SUPPLY CONTROL SAVINGS FOR HOG SLAUGHTERING-PROCESSING PLANTS

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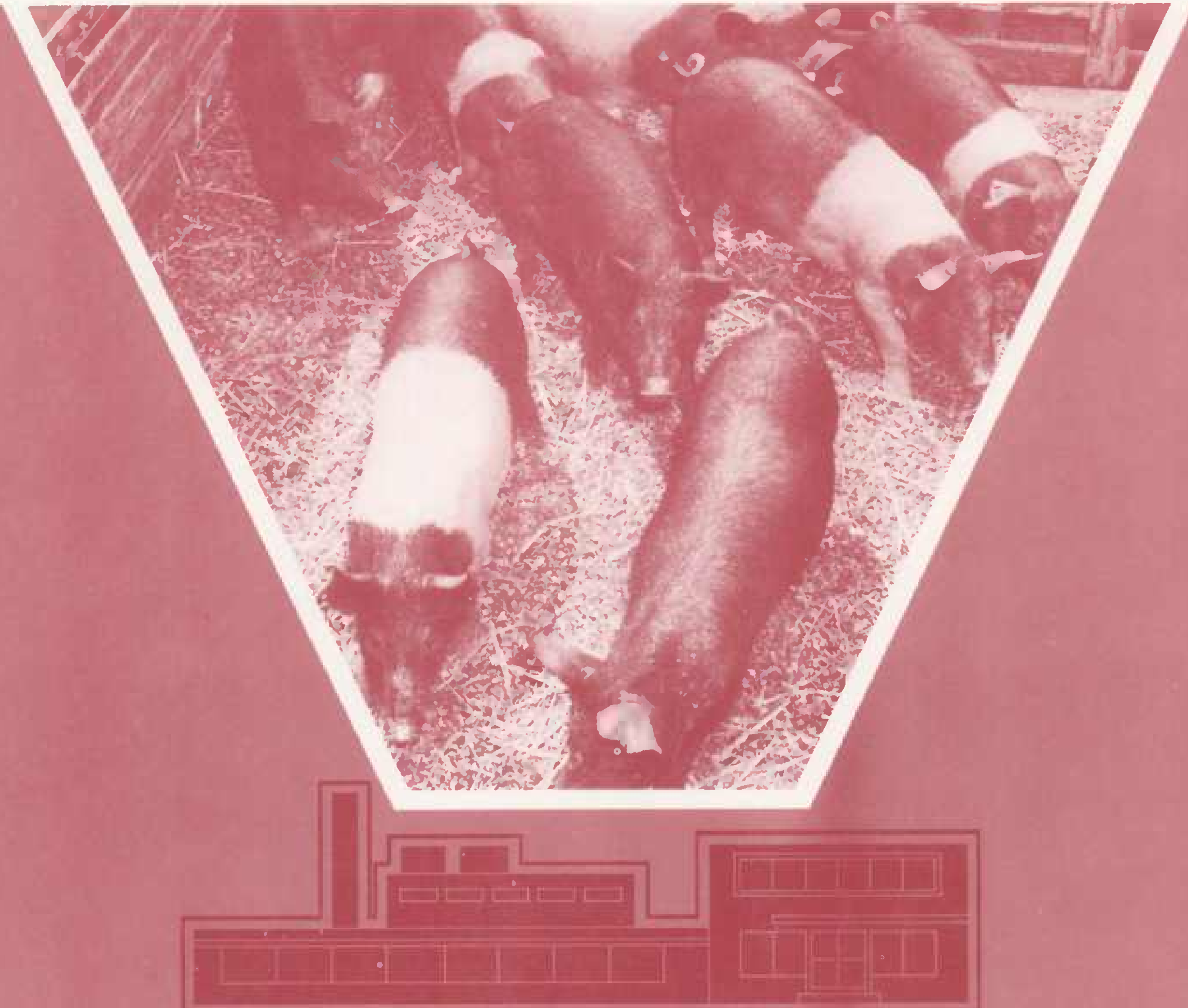

ABSTRACT

According to a random-process simulation model, slaughter plant cost savings of over 10 percent could be realized if complete market hog supply control were to be obtained. For the five sizes of plants studied, costs could be reduced by an average of $1.33 per hog. Cost savings via complete supply control ranged from $1.02 per hog for a 600-head-per-hour plant to $1.80 per hog for a 50-head-per-hour plant. Even though a high daily variation was considered, seasonal variation was the major determinant of costs attributed to supply variation. A feature of the model used in the systems analysis is the random component in determining the actual per hour productivity of workers in the slaughtering, cutting, processing, and rendering operations.

Keywords: Hogs, Marketing, Supply, Control, Costs, Slaughtering, Processing, Economies of scale, Seasonal, Fluctuations.

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PREFACE

This publication is one of a series reporting the research of the Hog-Pork Subsector Research Project, undertaken by the U. S. Department of Agriculture's Economic Research Service, Purdue University, and Michigan State University. This project uses a systems analysis approach to examine production and marketing of hogs and pork. While one of the major objectives is to examine the possible trend toward vertical coordination and the various factors involved, a number of related studies have been undertaken to encompass all segments of the hog-pork industry.

A basic reason for studying the entire swine subsector at one time is that the interdependencies within and between the production, slaughtering-processing, and marketing systems make it impossible to deal effectively with a number of signficant problems unless all related aspects are brought within the same analysis. Since other components of the broader project have explored in detail the short- and long-run supply response as well as fluctuations in the demand for pork cuts, this study considers both supply and demand to be given.

The primary objective of this study is to evaluate slaughtering-processing, cost economies associated with control (smoothing) of daily and seasonal supply of market hogs to a packing plant. Economies of scale are also computed.

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SUMMARY

Slaughter plant cost savings of 10.6 percent could be realized if complete market hog supply control were to be obtained, according to a random-process simulation model. For the five sizes of plants considered, total costs could be reduced by an average of $1.33 per hog.

Daily and seasonal variations in hog supplies were estimated and included in the model. Even though a high daily variation was considered, the seasonal variation was the major determinant of costs attributed to supply variation. Seasonal variations would also be the most difficult to change substantially, as they reflect production, management, and marketing decisions made by many diverse interests. Total costs were reduced by 9.1 percent via complete control of seasonal variation, but only 2.2 percent by complete control of daily variation.

The objective of the study was to demonstrate how cost savings may be achieved via control of daily and seasonal supply variation for typical sized plants in the meatpacking industry. As a complementary objective, economies of scale for the five sizes were calculated. The 600-head-per-hour slaughter plant consistently displayed the greatest economies of scale in all combinations of seasonal and daily variation analyzed. However, it had the smallest cost savings of the five plant sizes studied--only $1.02 per hog--with complete supply control, while the smallest plant--50-head-per-hour--had a savings of $1.80 per hog. The other three plant sizes (125, 300, and 800-head-per-hour) had savings between these extremes.

A feature of the model used in the systems analysis is the random component in determining the actual per hour productivity of workers (in number of hogs or pounds of pork) in the slaughtering, cutting, processing, and rendering operations. Also, the model was constructed so that specialized slaughtering or processing plants could be considered, with allowances for product flows between the fulltime packers and the specialized packers and processors.

SUPPLY CONTROL SAVINGS FOR HOG SLAUGHTERING–PROCESSING PLANTS

by

J. B. Holtman, J. D. Sullivan, and H. F. Barreto 1/

INTRODUCTION

Hog production has been trending toward fewer but larger producing units. The 1969 Census showed 11 percent of the Nation's farms had 200 or more hogs and pigs, representing 52 percent of the total inventory. The 1964 Census showed only 6 percent of the farms with 200 or more hogs and pigs, accounting for 39 percent of the total inventory. Another important trend in hog production has been the separation of farrowing from the hog feeding-finishing operation.

Concentration of hog production has remained stable since 1950. The 10 major Corn Belt States--Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, South Dakota, Nebraska, and Kansas--produce about 75 percent of the U.S. pig crop. Traditionally, Iowa has been first and Illinois second in hog production.

The slaughtering-processing industry has been undergoing deconcentration and decentralization. As late as 1950, about 40 percent of the hogs purchased by packers moved through terminal markets. However, by 1970, only 17 percent moved through terminal markets. The rest were purchased direct or through dealers (69 percent) and through auctions (14 percent).

Slaughter plants under Federal inspection and nonfederally inspected plants with an annual live weight output of 300,000 pounds or more numbered 3,869 on March 1, 1970, an increase of 912 since 1963. Eighty-three percent of these plants slaughtered hogs, but only 4 percent of the plants slaughtered only hogs. The most common combination was cattle-calves and hogs, as in 40 percent of the plants. 2/ Only 371 of the 3,196 plants slaughtering hogs were federally inspected. However, approximately 90 percent of commercial hog slaughter was performed by federally inspected plants.

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2/ Number Livestock Slaughter Plants March 1, 1970, U.S. Dept. Agr., Statis. Rptg. Serv., SRS-8, May 1970.

About 70 percent of the pork carcass is processed before sale to the consumer. Processed pork products such as ham, bacon, sausage, and luncheon meat usually are graded and to some extent quality controlled. Thus, they have a differentiated product consumer image and some protection against fluctuating prices. On the other hand, most fresh pork has not been graded, has no uniform identification, and offers no assurance of consistent quality. Because of this lack of national meat quality grades for pork, most meatpackers consider fresh pork prices to be extremely sensitive to changes in supply and demand.

PROBLEMS AND OBJECTIVES

Structural characteristics of the hog-pork subsector make it difficult for the industry to translate consumption levels of pork (demand) into packer demand for live hogs (supply of market hogs). Although hog procurement is subject to the conventional concepts of supply and demand, the uncertainties of supply are greater than typically found in manufacturing industries. This situation is the result of three factors.

First, raw material (live hogs) is supplied by a large number of producers. Total hog supply is subject to wide fluctuations, and it is difficult for a firm to secure a dependable source for an extended period.

Second, market hogs are not of uniform quality nor generally purchased on any guarantee of quality. Hog buyers bid and contract for animals by subjective evaluation, and while they often become quite proficient in this respect, the overall procurement procedure is plagued with more uncertainties than in manufacturing firms which contract for a specified volume of standarized and quality-controlled inputs from a few reliable sources.

Third, purchasing and processing hogs is a breakdown process rather than a conventional manufacturing process. From the green-cut stage to the finished pork product, the processing operation is much like other manufacturing processes. However, meatpackers are manufacturing a large number of pork products rather than just one product. Also, the finished products do not make use of raw materials (green pork cuts) in the same proportion as they are purchased in the live hog. Therefore, problems develop in balancing the number of hogs to slaughter and the raw material needs for consumer cuts of pork. Before buying market hogs, the packer must translate demand for finished pork cuts into demand for raw materials (green cuts) and then into his demand for market hogs.

Specifically, this study is concerned with evaluating slaughtering-processing costs associated with varying degrees of supply (input of market hogs) control. The objectives are: (1) to develop data needed for computing the costs of slaughtering, cutting, processing, and rendering; (2) to develop a random-process simulation model for determining costs of slaughtering, cutting, processing, and rendering for any given time series on market hog supply and wholesale pork-cut demand and, (3) to determine the influence of market hog supply control on the above costs and economies of scale.

Seasonal variability of market hog supply contributes to plant inefficiency. Most packing plants are built to handle volumes during the peak of the slaughtering season and operate at less than capacity during the low points of the season. In larger plants, flexibility of operations is achieved by using several combinations of men and line speed. This flexibility is almost imperative to eliminate inefficiencies from the uneven supply of hogs coming to market during the year. However, smaller plants have more difficulty in attaining flexibility because of the variability of supply coupled with fewer alternative jobs for employees. Therefore, when the supply of hogs for slaughter is reduced, and the rate of kill reduced, often the labor hours are not reduced proportionately. This inefficiency was not modeled into the study, although variable labor productivity is considered.

Minimizing or controlling variations in hog and pork supplies should improve the overall efficiency of the vertical continuum from production to consumption. More effective utilization of hog production, marketing, and slaughtering-processing facilities should be realized, thus yielding lower costs, assuming that costs of implementing control do not exceed plant savings. Also, greater stabilization of supply should lead to more effective industry response to consumer demand.

THE SIMULATION MODEL 3/

The cost model in this study simulates costs accrued on a daily basis, given the actual number and market weight distribution of hogs supplied to a plant on a given day. The main concept underlying the model is that for a given plant size and number and size distribution of market hogs, the model will determine for each of the four operations (slaughtering, cutting, processing, and rendering) the actual rate of work and the hours to be worked for that day. However, they do change from one operation to another. Given the above input data, labor costs and utility costs are immediately computed for the packing plant operations. To reflect the variation in costs associated with plant size, hog slaughter plants with a designed slaughter rate of 50, 150, 300, 600, and 800 head per hour were selected for the study. Daily variable costs associated with labor and utilities are accumulated weekly and yearly. The accumulative yearly variable costs are then added to the fixed costs associated with each of the plant sizes to determine total costs (equation 1).

$$(1) \quad TUC = TUVC + TUFC$$

Where:

TUC = Total unit cost (dollars/head)

3/ The physical flow structure and engineering data for the study are based upon discussions with Donald Slotkin, president of Crown Packing Company, Detroit, Michigan. The information obtained was used to establish the input-output relationships underlying the cost estimates.

TUVC = Total unit variable cost--utility cost and labor cost (dollars/head)

TUFC = Total unit fixed costs associated with slaughtering, cutting, processing, and rendering (dollars/head).

For each plant size, a choice between two crew sizes was permitted for each of the four packing plant operations. It was assumed that the rendering operation was not performed by the smallest plant (50 head/hour) and that the plant could dispose of the byproducts at no cost. One crew size reflected the number of men required to operate at nominal plant capacity (C_n); the other crew size, the number of men required to operate at 80 percent of nominal capacity ($C_{0.8}$). The size of crew was determined by the following decision rule:

Let: TH = Total hours worked in previous 2 weeks.

C_i = Crew size in week i.

If: $TH > 72,\ C_i = C_{.8}$

$72 \geq TH \geq 88,\ C_i - C_i - 1$

$TH > 88,\ C_i = C_n$

An initial crew size of C_n and 40 hours worked in each of the preceding weeks was assumed for every yearly simulation.

Effective plant slaughter capacity (actual rate of slaughter) in each week was assumed to be less than the nominal slaughter capacity inferred from the crew size selection (C_n or $C_{0.8}$). A random variable, Z, was defined as effective hourly capacity divided by nominal hourly capacity. 4/ It was assumed that a series of unpredictable factors such as weather conditions, machine failure,

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4/ The random variable Z is assumed to be defined by the following probability density function:

$$f(Z) = \begin{bmatrix} 0.0 & \_\_\_\_ & \infty < y \leq 0.9 \\ \frac{20.0}{0.7} & (y - .0.9) & .9 < y \leq 0.97 \\ \frac{20.0}{0.3} & (1.0 - y) & .97 < y \leq 1.0 \\ 0.0 & \_\_\_\_ & 1.0 < y\ \infty \end{bmatrix}$$

health problems, and quality of hogs changed the actual slaughter rate from the designed slaughter capacity rate. Independent observations of Z were employed to compute the effective hourly rate for each of the four packing operations for each week of the simulation. The inverse transform method was used to generate observations of Z from observations of a uniform zero-one random variable.5/ It was assumed that the full effect of this variation would not exceed plus or minus 10 percent of the rated capacity.

For the slaughtering, cutting, and rendering operations, the actual plant rate for a particular week was expressed in number of hogs per hour and computed by multiplying the nominal capacity by an observation of the random variable Z. Crew hours worked in any particular day were then computed by dividing input (number of hogs) by the throughput rate.

Processing throughput rate and load were based on pounds of pork rather than on number of hogs. To convert the actual plant rate for processing to pounds per hour, the number per hour obtained by the procedure described above was multiplied by 50 since it was assumed that the plants were designed to process 50 pounds of pork per head slaughtered. Using the gross cutout coefficients of table 1, the gross weight of each of the six primal cuts was computed. The processed final weight of each of the six cuts was then computed by multiplying the gross weights by the following coefficients: hams, 0.946 loins, 0.988; bellies, 0.768; ribs, 1.0; butts, 0.996; and picnics, 0.837. The total processing load for the day was then assumed to be the sum of pounds of trimmed bellies and hams plus .2 X 1.3 times the pounds of trimmed picnics, butts, loins, and ribs. 6/ The remainder of picnics, butts, loins, and ribs was assumed to be sold fresh with no processing costs incurred. Processing crew hours worked in a day were then computed by dividing the processing load (pounds) by the processing throughput rate (pounds/hour).

For plants operating at full capacity, daily labor costs were computed by multiplying the crew hours worked by the average hourly wage and adding $.30 per man hour for insurance and $.73 per man day to cover such incidentals as relief time and clothes-changing time. The crew sizes and associated labor costs for the sizes of plants considered in the study are given in table 2. For plants operating at 80 percent of full capacity, the crew size and average hourly wage were multiplied by 0.84 and 0.88, respectively, before the daily labor computation began. These factors are associated with a designed rate reduction of 80 percent productivity. Conversely, reducing the number of men by 16 percent causes a drop of productivity of 20 percent (mainly because labor is not perfectly divisible) and a wage reduction of only 12 percent (because usually the men dismissed are at the lower range of the salary scale). Each day, a check for any overtime requirements was made and charged accordingly. At the end of a week, a check was made to determine if 36 hours of work had been provided, and if not, wages at the normal rate were paid and added to the total labor costs. Eight days of paid holidays each year were assumed.

5/ Hiller, F.S., and G.J. Lieberman, Introduction to Operations Research Holden-Day, 1967.

6/ The fraction of picnics, loins, butts, and ribs processed is an exogenous variable that may be changed depending upon plant policy. The factor used here accounts for trimmings and was obtained from Donald Slotkin, Ibid.

Table 1--Primal cutout coefficients for six market categories of hogs 1/

Market hog weight category	Hams	Loins	Bellies	Ribs	Butts	Picnics
	Percentage of live weight					
180-200.....	14.01	12.03	11.09	2.36	4.72	6.44
200-220.....	13.87	11.91	11.68	2.25	4.72	6.39
220-240.....	13.62	11.63	12.14	2.21	4.71	6.33
240-270.....	13.66	11.21	12.53	2.16	4.70	6.34
270-plus....	13.54	11.00	12.64	2.17	5.01	6.36
Sows and boars......	13.60	9.56	14.02	2.10	4.91	6.35

1/ Yield in terms of pounds of cut was calculated at the midpoint of the market categories with the exception of the 270-plus and Sows-boars categories, where 300 to 400 pounds live weight were assumed midpoints.

Source: Unpublished data obtained from Livestock Division, Agricultural Marketing Service, U.S. Dept. Agr., Washington, D.C.

Table 2--Labor costs and crew sizes for slaughtering, cutting, processing, and rendering, by size of plant operating at full capacity

Plant operations	Crew sizes for slaughter capacity (hogs/hour) of--				
	50	125	300	600	800
	Number of workers				
Slaughtering	27	46	79	151	210
Cutting	15	32	50	99	143
Processing	42	67	170	320	425
Rendering	NA	3	7	12	16
	Labor costs for slaughter capacity (hogs/hour) of--				
	50	125	300	600	800
	Dollars per hour				
Slaughtering	94.50	157.75	292.15	581.25	852.85
Cutting	53.20	116.80	189.90	401.00	609.60
Processing	147.00	244.55	654.50	1,280.00	1,789.25
Rendering	NA	10.95	26.95	48.00	67.36

NA = not applicable.

Total daily utility costs for plants operating at full capacity were obtained by multiplying the crew hours worked by the hourly utility costs and adding the fixed utility costs (table 3). If the plant was operating at 80 percent of full capacity, the hourly utility costs were multiplied by .9 before this computation was made. It was assumed that a plant operating at less than full capacity would reduce its use of personnel facilities that require utility expenditures.

Annual fixed costs for plants of various slaughter capacity are given in table 4. These costs are added to annual labor and utility costs to determine total unit costs.

Table 3--Daily variable costs and fixed costs of utilities for slaughtering, cutting, processing, and rendering operations, by size of plant operating at full capacity

Operation and utility	Costs for slaughter capacity (hogs/hour) of-- 50	125	300	600	800
			Dollars per hour		
Slaughtering:					
Gas	2.33	5.09	11.31	21.10	27.33
Electricity	0.83	1.98	4.60	9.00	12.75
Water	1.68	4.20	10.08	17.76	23.68
Cutting:					
Electricity	0.54	1.27	2.96	5.78	8.20
Water	0.21	0.52	1.26	2.22	2.96
Processing:					
Gas	1.81	3.06	5.02	9.38	12.52
Electricity	2.08	4.94	11.50	22.50	31.87
Water	0.63	1.56	3.78	6.66	8.88
Rendering:					
Gas	NA	1.27	3.77	7.04	9.12
Electricity	NA	1.70	3.94	7.72	10.93
Water	NA	1.56	3.78	6.66	8.88
			Dollars per day		
Fixed utility costs	44.00	93.00	234.00	439.00	631.00

NA = not applicable.

Table 4--Annual fixed costs by size of slaughter plant

Hogs per hour capacity	Annual costs
	Dollars
50	384,035
125	892,102
300	1,575,930
600	2,577,290
800	3,270,930

TREATMENT OF DATA

In line with the objective of the overall project--determining effects of vertical coordination--it was natural to study the reduction in costs associated with more uniform delivery over time. It was assumed that a more uniform flow of market hog supply could be achieved under a more coordinated or integrated system of procurement.

Observable variations in supply (daily numbers of market hogs) are made up of two effects, one superimposed on the other. The one component, daily variation, was assumed to describe shortrun variation associated with an unpredictable random set of factors such as prices and weather at marketing time. The second component, seasonal variation, was assumed to be a result of the technical and economic structure of the U.S. hog-pork subsector. The latter is affected by several factors such as past hog prices and future price expectations, price of corn, consumption patterns, and level of pork storage. It was assumed that the total variation from the annual average was the sum of the seasonal and daily variations.

The two defined sources of supply variation were estimated by smoothing daily market hog slaughter data from a sample of eight federally inspected Iowa and Illinois meatpacking plants for 1970. 8/ Daily supply fluctuations were eliminated by computing a moving 20-day average (4 weeks) for each of the plants. It was then assumed that the resulting smoothed time functions represented seasonal variations for these particular plants during the year. Observations of daily variations were obtained by computing the difference between the original slaughter time series and the smoothed series. The standard deviation and coefficient of variation of the original eight plants' daily sequence from the smoothed sequence was then computed. The deviation of the smoothed daily kill from the annual mean of the original time series provided observations of seasonal variation. Coefficients of variation (standard deviation divided by mean daily slaughter) of the original, smoothed, and daily time series plus the mean daily kill for the eight sample plants are given in table 5.

An effort was made to determine if a relationship existed between plant size (mean daily kill) and supply variation. While a regression analysis suggested that no relationship existed, the number of observations was small and no definite conclusion should be drawn. However, it was assumed for this analysis that the coefficients of variation were independent of plant size.

To characterize the seasonal variation over a length of time which might contain conditions representative of an entire hog cycle, data for 4 years

8/ The data consisted of daily slaughter volume, slaughter rate, and hours worked. It was obtained from Animal and Plant Health Inspection Service, U.S. Dept. Agr., Washington, D.C.

Table 5--Daily hog slaughter and original, smoothed, and daily coefficients of variation for sample of Iowa and Illinois slaughter plants under Federal inspection, 1970

Plant	Total daily kill (hog numbers) 1/	Original coefficient of variation	Smoothed coefficient of variation	Daily coefficient of variation
1	2,952	0.20	0.110	0.16
2	3,071	0.10	0.034	0.09
3	1,072	0.13	0.061	0.11
4	896	0.24	0.099	0.21
5	1,615	0.16	0.133	0.09
6	2,778	0.15	0.106	0.10
7	4,643	0.14	0.050	0.13
8	150	0.19	0.151	0.09

1/ Data from Animal and Plant Health Inspection Service, U.S. Dept. Agr., Washington, D.C.

(1967-70) of U.S. federally inspected weekly slaughter were used. 9/ The published weekly time series was smoothed via the computation of a 20-day moving average (4 weeks). Each 4-week average value was assumed to be indicative of the seasonal supply in the middle of that 4-week period. Linear interpolation was then used to generate daily observation of seasonal supply for each working day of the 4-year period.

Coefficients of variation of these generated daily supply functions were as follows: 1967--0.10; 1968--0.08; 1969--0.07; 1970--0.11. Note that the smoothed U.S. coefficients of variation for 1968 and 1969 (0.08 and 0.07) were substantially smaller than the coefficients of variation of the smoothed Iowa-Illinois plant sample data. It was assumed that this difference was characteristic of the effect of aggregation of individual plant data into national totals. To observe the influence of the largest seasonal variation which might be expected, the difference from the annual mean of each observation of the U.S. daily smoothed series was increased by the factor (.108/.07) to eliminate the aggregation effect from the 4-year sample data. The resulting smoothed, interpolated, and adjusted 4-year daily time series was assumed to characterize seasonal market hog supply to a packing plant.

9/ Livestock and Meat Statistics, Supplement for 1969 and 1970 to Statis. Bul. 333, Econ. Res. Serv., Consumer Mktg. Serv., and Statis. Rptg. Serv., U.S. Dept. Agr., Washington, D.C., July, 1971.

To use the data sequence of U.S. weekly hog slaughter as daily supply input into a plant, it had to be scaled to a packing plant's capacity and the daily variation added to it. By scaling data to plant size, both time series were made congruent.

Daily hog supply series for individual plants were generated annually. Equation 2 was used to simulate daily supply to a packing plant for each of the 4 years.

$$(2) \quad S_i = \frac{E(Z).H.CAP.\ [(US_i - \overline{US})\ SEAVAR + \overline{US}]}{\overline{US} + SEAVAR\ (US_{max} - \overline{US})} + \frac{E(Z).H.CAP.US.CF.DAYVAR.Y}{\overline{US} + SEAVAR(US_{max} - \overline{US})}$$

S_i = Daily market hog supply on ith day to a packing plant (number of hogs).

E(Z) = Expected value of the random variable Z = .957 10/ (Z is the ratio of effective hourly capacity divided by nominal hourly capacity.)

H = Nominal hours worked/day (8.0).

CAP = Nominal rated slaughter capacity. CAP takes on one of the five values: 50, 125, 300, 600, or 800 (head/hour).

US_i = Number of hogs slaughtered on ith day of U.S. slaughter data.

$\overline{US}$ = Average value of US_i over the year being simulated.

US_{max} = Maximum value of US_i over the year being simulated.

CF = Maximum coefficient of variation of daily fluctuations to be considered. 11/

SEAVAR = Level of seasonal variation considered (values of 1.0, 0.707, 0.5, and 0.0 were used).

DAYVAR = Level of daily variation considered (values of 1.0, 0.707, 0.5, and 0.0 were used).

Y = An observation of a normal random variable of mean zero and variance one.

10/ See footnote 5 for definition of the probability density function of the random variable Z.

11/ CF = 0.24 was used rather than the maximum of 0.21 found in the individual plant sample data to observe the effect of larger variations to reflect various degrees of market hog supply control (table 5).

Thus, the U.S. hog slaughter data, US_i, were adjusted so that the maximum value of the series was scaled to the average throughput capacity of a packing plant operating with a full crew. The net effect of SEAVAR and DAYVAR was to adjust the coefficients of variation of seasonal and daily fluctuations to reflect various degrees of market hog supply control. The seasonal and daily components of equation 2 are given in equations 3 and 4, respectively.

(3) $$\text{Seasonal variation} = \frac{E(Z).H.CAP.[US_i - \overline{US})\ SEAVAR + \overline{US}]}{\overline{US} + SEAVAR\ (US_{max} - \overline{US})}$$

(4) $$\text{Daily variation} = \frac{E(Z).H.CAP.US.CF.DAYVAR.Y}{\overline{US} + SEAVAR\ (US_{max} - \overline{US})}$$

A value of SEAVAR equal to one implies no control of seasonal fluctuations, while SEAVAR =0.707 implies that the standard deviation of seasonal fluctuations is multiplied by 0.707--that is, the variance is reduced by one-half via supply control.

Consider the special case:

SEAVAR = 1.0
DAYVAR = 0.0

Here, daily fluctuations via market hog supply control (perhaps contracting) have been completely eliminated, but the seasonal variation remains. The supply generation equation 2 then reduces to:

(5) $$S_i = \frac{E(Z).H.CAP.US_i}{US_{max}}$$

All that was done in this case was to scale the aggregate U.S. slaughter series, US_i, down to the average capacity of the plant.

Assuming no seasonal or daily supply control (SEAVAR = 1.0, DAYVAR - 1.0), the simulated supply function becomes:

(6) $$S_i = \frac{E(Z).H.CAP.US_i}{US_{max}}$$

(Same as last special case)

$$+ \frac{E(Z).H.CAP.\overline{US}.CF.Y}{US_{max}}$$

(The daily variation)

The second term of equation 6 is a normal random variable of zero mean and standard deviation scaled down to plant capacity.

A special case of completely effective supply control (DAYVAR = 0.0, SEAVAR = 0.0)--a constant daily hog supply equal to the average plant throughput capacity--is given by equation 7:

(7) $S_i = E(Z).H.CAP$

The extremes of supply control in equations 5 and 7--no control and complete control--are somewhat arbitrary, for the study's objective was to indicate the plant cost savings which might result from controlling the market hog supply to some degree.

The supply of market hogs on any given day is composed of the number of hogs in various market categories. For this study, the daily supply of market hogs was divided into six market-weight groups:

(1) 180-200 pound barrows and gilts.
(2) 200-220 pound barrows and gilts.
(3) 220-240 pound barrows and gilts.
(4) 240-270 pound barrows and gilts.
(5) 270-plus pound barrows and gilts.
(6) Sows and boars, all weights.

The basis for dividing the slaughter data was the percentage distribution of hogs in the above six market groups sold at seven Midwest livestock markets. 12/ The percentage distribution sample covered an 18-month period, July 1968--December 1970. Because similar information for the entire 4-year hog cycle (1967-70) could not be provided, this sample was assumed to represent the 1967-70 period. The percentage distribution data used for dividing the slaughter sample data are given in table 6.

Absolute cost values were not of primary concern in this study. Only the marginal difference in costs between various degrees of market hog supply control to the plant and plant size were considered. Two types of costs were identified as the major determinants of these margins--utility costs and labor costs. Obviously, the utility costs can be spread over a greater number of hogs if the plant is operated at full capacity throughout the year. Excluding the cost of livestock, labor was approximately 45 percent of the meatpacker's total operating costs in 1970. 13/ Labor may vary in more than one dimension

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12/ Information on the percentage distribution was obtained from the Market News Branch, Livestock Division, Agr. Mktg. Serv., U.S. Dept. Agr. The seven markets include Indianapolis, Kansas City, Omaha, National Stockyards, Sioux City, South St. Joseph, and South St. Paul.

13/ Financial Facts About the Meat Packing Industry, 1970, American Meat Institute, Dept. of Mktg., Chicago, Ill., Aug. 1971, p. 3.

Table 6--Percentage distribution of six market groups of hogs sold at seven Midwest markets, by month 1/

Month	Barrows and gilts: 180-200 pounds	Barrows and gilts: 200-220 pounds	Barrows and gilts: 220-240 pounds	Barrows and gilts: 240-270 pounds	Barrows and gilts: 270-plus pounds	Sows and boars
	Percent					
January	2.39	19.27	31.41	29.17	12.19	5.57
February	3.76	24.04	32.66	27.02	7.58	4.94
March	2.32	21.86	36.34	27.49	7.67	4.42
April	1.42	16.95	31.41	33.32	12.06	4.84
May	1.02	15.21	33.57	31.41	12.96	5.83
June	2.59	20.51	28.56	24.97	15.95	7.42
July	3.76	27.06	34.74	21.08	5.53	7.83
August	3.77	26.39	48.92	11.10	2.33	7.49
September	3.12	32.70	42.80	13.15	1.42	6.81
October	3.67	16.07	38.24	32.13	3.35	6.54
November	3.30	15.20	34.04	31.11	10.07	6.28
December	4.81	21.62	24.60	30.84	11.76	6.37

1/ Seven markets include Indianapolis, Kansas City, Omaha, National Stockyards, Sioux City, South St. Joseph, and South St. Paul.

Source: Unpublished data obtained from Market News Branch, Livestock Division, Agr. Mktg. Serv., U.S. Dept. Agr., Washington, D.C.

because of: (1) increases or decreases in the labor force, (2) increases or decreases in hours worked per man, or (3) some combination of (1) and (2).

Labor cost variability with hog supply control is a result of labor-management agreements reached through collective bargaining during labor contract negotiations. Following the industry pattern, the following features were assumed to be characteristic of these agreements:

(1) Thirty-six hours of work (and thus pay) is guaranteed to any worker in a week in which the worker works on the first day of that week.

(2) Overtime wage rate (1-1/2 times normal hourly rate) is payed for any work exceeding 8 hours on a given day or 40 hours each week.

(3) The labor force (number of men) for a week is determined on the first work day of the week and is not changed during the week.

SIMULATION RESULTS

Simulations were made for the 16 possible SEAVAR-DAYVAR combinations for each of the 4 years of supply data and for the five plant slaughter capacities. Furthermore, each of these 320 annual simulations was repeated three times to obtain an estimate of the average effect of the random throughput. A summary of the results by plant size and degree of supply control averaged over all 4 years (1967-70) is given in table 7. Figure 1 shows the results for a 600-head-per-hour plant. The other four sizes of plants had similar shaped curves for the given degree of supply control. The results had some irregularities which could be removed by increasing the number of repetitions of the simulation. However, the additional accuracy did not seem to justify the additional computing costs, so no attempt was made to smooth the results.

The special cases described in equations 5-7 constitute three extreme points of the sensitivity analysis of the cost-supply relationships. Other total cost points indicate the cost savings achievable with partial market hog supply control (table 7). The relationship between partial supply control and total costs by size of plant is shown in figure 2. For example, given SEAVAR = 0.707 and DAYVAR = 0.707 for a 600-head-per-hour slaughter plant, the total costs of slaughtering, cutting, processing, and rendering were $10.10 per hog, compared with $10.47 per hog with no effective supply control. Technically, the standard deviation of seasonal variation and daily variation were multiplied by 0.707. Thus, the variance of the two supply components were multiplied by 0.5. Similarly, given that SEAVAR = 0.5 and DAYVAR = 0.5, then the standard deviations of seasonal and daily variations were multiplied by 0.5, or the variances were multiplied by 0.25. Therefore, cost savings of $.62 per hog ($10.47 - 9.85 = 0.62) are achieavable for a 600-head-per-hour slaughter plant (table 7 and fig. 2).

Table 7--Simulated costs per hog for given degrees of daily and seasonal variation of market hog supply control, by size of slaughter plant operating at full capacity

Plant capacity and daily variation	Seasonal variation: 0.0	0.5	0.707	1.0
	Dollars per hog			
50 head per hour:				
0.0	15.06	15.64	15.96	16.46
0.5	15.13	15.76	16.08	16.56
0.707	15.21	15.87	16.16	16.70
1.0	15.32	16.02	16.38	16.86
125 head per hour:				
0.0	11.69	12.21	12.48	12.88
0.5	11.73	12.33	12.58	12.97
0.707	11.77	12.34	12.64	13.05
1.0	11.86	12.48	12.73	13.15
300 head per hour:				
0.0	10.08	10.46	10.67	11.00
0.5	10.11	10.53	10.75	11.09
0.707	10.15	10.58	10.81	11.15
1.0	10.22	10.71	10.94	11.25
600 head per hour:				
0.0	9.45	9.77	9.96	10.26
0.5	9.50	9.85	10.04	10.34
0.707	9.53	9.90	10.10	10.39
1.0	9.63	9.99	10.23	10.47
800 head per hour:				
0.0	9.64	9.97	10.21	10.56
0.5	9.67	10.05	10.29	10.63
0.707	9.74	10.15	10.36	10.70
1.0	9.80	10.24	10.46	10.83

SIMULATED COSTS PER HOG FOR 600-HEAD-PER-HOUR SLAUGHTER PLANT, WITH DAILY AND SEASONAL SUPPLY CONTROLS

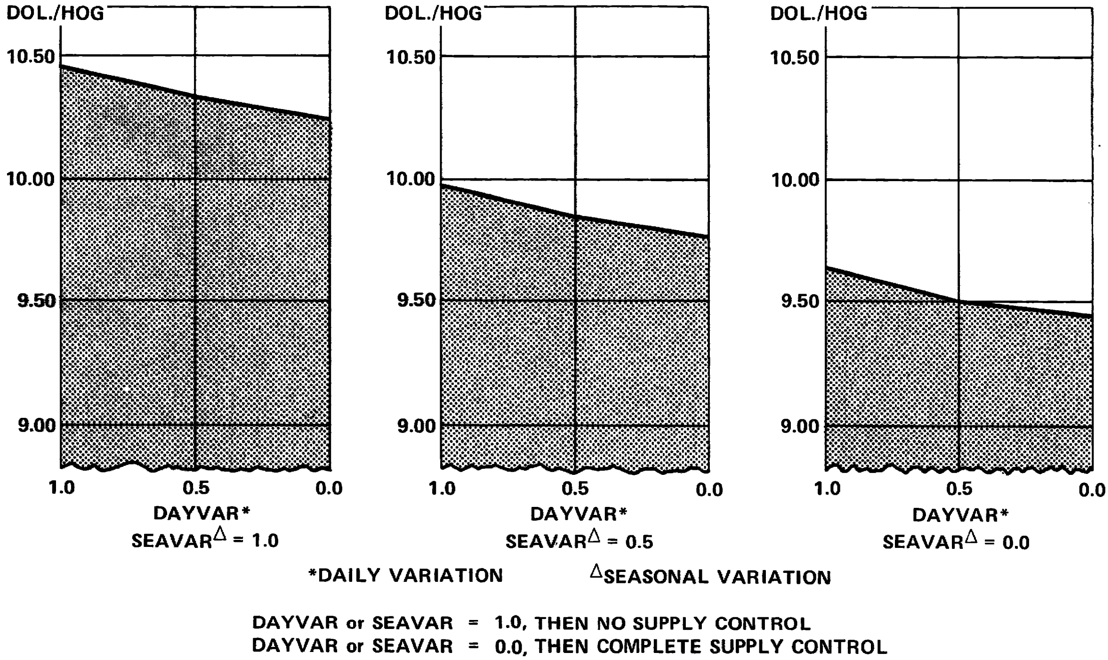

Figure 1

SIMULATED COSTS PER HOG FOR SLAUGHTER PLANTS, WITH DAILY AND SEASONAL SUPPLY CONTROLS†

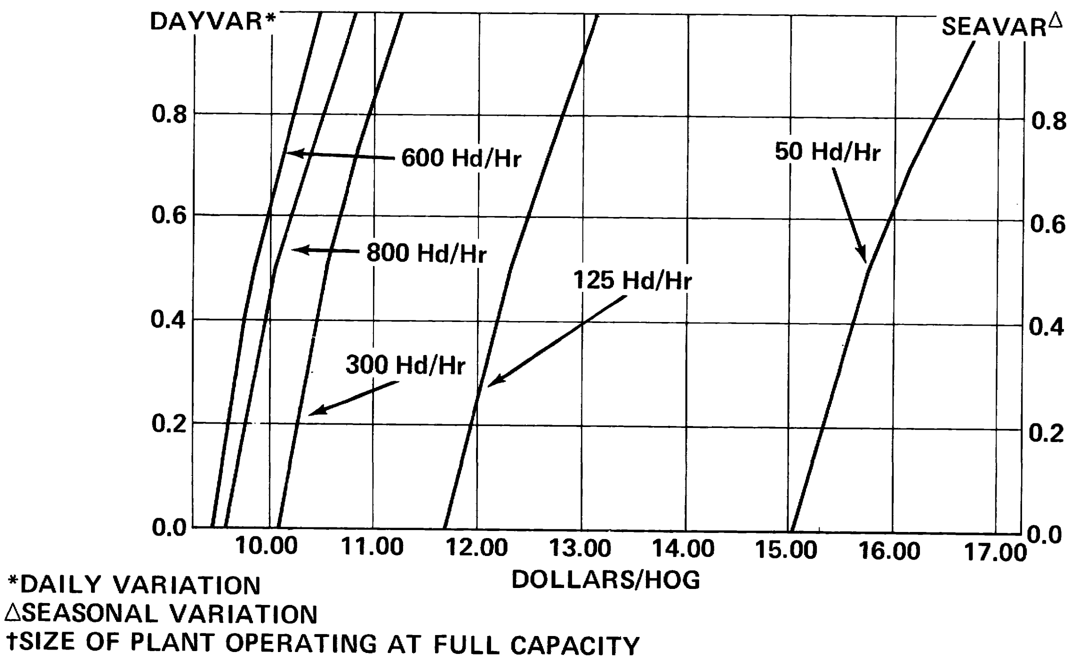

Figure 2

Slaughter plant cost savings of 10.6 percent are achievable via complete market hog supply control. The analysis showed that total costs per hog could be reduced by as much as $1.33 for the five sizes of packing plants considered (table 7). The cost savings via complete supply control ranged from $1.02 per hog for a 600-head-per-hour plant to $1.80 per hog for a 50-head-per-hour plant. Even though a rather high daily variation was considered, the seasonal variation was the major determinant of costs attributed to supply-time variations.

Tables 8 and 9 indicate that total costs could be reduced by an average of 9.1 percent with complete control of seasonal variation, while complete control of daily variation would reduce costs on the average only 2.2 percent. These figures are particularly significant in that seasonal market hog supply controls would probably be more difficult to achieve than daily controls. The production, storage, and consumption patterns over the year would have to be dramatically modified to eliminate seasonal variations.

Although economies of scale in hog slaughtering-processing plants were not of primary concern, they were calculated. The lowest total costs for the four packing operations studied was associated with the second largest plant size considered--600 head per hour (figs. 2, 3, and 4). This particular size plant consistently displayed the greatest economies of scale in all combinations of SEAVAR-DAYVAR analyzed. The diseconomies of scale resulted from assumed increased labor cost for the 800-head-per-hour plant. The 600-head-per-hour slaughter plant displayed the smallest cost reduction of the five plant sizes studied. With complete control of daily variation, this size plant would have a cost savings of only 2.0 percent ($.21 per hog), compared with an average of 2.2 percent ($.28 per hog) for all plant sizes (table 10). Similarly, with complete control of seasonal variation, a cost reduction of 8.0 percent ($.84 per hog) would be realized for the 600-head-per-hour plant, while the average for all five plant sizes would be 9.1 percent ($1.14 per hog) (table 9). With complete control of both variables, the 600-head-per-hour plant would have a cost savings of 9.7 percent ($1.02 per hog), compared with an average of 10.6 percent ($1.33 per hog) for all plant sizes.

Although the 50-head-per-hour slaughter plant displayed the largest absolute cost reduction, it did not always have the greatest percentage cost reductions (tables 8, 9, and 10). With complete supply control, plants slaughtering 125 or 800 head per hour would have greater percentage cost savings than the 50-head-per-hour plant.

IMPLICATIONS

This study has been concerned with how market hog supply control would affect costs of slaughtering, cutting, processing, and rendering for five sizes of hog slaughtering plants. The results indicate the influence of daily and seasonal supply variation on per unit costs and the cost savings achievable via supply control. In addition, the economies of scale were examined for daily and seasonal variations in market hog supply.

Table 8--Reduction in costs per hog associated with complete control of daily and seasonal market hog supply, by size of slaughter plant operating at full capacity

Item	Costs for slaughter capacity (head/hour) of--					
	50	125	300	600	800	Average
	Dollars per hog					
No control of daily or seasonal variation	16.86	13.15	11.25	10.47	10.83	12.51
Complete control of daily and seasonal variation	15.06	11.69	10.08	9.45	9.64	11.18
Reduction in total cost	1.80	1.46	1.17	1.02	1.19	1.33
	Percent					
Percentage cost reduction	10.7	11.1	10.4	9.7	11.0	10.6

Table 9--Reduction in costs per hog associated with complete control of only seasonal market hog supply, by size of slaughter plant operating at full capacity 1/

Item	Costs for slaughter capacity (head/hour) of--					
	50	125	300	600	800	Average
	Dollars per hog					
No control of seasonal variation	16.86	13.15	11.25	10.47	10.83	12.51
Complete control of seasonal variation	15.32	11.86	10.22	9.63	9.80	11.37
Reduction in total costs	1.54	1.29	1.03	.84	1.03	1.14
	Percent					
Percentage cost reduction	9.1	9.8	9.2	8.0	9.5	9.1

1/ Daily variation was held constant at 1.0--that is, no control of daily fluctuations in market hog supply.

SIMULATED COSTS PER HOG FOR SLAUGHTER PLANTS, WITH NO CONTROL AND COMPLETE CONTROL OF DAILY AND SEASONAL SUPPLY

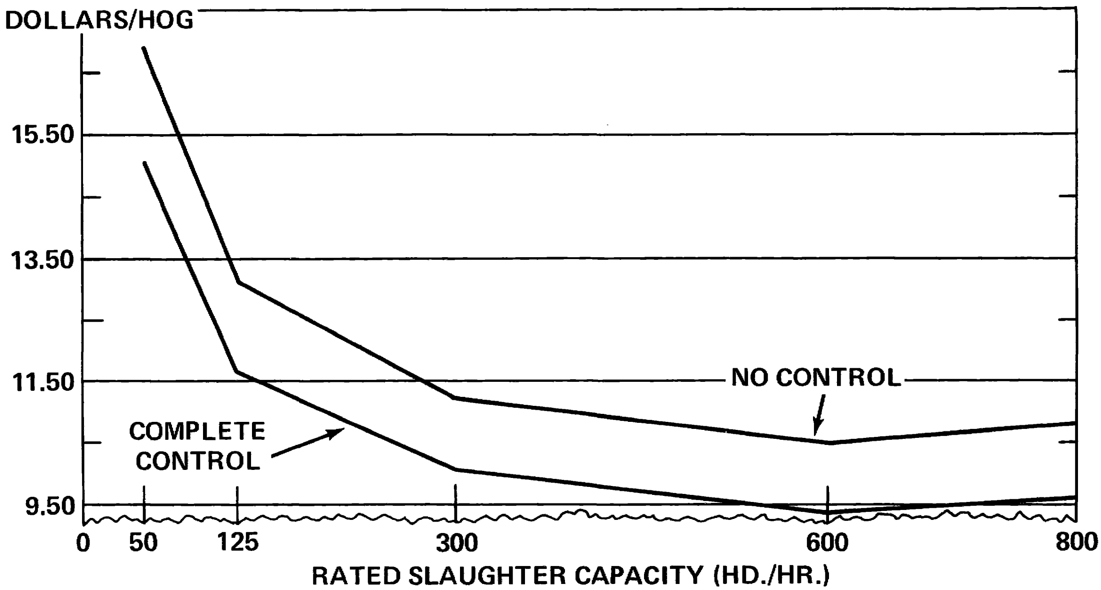

Figure 3

SIMULATED COSTS PER HOG FOR SLAUGHTER PLANTS, WITH COMPLETE CONTROL OF DAILY SUPPLY

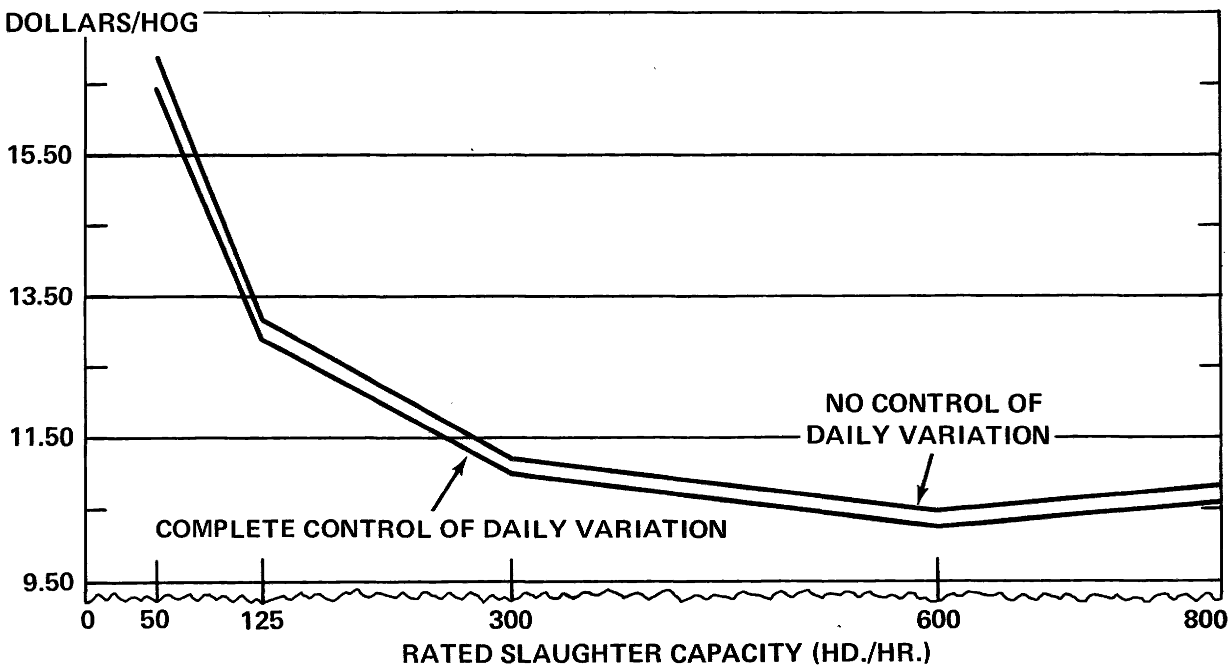

Figure 4

Table 10--Reduction in costs per hog associated with complete control of only daily market hog supply, by size of slaughter plant operating at full capacity 1/

Item	Costs for slaughter capacity (head/hour) of--					
	50	125	300	600	800	Average
	Dollars per hog					
No control of daily variation	16.86	13.15	11.25	10.47	10.83	12.51
Complete control of daily variation	16.46	12.88	11.00	10.26	10.56	12.23
Reduction in total costs	.40	.27	.25	.21	.27	.28
	Percent					
Percentage cost reduction	2.4	2.1	2.2	2.0	2.5	2.2

1/ Seasonal variation was held constant at 1.0--that is, no control of seasonal fluctuations in market hog supply.

This study should be useful in planning alternative forms of coordination, for the results show that control of market hog supply significantly influences plant costs. Also, the study results should be useful in the overall hog-pork project's task of evaluating vertical coordination. However, since the costs and implications of particular degrees of market hog supply control were not considered in the study, these must be determined before the study's results can be applied directly.

Another possible application of the model and its results would be in comparing the economic advantages of geographic locations. If the market hog supply-time input curve were substantially smoother (less variation) in one region than another, the slaughter plant cost advantage demonstrated here would be significant and could be estimated by the model. The results should also be useful to research workers in evaluating the future structure of the hog-pork subsector with respect to alternative forms of coordination combined with costs of implementing the coordination schemes.

In all these potential applications, however, the limitations of the model and scope of the study should be kept in mind. A very important limitation was the implicit assumption that some form of vertical coordination would affect the seasonal hog supply pattern. Market hog supply control of the magnitude illustrated in this study would require modification of production, marketing, and consumption patterns. Furthermore, the variation between plants with respect to technology and operational characteristics was not analyzed. However, the variations were recognized, and those which were significant were formulated in the model.