recursive Process

Consider one year of 364 days divided into 26 two-week periods. During this year the following events occur:

1. sows are farrowed;
2. weight is added to market-bound pigs;
3. finished hogs are marketed.

Other activities essential to the production and marketing of pork also occur during this year. For example, feed ingredients are purchased, mixed, and fed.

The chronological ordering of the farrowing, weight-adding, and selling activities for one year is shown in Appendix Table III.2.

The first pigs were born on August 24, 1960. Pigs born then reached 180 pounds on 1/7/61. These pigs were either sold at 180 pounds, or retained in the system while weight was added at the rates shown in Appendix Table III.1.

The 364th day after August 24, 1960 was August 22, 1961. Thus, the first year ended at 11:59 p.m., August 22, 1961.

All activities entering the basis during the first 364 days become part of the optimum strategy. The reader should note, however, that there is a substantial lag between farrowing and sales. The lag is as few as 137 or as many as

Appendix Table III.2. Chronological ordering of farrowing, weight adding, and selling activities, first year

Date	Events occurring on the date	Events occurring on or after the date, but before the next date
8/24/60	Farrow; begin adding weight to 180 pounds	
9/7/60	"	
9/21/60	"	
10/5/60	"	
10/19/60	"	
11/2/60	"	
11/16/60	"	
11/30/60	"	
12/14/60	"	
12/28/60	"	Sell 180 pound pigs. Add weight to 180 pound pigs.
1/11/61	"	Sell 180, 190, 200, or 210 pound pigs. Add weight to 180, 190, 200, or 210 pound pigs.
1/25/61	"	Sell 180, 190, 200, 210, 220, 230, or 240 pound pigs. Add weight to 180, 190, 200, 210, 220, 230, or 240 pound pigs.
2/8/61	"	Sell 180, 190, 200, 210, 220, 230, 240, 250, or 260 pound pigs. Add weight to 180, 190, 200, 210, 220, 230, 240, 250, or 260 pound pigs.

Appendix Table III.2. (continued)

Date	Events occurring on the date	Events occurring on or after the date, but before the next date
2/22/61	Farrow; begin adding weight to 180 pounds	Sell 180, 190, 200, 210, 220, 230, 240, 250, or 260 pound pigs. Add weight to 180, 190, 200, 210, 220, 230, 240, 250, or 260 pound pigs.
3/8/61	"	"
3/22/61	"	"
4/5/61	"	"
4/19/61	"	"
5/3/61	"	"
5/17/61	"	"
5/31/61	"	"
6/14/61	"	"
6/28/61	"	"
7/12/61	"	"
7/26/61	"	"
8/9/61	"	"

172.8 days (Appendix Table III.1). Therefore, any 364-day period will provide an optimum marketing plan for only (the final) six months of the 364-day period (Appendix Table III.2). The optimum farrowing and weight-adding plan for the whole year is provided. Since 364 days is just time enough for six months of marketing to occur, it is necessary to optimize for twenty 364-day years to gain ten years optimum marketing information. This was accomplished by starting each new 364-day year on the 183rd day (six months) after the beginning of the previous 364-day year. Thus, the first year in the model started on August 24, 1960, and the second year on February 22, 1961 (2/22/61 is the 183rd day after 8/24/60).

All activities entering the basis during the first year are optimal. For any two years, there is an overlap period of 182 days. For the first and second years, this overlap period extended from 2/22/61 to 8/22/61 (Appendix Table III.2). During the overlap period the model farrows, adds weight, and sells. Sales dates, weights, prices, numbers of pigs, and quantities of pork marketed are recorded under the optimum marketing plan. All farrowing and weight-adding decisions taken during the 182-day overlap period are recorded. They are then forced into the optimization procedure for the ensuing year. The farrowing and weight-adding activities during the overlap period are the farrowing and

weight-adding activities from the second 182 days of the first year. They become the farrowing and weight-adding activities for the first 182 days of the second year.