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A SYSTEMS ANALYSIS OF THE HOG-PORK SUBSECTOR
SULLIVAN, J.D. LIU, C.Y. VINCENT, W. 1 OF 1

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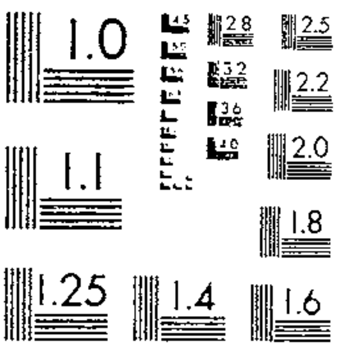


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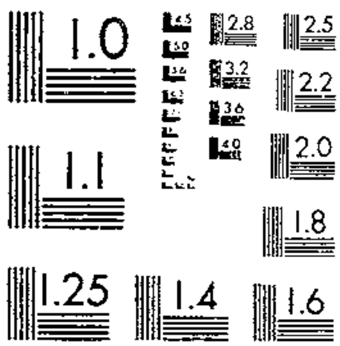


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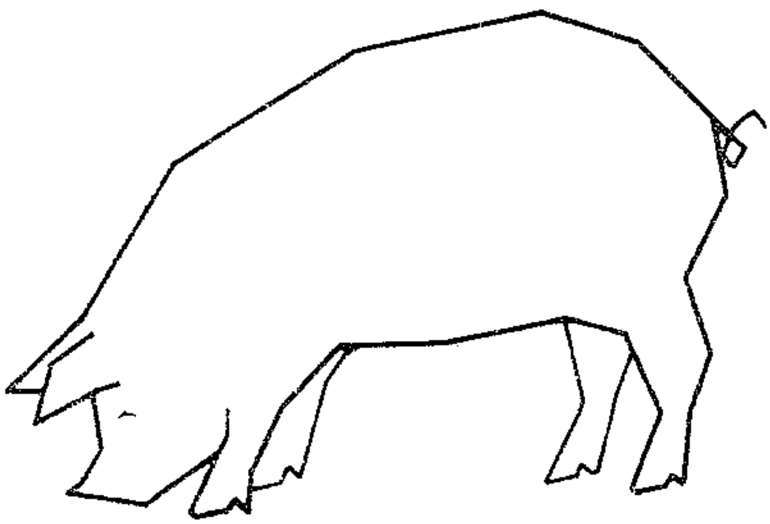
# A Systems Analysis of the Hog-Pork Subsector



A SYSTEMS ANALYSIS OF THE HOG-PORK SUBSECTOR. By James D. Sullivan, Charles Y. Liu, and Warren Vincent. Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1536.

## ABSTRACT

A model for simulating the economic behavior of the hog-pork subsector is described. A recursive model was constructed and causal economic relationships were estimated from monthly data for January 1965–December 1974. The model satisfactorily traces the time paths for endogenous variables and can assist in evaluating policy alternatives that affect the performance or change the structure of the hog-pork subsector.

Key Words: Systems analysis, market hogs, wholesale and retail pork cuts, production, marketing, distribution, pricing model, simulation.

Washington, D.C. 20250 February 1976

## FOREWORD

This study was begun in cooperation with Purdue University and Michigan State University in 1970. The idea was to analyze the potential for major change in the form of vertical coordination. A principal task was to assess the strength of the forces which might bring about a shift to contracting or ownership integration in pork production, processing, and distribution.

The Economic Research Service (ERS) and the Michigan Agricultural Experiment Station constructed a simulation model of the hog-pork subsector. By using this model, the potential impacts of a number of possible changes in the form of vertical integration were analyzed. This report of the modeling effort is one of two ERS publications resulting from the research effort. The other report, *Effects of Changes in Vertical Coordination on Pork Production and Prices*, Agricultural Economic Report No. 303, August 1975, uses the model to evaluate the impact of potential change. Other results of the hog-pork subsector research effort have been reported by the Purdue University Agricultural Experiment Station and the Michigan Agricultural Experiment Station.

## CONTENTS

## SUMMARY

A model was structured to simulate the hog-pork subsector. The model was validated for the period January 1965 through December 1971.

The systems analysis framework represents a relatively new approach in economic research. It provides the means for incorporating an entire economic system into a single analysis. With this model, any qualified researcher can perform an examination and gain an understanding of the hog production and pork marketing complex in a systematic way.

The model is recursive and operates on a monthly basis on self-generated data with the exception of the initial lagged endogenous variables and a few exogenous variables. Since this is a behavorial simulation model, no attempt is made to obtain simulated values which minimize the overall model error. Most of the error in the validated model for the 7-year period is in the 4- to 6-percent range.

The results presented are conditioned by the structure and the conceptual framework of the systems approach employed. The model should be useful in evaluating the impact of policies of the Federal Government or of industry on performance of the production and marketing stages of the hog-pork industry. As a device for simulating the aggregate behavior of the subsector, it may prove useful to individual firms interested in making their own forecasts based upon industry forecasts. The model may also be used to trace the effects of structural changes over time by altering the values of any of the variables.

## ACKNOWLEDGMENTS

The authors acknowledge the contributions of Richard Crom, Lawrence Duewer, Hovav Talpaz, and Dan Tsai. Richard Crom served as overall coordinator for the subsector model and acted as a consultant on theoretical matters. Lawrence Duewer provided the methodology for disaggregating much of the consumption data and performed the empirical estimation of the retail price equations. Hovav Talpaz designed the mathematical structure and developed the production-feeding system while a Michigan State University graduate assistant, under the guidance of Warren Vincent. A special debt of gratitude is owed to Dan Tsai of Michigan State University for his help in computer programming and in debugging the model.

# A SYSTEMS ANALYSIS OF THE HOG-PORK SUBSECTOR

*by*
*James D. Sullivan, Charles Y. Liu, and Warren Vincent*[1]

## INTRODUCTION

Systems analyses of the hog-pork sector are designed to confront many industry problems. The analysis here is designed to deal with vertical coordination. This report provides detailed information on the methodology used in desigining an econometric model of the hog-pork sector. The overall objectives of the hog-pork sector study are reported in the proceedings of a workshop that helped formulate the project (*7*).[2] The findings of the study are published in Effects of Changes in Vertical Coordination on Pork Production and Prices (U.S. Dept. of Agr., Econ. Res. Serv., Agr. Econ. Rpt. No. 303, Aug. 1975).

The research was designed to appraise the probable nature of future vertical coordination and determine the extent to which contract production and vertical integration might take over coordination of the hog-pork industry from traditional markets. To answer this important policy problem for hog producers, meatpackers, retailers, and Government officials, the analysis was focused on a subsector model. An additional objective was to simulate the aggregate production-processing-distribution activity of the hog-pork industry over time, showing resulting prices and output when one form of coordination expands at the expense of others (*2*). The specific objectives of the systems model were:

1. To describe in quantitative terms the economic relationships existing in the U.S. hog production-pork marketing system.
2. To simulate industry performance over an historical time period.
3. To establish generalized criteria with respect to the behavior of the hog-pork industry.
4. To provide insight into the coordination and structure of successive stages of production, marketing, pricing, and processing-distribution.

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[2] Italicized numbers in parentheses refer to references listed on p. 30.

## STRUCTURE OF THE HOG-PORK SUBSECTOR

For most purposes, an agricultural subsector can be regarded as a part of the agricultural economy that produces and markets a single farm product of a group of related products. For this study, a subsector was defined as a meaningful group of economic activities related vertically and horizontally by production and marketing relationships. In this respect, the hog-pork subsector includes all economic activities associated with breeding the sow, feeding and marketing hogs, slaughtering, processing, transportation, and wholesale and retail distribution.

### The Problem Setting

Review of the hog-pork subsector reveals a number of ways in which the present system performs poorly. Many independent hog producers sell to a smaller number of meatpackers at various coordinated levels who, in turn, sell pork products to even fewer but larger distribution outlets. It is a dynamic subsector characterized by cyclical, seasonal, and regular, as well as irregular, behavior patterns. Hog producers, input suppliers, meat packers and processors, wholesalers, retailers, and consumers are directly affected by this oscillatory behavior.

These groups do not share equally in the rewards which occur during different phases of the cycle. The long-run competitive position of hog producers is extremely difficult to evaluate. Success or failure of a decision to expand productive or to market is largely determined by the price position in the hog cycle at the time of the decision. Packers and processors invest millions of dollars in plant and facilities without control over input supply in the immediate area. Consequently, with the fluctuating hog supply, they may have to procure inputs from greater and greater distances. Because the hog-pork subsector operates under fairly competitive conditions with a wide range of production efficiency, prices may fall below average variable costs.

As a result, some firms may constrict or cease operations, which leads to less competition.

The present organization of the subsector has, or at least once had, good reasons for its structure. Changes to make the system more efficient might cost more than they are worth. But this is unlikely since the subsector is currently undergoing organizational change. Important potential changes appear to involve some sort of closer coordination of successive stages of production-feeding, slaughter-processing, and distribution. Reorganization of the hog-pork subsector would present participants in the subsector with important long-range decisions. They would like to know what the future organizational pattern would be and how they would fit into it. Information about the basic economic forces at work is needed so that producers, packer-processors, and consumers can formulate their plans for the future. Also, the number of public policy alternatives is greatest in the first stages of change; once reorganization has occurred, not much can be done to alter it. The systems-oriented model formulated here will aid analyses of how changes in any or all three subsystems of the hog-pork subsector will affect that subsector.

## Production-Feeding[3]

The well-known hog cycle was a familiar phenomenon as early as the beginning of the 20th century. Farmers typically do not produce for a specific market but for a price. When current prices are good, they tend to breed more gilts and sows, which results in increased supply and lower prices at a later date. Then, too little production is undertaken leading to short supplies and high prices. Since sufficient productive capacity must be available to handle peak volume, capacity is underutilized much of the time, leading to some inefficiency and consequently higher costs. The producer's strong tendency to stick to two farrowings a year is partly because most hogs are produced on farms where labor needs for crop production are highest in late spring and summer. Seasonal variation in production has been reduced somewhat by more multiple farrowings, but it has not been eliminated.

The U.S. hog-pork subsector has been undergoing structural changes. The trend in hog production has been toward fewer but larger producing units. The scale and methods of production vary widely. Some producers have a few sows and use hogs mainly as a way of gaining some return for family labor and feed, for which alternative outlets are poor. The larger producers may use a farrowing-pasture system and market 300 to 400 hogs annually, or one of confinement housing and feeding where usually 1,000 or more hogs are sold annually. In 1969, the U.S. Census showed that 11 percent of the farms had 200 or more hogs, with these representing 52 percent of the national hog inventory (*22*). In contrast, the 1964 census showed that only 6 percent of the farms had 200 or more hogs, and these accounted for 39 percent of the total inventory.

Since 1950, the 10 major Corn Belt States—Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, South Dakota, Nebraska, and Kansas—have produced 75 percent of the U.S. pig crop. However, the economic and technological conditions that long favored production of hogs and feed grains on the same farm are changing. Mechanization has increased the optimal acreage of crop farms and the importance of capital inputs relative to labor. An efficient crop production system has become less compatible with hog production. Rising farm labor costs and developments in feed manufacturing made the purchase of feed for hogs, instead of the use of homegrown grain, more attractive than it used to be. The large, specialized producer of today requires large amounts of inputs, primarily from outside sources. He purchases most of his feed directly from a feed manufacturer or local dealer. Producers of 10 years ago may have kept 8 or 10 sows as mainstays of their breeding and hog-raising operations, but today's specialized producer may have no sows, purchasing all of his hogs as feeder pigs from other farmers. The input supplier is no longer just the local feed dealer providing concentrates and supplements. In this modern setting, the input supplier may be one or more of the following: feeder-pig supplier, financing agency, feed manufacturer, or veterinary-medical specialist. This is in contrast to hog operations of the past, which were financed by the producer from funds generated from his whole farming operation.

## Slaughtering-Processing

Deconcentration and decentralization have been the structural changes occurring within the slaughtering-processing component of the U.S. hog-pork subsector.

Slaughter plants under Federal inspection and nonfederally inspected plants with an annual liveweight output of 300,000 pounds or more numbered 3,869 on March 1, 1970, compared with 2,957 in 1963. Of the 3,869 plants in 1970, 83 percent (3,196) slaughtered hogs. Only 3 percent (99 plants) slaughtered hogs only (*21*). Most of the plants slaughtering hogs also killed other kinds of livestock. The most common slaughter combination was cattle-calves and hogs (40 percent of the plants). Many of the hog slaughtering plants were relatively small, since only 371 of the March 1, 1970, plants were federally inspected, and they accounted for about 90 percent of the commercial hog slaughter in 1970 (*21*).

With the declining importance of terminal markets, most market areas for hog procurement are now smaller than a single State. 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 branded and to some extent quality

[3] The material for the production-feeding subsystem was taken from the unpublished Ph.D dissertation of Hovav Talpaz, "Simulation Decomposition and Control of a Multi-Frequency Dynamic System: The United States Hog Production Cycle," Michigan State Univ.

controlled. On the other hand, the 30 percent carcass which is sold fresh has not been graded, has no uniform identification, and offers no assurance of consistent quality. There are no national meat quality grades for pork. While processed pork has a differentiated product, a consumer image, and some protection against fluctuating prices, most meatpackers consider fresh pork to be a product whose price is very sensitive to changes in supply and demand.

Structural characteristics of the slaughtering-processing component create a problem in translating 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 in most manufacturing industries. This is the result of three factors. First, the raw material (live hogs) coming from a large number of producers fluctuates widely. Second, market hogs are not of uniform quality nor generally purchased on any guarantee of quality. Hog buyers bid and contract for animals by purely subjective evaluation, and while they become quite proficient in this respect, the overall procurement procedure is plagued with more uncertainties than is true for manufacturing firms able to contract for a specified volume of standardized quality. Finally, purchasing hogs and processing them to the green-cut stage 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. The meatpackers are not manufacturing one product (pork) but a large number of pork products. The mix of finished products does not make use of raw materials (green pork cuts) in the same proportion as they are purchased in the live hog. This causes problems in balancing the number of hogs to slaughter and the raw material needs for final consumer cuts of pork. Before buying market hogs, the packer must translate the demand for finished pork cuts into the demand for raw materials (green cuts) and finally his demand for butcher hogs.

Seasonal variability of supply contributes to packing plant inefficiency. Most plants are built to handle large volumes in the peak slaughtering season and operate below capacity the rest of the time. In larger plants, flexibility is achieved by using several combinations of men and line speed. This is almost imperative to lessen inefficiencies arising from the uneven seasonal supply of hogs. The smaller plants have more difficulty in attaining this kind of flexibility because they have fewer alternative productive jobs for employees. This is one reason why reductions in the supply of hogs and the rate of kill do not reduce the number of labor hours proportionately.

## Distribution-Consumption

Fresh and processed pork products are distributed to wholesale and retail markets by packers, processors, merchant wholesalers, and brokers. Speciality wholesalers have attained an important position in meat distribution. In 1972, they handled about two-thirds of the total sale of meat and meat products by wholesalers (*23*).

On the buying side of the wholesale market, $35 billion was spent for away-from-home food consumption in 1972 (*20*, p. 103). For all meat, the retail value spent in hotels, restaurants, and institutions (HRI) was reported as $40 billion. Retail outlets, the other participants in the buying of meat products, consist of chain supermarkets, independent supermarkets, and convenience grocers. The number of independent stores, large or small, declined steadily from 1938 to 1972, and while there was a sharp decrease in the number of chain stores until 1956, these stores increased from 1969 to 1972 at the expense of the small "mom and pop" stores (table 1). At the same time, independent supermarkets increased, but at a slower rate (table 2). The total value of sales reflects the same growth pattern (table 3).

Fresh and processed pork distributed through HRI outlets is consumed at away-from-home eating establishments, while that purchased through retail stores is usually consumed at home. During 1950-72, total pork consumption increased from 10.4 billion to 13.9 billion pounds. Per capita consumption remained fairly stable, ranging from a low of 58.1 pounds in 1966 to a high of 73 pounds in 1971 (*19*, p. 123).

Table 1—Number of stores and sales of chain stores and independent stores, selected years, 1938-72

| Year | Stores | | | Sales | | |
|---|---|---|---|---|---|---|
| | Chain | Independent | All stores | Chain | Independent | All stores |
| | *Number* | *Number* | *Number* | *Billion dollars* | *Billion dollars* | *Billion dollars* |
| 1938 | 46,500 | 390,750 | 437,250 | 2,657 | 5,076 | 7,733 |
| 1946 | 33,500 | 375,500 | 409,000 | 6,790 | 12,250 | 19,040 |
| 1956 | 18,000 | 292,000 | 310,000 | 15,900 | 27,000 | 42,900 |
| 1966 | 25,205 | 201,800 | 227,005 | 29,350 | 38,500 | 67,850 |
| 1972 | 38,850 | 162,200 | 201,050 | 49,730 | 51,970 | 101,700 |

Source: Progressive Grocer, Annual Report, Apr. 1973, p. 100.

Table 2--Number and percentage of grocery stores, by ownership, 1969-72

| Item | Stores | | | | Percentage of total | | | |
|---|---|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1971 | 1972 | 1969 | 1970 | 1971 | 1972 |
| | *Number* | *Number* | *Number* | *Number* | *Percent* | *Percent* | *Percent* | *Percent* |
| Chain:[1] | 24,700 | 27,700 | 29,200 | 32,550 | 11.3 | 13.3 | 14.2 | 16.2 |
| Supermarkets | 19,700 | 20,400 | 20,700 | 21,700 | 9.0 | 9.8 | 10.1 | 10.7 |
| Superettes | 5,000 | 7,300 | 8,500 | 11,050 | 2.3 | 3.5 | 4.1 | 5.5 |
| Independent: | 43,480 | 44,100 | 43,400 | 44,000 | 19.9 | 21.2 | 21.2 | 21.9 |
| Supermarkets | 17,480 | 17,900 | 18,200 | 19,100 | 8.0 | 8.6 | 8.9 | 9.5 |
| Superettes | 26,000 | 26,200 | 25,200 | 24,900 | 11.9 | 12.6 | 12.3 | 12.4 |
| Small stores: | 151,150 | 136,500 | 132,300 | 124,500 | 68.8 | 65.5 | 4.6 | 61.9 |
| All stores | 219,330 | 208,300 | 204,900 | 201,050 | 100.0 | 100.0 | 100.0 | 100.0 |

[1] Definition of stores: Chain—operation of 11 or more stores; independent—operation of 10 or fewer stores; supermarkets—sales of $500,000 or more per year; superettes—sales of $150,000 to $500,000 per year; small stores—sales less than $150,000 per year.

Source: Progressive Grocer, Annual Report, Apr. 1970-72.

Table 3--Sales of grocery stores, by ownership, 1969-72

| Item | Sales | | | | Percentage of total | | | |
|---|---|---|---|---|---|---|---|---|
| | 1960 | 1970 | 1971 | 1972 | 1969 | 1970 | 1971 | 1972 |
| | *Billion dollars* | *Billion dollars* | *Billion dollars* | *Billion dollars* | *Percent* | *Percent* | *Percent* | *Percent* |
| Chain:[1] | 37,400 | 41,330 | 44,660 | 49,040 | 45.4 | 46.8 | 47.3 | 48.2 |
| Supermarkets | 36,120 | 39,350 | 42,420 | 45,900 | 43.9 | 44.5 | 44.9 | 45.1 |
| Superettes | 1,280 | 1,980 | 2,240 | 3,140 | 1.5 | 2.3 | 2.4 | 3.1 |
| Independent: | 35,280 | 36,715 | 39,755 | 41,710 | 43.0 | 41.5 | 42.0 | 41.0 |
| Supermarkets | 26,280 | 27,315 | 29,965 | 32,810 | 32.1 | 30.9 | 31.7 | 32.3 |
| Superettes | 8,900 | 9,400 | 9,790 | 8,900 | 10.9 | 10.6 | 10.3 | 8.7 |
| Small stores | 9,525 | 20,370 | 10,055 | 10,950 | 11.6 | 11.7 | 10.7 | 10.8 |
| All stores | 82,205 | 88,415 | 94,470 | 101,700 | 100.0 | 100.0 | 100.0 | 100.0 |

[1] Definition of stores: see footnote 1 in table 2.

Source: Progressive Grocer, Annual Report, Apr. 1970-73.

# STRUCTURE OF SUBSECTOR MODEL

## Development of Subsystems

A quantifiable, dynamic economic model is a necessary tool for a systems analysis of a particular subsector. Operation of the model simulates the dynamics of market performance. The model can be used to show the effect of alternative forms of market or production organization on performance. The framework for the hog-pork subsector model discussed here consists of equations and variables for three subsystems—production-feeding, slaughtering-processing, and distribution-consumption. The structural equations are the price-output relationships within the subsector and may be either definitional or behavioral. The definitional equations consist of physical, biological, technical, and organizational variables, while the behavioral equations are comprised of economic variables.

The three subsystems are depicted in figure 1. The physical flows from the breeding of the sow and gilt to consumption are one-directional. The level of the price structure is established in the wholesale market, inasmuch as the consumer is a price-taker and quantity-adjuster. Retail prices and live hog prices flow from the wholesale level as derived prices. The third dimension (the focal point of the project) is the coordinating system(s) which regulates the physical flows. The coordination is accomplished through prices determined at the indicated pricing points under the existing—current and historical—market structure.

The production and marketing system for hogs and pork presents a complex set of technical, organizational, and economic relationships. The subsector model constructued here is a dynamic monthly model in which the basic behavioral feature is a recursive series of equations moving from production decisions to consumer meat purchases. The model is completely recursive: one-at-a-time computations of [successive] values for endogenous variables can be successively sequenced in such a way that, for any month, the value of each endogenous variable may be computed given only exogenous variables, lagged endogenous variables, and preceding current endogenous variables in the sequence. Since it is a simulation model, a number of mathematical techniques—ordinary least squares, autoregressive least squares, and nonlinear distributed lags—were used to estimate the behavioral relationships.

The first step in developing the simulation model was to formulate a model capable of validation over an historical period. The aim was to simulate total hog production and pork distribution and consumption, to establish prices for live hogs and for wholesale and retail cuts of pork, and to determine market quantities which would be supplied to different types of wholesale and retail outlets. The hog-pork subsector at the present time is not fully integrated. Therefore, the model which was validated for the 1965-71 period is a free market model.

## Empirical Development and Estimation of Subsystems

The systems approach to research in the hog-pork subsector necessitated the identification of a large number of variables for the simulation model. However, the model generates more information than needed for the simulation objective itself. To permit an evaluation of the model and to validate its performance, only the important variables are presented here. The computer program and variable identification of the simulation model are given in the appendix.

## Production-Feeding Subsystem

The subsystem is a multifrequency cobweb model incorporating the features of three basic models—the Cobweb, the Harmonic Motion, and Distributed Lags. It reflects an integrated multifrequency decision process resulting from the feedback of production response to the hog-corn ratio signal through fixed, multiple-production lags. Long, intermediate, and short run decisions are continually made, and their impacts are projected to future decisions and production processes.

As illustrated in figure 2, the total supply of hogs is largely a response to past decisions and conditions. This comes about because of delays for physical and biological reasons as well as because of delays between planning and execution by the producer. If breeding stock is increased to meet a sudden rise in hog price, then the duration of the production delay ranges from 10 to 12 months, corresponding to the *Gestation-Maturation Delay*.

About 90 percent of all farrowing take place between 111 and 119 days after breeding. Pigs are weaned at about 2 months, and gilts come into first heat at 3 months of age. However, gilts are normally not bred until they weigh an average of 250 pounds, or are about 8 months old. Market barrows and gilts are commercially slaughtered at 180 to 300 pounds.

The simulation begins with estimated sow farrowings and flows sequential from the weaning of pigs to the marketing of hogs. Hogs are marketed as five weight groups of barrows and gilts plus a category for cull sows and boars (fig. 3).

The producer's breeding decision determines the number of sows farrowing. A number of factors influence this breeding decision. One is the variable and fixed costs on the farm. For some inputs, purchase costs are substantially greater than their salvage values. Hence, the supply curve is more elastic when the price of hogs is increasing than when it is decreasing. During an upswing in prices, producers respond by increasing production to full capacity, with additional investments in buildings and equipment to increase production capacity. The new investment becomes a fixed cost. However, during a downturn in prices, production will not be contracted as long as variable costs are being covered. Another factor

# Figure 1.
# A Systems Analysis of the Hog-Pork Subsector

——— Physical Flows

- HS Hog Slaughter
- BP By Products
- GF Growing and Finishing
- PS Pigs per sow
- PP Pig Production
- SF Sows Farrowing
- BS Breeding stock
- PS Pork storage
- C Consumption
- RO Retail outlets
- IU Institutional use

—·— Vertical Coordination Systems

- PdSS Producer Sales System
- PdPS Producer Procurement System
- BdSS Breeder Sales System
- PkPS Packer Procurement System
- PkSS Packer Sales System
- PcPS Processor Procurement System
- IvCS Inventory Control System
- PcSS Processor Sales System
- IvCS Inventory Control System
- PcSS Processor Sales System
- RtPS Retail Procurement System
- HhCS Household Consumers
- IsBS Institutional Buyers
- BdDS Breeding Decisions

— — — Pricing-Structure O Pricing points

- HOGP Hog Prices
- BYPP By-Product Prices
- FDPP Feeder Pig Prices
- RETP Retail Prices
- WHOP Wholesale Prices

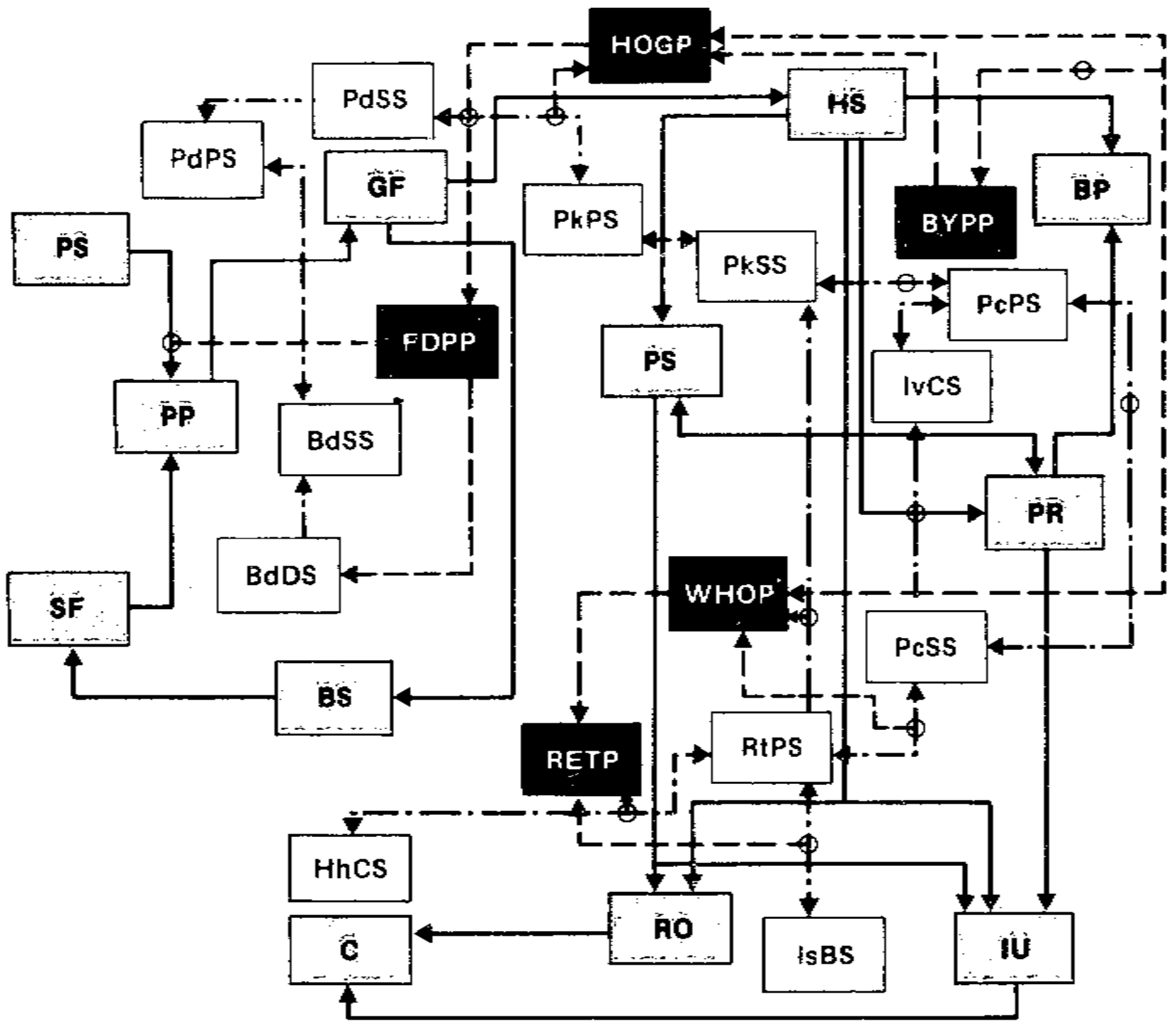
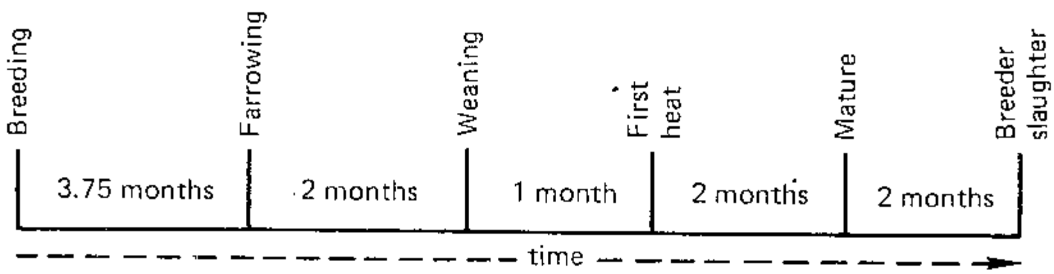


Figure 2.
Gestation-maturation delay




is the influence of expected future market conditions, which is represented in the model by the hog-corn price ratio (HCPR)—the number of bushels of corn equal in value to 100 pounds of live hogs.

Analytically, the breeding decisions of hog producers can be approximated by the number of sows farrowing (equation 1). The estimated coefficients and corresponding statistical properties for equation 1 are given in table 4. All equations were estimated by using an ordinary least-squares stepwise-delete algorithm.

(1) $SF_t = F(HCPR_{t-5}, HCPR_{t-21}, SF_{t-6}, T_cC, SD, PC)$

where:

- $SF_t$ = number of sows farrowing in month t—1,000 head.
- $HCPR_{t-5}$ = hog-corn price ratio lagged 5 months.
- $HCPR_{t-21}$ = hog-corn price ratio lagged 21 months.
- $SF_{t-6}$ = number of sows farrowing lagged 6 months.
- $T_cC$ = exogenous cyclical variables—Fourier series.
- SD = zero-one monthly dummy variables, where December served as the *a priori* excluded.
- PC = monthly price change between average hog price 4 months earlier and 11 months earlier.

The 6-month lag sow farrowing variable was used since it reflects the relationship between the spring and fall farrowings. $HCPR_{t-5}$ and $HCPR_{t-21}$ reflect the short- and long-run breeding decisions as a response to price conditions. If it is assumed that it takes some time before realized hog and corn prices become known to producers, the 5-month lag is a last minute change in planned production as a result of an assessment of current market conditions. The 21-month lag reflects the longer run investment-disinvestment decisions. These decisions, such as new building and equipment, represent additional potential production capacity, which under a

Table 4.—Sows farrowing equation (SF), coefficients and statistical information[1]

| Independent variable | Regression coefficient | Standard error of coefficient | t-Value |
|---|---|---|---|
| Constant | -231.32 | 58.86 | -3.93 |
| $SF_{t-6}$ | 0.397 | 0.045 | 8.87 |
| $HCPR_{t-5}$ | 12.981 | 1.91 | 6.79 |
| $HCPR_{t-21}$ | 11.730 | 2.28 | 5.14 |
| Sine $(2w_0t)$ | 39.750 | 8.66 | 4.59 |
| Sine $(4w_0t)$ | 1,145.61 | 33.95 | 33.75 |
| Jan. dummy[2] | -312.98 | 24.19 | -12.93 |
| Feb. dummy | -506.85 | 33.66 | -15.06 |
| March dummy | -380.99 | 45.10 | -8.45 |
| June dummy | 529.45 | 30.83 | 17.17 |
| July dummy | 948.29 | 39.96 | 23.73 |
| Aug. dummy | 1,515.78 | 48.72 | 31.11 |
| Sept. dummy | 1,855.26 | 56.91 | 32.60 |
| Oct. dummy | 1,096.06 | 53.64 | 20.43 |
| Nov. dummy | 478.74 | 37.62 | 12.73 |
| Price change | 34.52 | 12.88 | 2.68 |

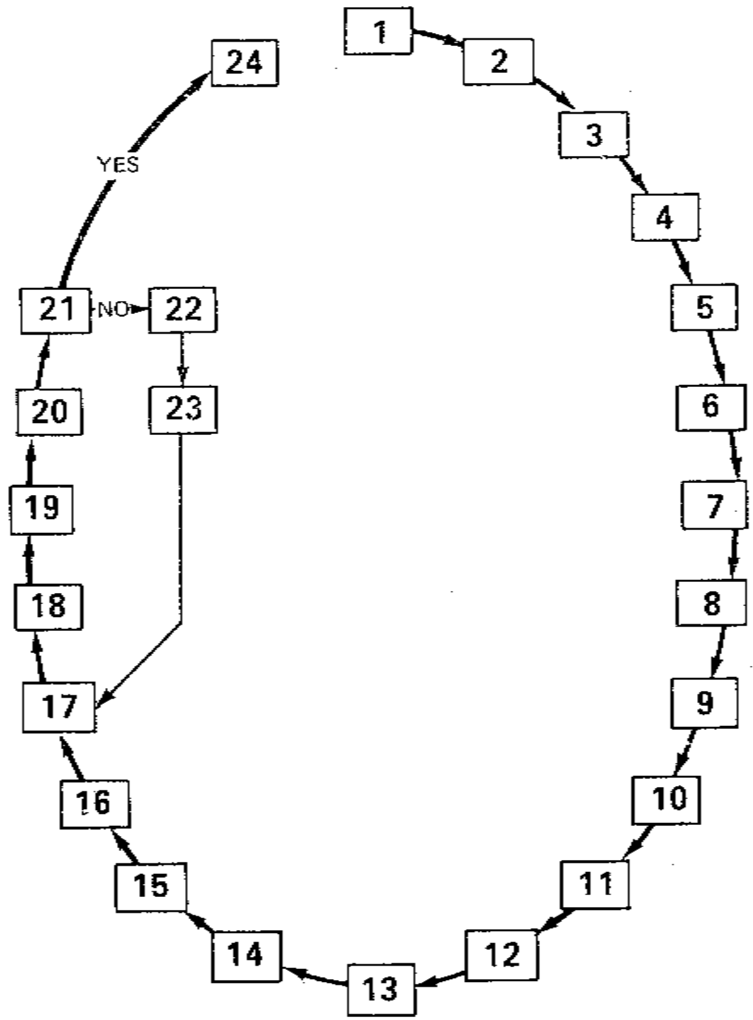
[1] $R^2$ = .9788; F = 256.93; mean SF = 1,030.93; D-W = 1.176; stand error of estimate = 50.55. [2] December served as the a priori excluded month for equations 1, 2, 4, and 5.

fixed cost situation induces the producer to change the number of sows farrowing. With respect to seasonal variations, all 11 monthly dummy variables had significant T-values. Also, the significance of the sine variables $(2\ w_0t)$ and $(4\ w_0t)$ suggest that the 2-year and 1-year cycles are not carried by the other independent variables.

From an econometric viewpoint, the regression coefficients for all independent variables are significant, with high t-values and small standard errors of estimate. However, the Durbin-Watson (DW) statistic indicates that some serial correlation exists. This implies that some of the estimated coeffficients are less significant than reported; but the coefficients can still be regarded as consistent and unbiased estimates which can be safely accepted.

Figure 3. Systems Flow of Production—Feeding Subsystem

1. Initialize exogenous & predetermined endogenous variables
2. Estimate sow farrowings ($SF_t$)
3. Compute pig crop
4. Transfer age groups & count for deaths
5. Estimate minimum size of breeding herd
6. Estimate sows sold ($SGS_t$)
7. Sell $SGS_t$ in accordance with minimum breeding herd size
8. Update total females held [$TFH_t$)
9. Sell boars
10. Update total males for breeding herd
11. Estimate targeted barrows & gilts sales
12. Estimate average liveweight (AVLW)
13. Calculate area under normal curve for each weight group
14. Compute number of barrows & gilts in each weight group
15. Compute liveweight for each weight group
16. Determine weight groups eligible for market
17. Draw a batch of barrows & gilts
18. Check current inventory for availability
19. Update inventory accordingly
20. Extend eligibility by 1 standard deviation
21. Target barrow & gilt marketings met
22. Check if weight constraints met
23. If weight constraints met, draw a market group
24. Transfer number of market hogs in each weight group to slaughtering—processing subsystem



The current pig crop or number of weaning pigs is computed by equation 2.

(2) $WPA_t = SF_t + f(SPPL, T)$

where:

$WPA_t$ = number of weaning pigs in month t.
$SF_t$ = identified in equation 1.
SPPL = number of 2-day old pigs saved per litter, seasonally adjusted.
T = time trend to allow for technological improvements because of reduction in mortality of newborn pigs.

The females in the breeding herd consist of sows and mature gilts. It was assumed that a fixed disposal rate was unrealistic because it does not allow for different management practices during expansion or contraction, for short-run market price effects, or for seasonal variations. Alternatively, the number of sows and gilts sold was estimated by using equation 3. The statistical properties of equation 3 are given in table 5.

(3) $SGS_t = f(SF_{t-3}, HCPR_{t-2}, SD)$

where:

$SGS_t$ = number of cull sows and mature gilts sold
$SF_{t-3}$ = number of sows farrowing lagged 3 months—1,000 head.
$HCPR_{t-2}$ = hog-corn price ratio lagged 2 months.
SD = seasonal dummy variables (p. ).

Table 5—Sows and gilts sold equation (SGS), coefficients, and statistical information[1]

| Independent variable | Regression coefficient | Standard error of coefficient | t-Value |
|---|---|---|---|
| Constant | 620.22 | 51.67 | 12.00 |
| $SF_{t-3}$ | 0.06 | 0.03 | 1.97 |
| $HCPR_{t-2}$ | -10.37 | 1.80 | -5.76 |
| Jan. dummy[2] | -75.82 | 23.25 | -3.26 |
| Feb. dummy | -145.78 | 29.93 | -4.87 |
| Mar. dummy | -127.86 | 28.51 | -4.48 |
| Apr. dummy | -77.21 | 24.08 | -3.21 |
| July dummy | 59.33 | 23.40 | 2.54 |
| Aug. dummy | 92.32 | 21.75 | 4.25 |

[1] $R^2$ = .7442; F = 31.19; mean SGS = 483.08; D-W = 1.30; standard error of estimate = 51.45. [2] December served as the a priori excluded month for equations 1, 2, 4, and 5.

Although the $R^2$ value is lower than in equation 1, the F-value is still high enough to give a high level of significance for the entire equation. The significance of $SF_{t-3}$ indicates that of the sows and gilts sold, a large number had just finished weaning their pigs. The short-run market price conditions are represented by $HCPR_{t-2}$. The negative sign on the $HCPR_{t-2}$ coefficient may be interpreted by the following consideration: When hog prices are favorable, producers will expand the breeding herd by reducing the culling rate. The seasonal zero-one variables were included, while the cyclical effects were excluded.

The number of barrows and gilts sold depends on past farrowings, market prices, and seasonal and cyclical variation (equation 4) subject to availability of pigs by age-weight distribution.

(4) $BGS_t = F(SF_{t-6}, SF_{t-8}, SF_{t-10}, HCPR_{t-12}, T_c^C, SD)$

where:

$BGS_t$ = number of barrows and gilts sold in month t—1,000 head.
$SF_{t-6}$ = number of sows farrowing lagged 6 months.
$SF_{t-8}$ = number of sows farrowing lagged 8 months.
$SF_{t-10}$ = number of sows farrowing lagged 10 months.
$HCPR_{t-12}$ = hog-corn price ratio lagged 12 months.
$T_c$ = identified in equation 1.
SD = identified in equation 1.

The estimated parameters of equation 4 are presented in table 6. This equation and equation 1 are two of the most important equations in the subsector model. They largely determine the major output of the subsystem, since marketings of barrows and gilts exceed 90 percent of total commercial hog slaughter (*19*). The 6, 8, and 10-month lags on SF variables indicate the relative size of pigs in these age groups. The $HCPR_{t-12}$ expresses the

Table 6—Barrows and gilts sold equation (BGS), coefficients and statistical information[1]

| Independent variable | Regression coefficient | Standard error of coefficient | t-Value |
|---|---|---|---|
| Constant | -2507.03 | 614.94 | -4.07 |
| $SF_{t-6}$ | 1.41 | 0.22 | 6.39 |
| $SF_{t-8}$ | 3.25 | 0.31 | 10.44 |
| $SF_{t-10}$ | 2.02 | 0.22 | 9.24 |
| $HCPR_{t-12}$ | 43.73 | 10.60 | 4.12 |
| Sine $(4w_ot)$ | 1896.32 | 244.45 | 7.76 |
| Feb. dummy[2] | -1551.41 | 154.25 | -10.06 |
| May dummy | -437.08 | 186.57 | -2.34 |
| June dummy | 1203.43 | 248.39 | 4.84 |
| July dummy | 2242.90 | 429.66 | 5.22 |
| Aug. dummy | 3915.05 | 557.85 | 7.02 |
| Sept. dummy | 4388.93 | 602.09 | 7.28 |
| Oct. dummy | 3630.47 | 490.45 | 7.40 |
| Nov. dummy | 1460.19 | 253.36 | 5.76 |

[1] $R^2$ = 0.8939; F = 54.77; mean BGS = 6237.17; D-W = 1.69; standard error of estimate = 269.37. [2] December served as the a priori excluded month for equations 1, 2, 4, and 5.

effects of intermediate market conditions. Significant seasonal and cyclical variations were included in the equation. The statistical properties of the BGS equation indicate a satisfactorily estimated equation with relatively high $R^2$, a high F-value, and low serial correlation (table 6).

While equation 4 provides an estimate of the total number of barrows and gilts sold, it does not specify the age- or weight- distribution for the month. This information is needed in the subsector model for inventory adjustments in the production-feeding subsystem and for allocating the barrows and gilts among five market weight groups for pricing in the slaughtering-processing subsystem.

The age-weight distribution is related to the average liveweight (equation 5) for the total number of barrows and gilts sold.

$$(5) \quad AVLW_t = F(SF_{t-7}, \; SF_{t-9}, \; SF_{t-10}, \; APBG_{t-8}, \; APBG_{t-8}, APBG_{t-26}, T_c^C, SD)$$

where:

$AVLW_t$ = average liveweight of market barrows and gilts in month t—pounds per hog.

$SF_{t-7}$ = number of sows farrowing lagged 7 months.

$SF_{t-9}$ = number of sows farrowing lagged 9 months.

$SF_{t-10}$ = number of sows farrowing lagged 10 months.

$APBG_{t-2}$ = average price of barrows and gilts lagged 2 months.

$APBG_{t-8}$ = average price of barrows and gilts lagged 8 months.

$APBG_{t-26}$ = average price of barrows and gilts lagged 26 months.

$T_c^C$ = identified in equation 1.

SD = identified in equation 1.

The estimated regression coefficients are given in table 7. As expected, the lagged SF variable contributed substantially to the determination of AVLW, simply because it reflects the corresponding volume farrowed with its age-weight distribution. The average hog price lagged 2, 8, and 26 months represented the sales response to market price changes. The effects of the time variables were explicitly included in the form of seasonal and cyclical variables. All explanatory variables exhibited high significance levels, resulting in a relatively high $R^2$ for the equation. The D-W value—1.69—indicates relatively low serial correlation.

Equations 1, 2, 4, and 5 represent the economic framework for the production-feeding subsystem. Having estimated the four econometric equations with satisfactory results, the next step was to simulate the process of growing and finishing market hogs. Thus, the inventory of market hogs must be continuously adjusted to allow for death, slaughter, and age-weight gain. To achieve this, a transfer matrix of hog-age groups was developed.

Table 7—Average liveweight equation (AVLW), coefficients and statistical information[1]

| Independent variable | Regression coefficient | Standard error of coefficient | t-Value |
|---|---|---|---|
| Constant | 217.36 | 2.73 | 79.49 |
| $SF_{t-7}$ | 0.006 | 0.001 | 5.52 |
| $SF_{t-9}$ | 0.01 | 0.0009 | 10.99 |
| $SF_{t-10}$ | 0.005 | 0.001 | 4.76 |
| $APBG_{t-2}$ | 0.08 | 0.09 | 9.09 |
| $APBG_{t-8}$ | -1.17 | 0.14 | -8.36 |
| $APBG_{t-26}$ | 0.34 | 0.05 | 6.77 |
| Cosine ($2w_ot$) | -0.95 | 0.33 | -2.84 |
| Cosine ($4w_ot$) | -4.81 | 0.44 | -10.94 |
| Cosine ($5w_ot$) | 0.59 | 0.26 | 2.76 |
| Cosine ($6w_ot$) | 0.32 | 0.23 | 1.43 |
| Sine ($1w_ot$) | -5.78 | 0.56 | -10.29 |
| Sine ($2w_ot$) | 2.17 | 0.24 | 9.05 |
| June dummy[2] | -5.65 | 0.88 | -6.45 |
| July dummy | -9.96 | 1.05 | -9.52 |
| Aug. dummy | -8.55 | 0.95 | -9.05 |
| Sept. dummy | -4.62 | 0.81 | -5.67 |

[1] $R^2$ = .9256; F = 65.49; mean AVLW = 234.83; D-W = 1.69; standard error of estimate = 1.33. [2] December served as the a priori excluded month for equations 1, 2, 4, and 5.

In the early development stage, the transfer matrix was a diagonal matrix with death and farm slaughter rates for each age group of pigs on the diagonal. Later, it was found necessary to deal with pigs born on a weekly basis, so the matrix was enlarged. The sum of death and farm slaughter rate assumed in the study is as follows: 2.5 percent in the first month; 1.5 percent in the second; 1.3 percent in the third; 1.0 percent each in the fourth and fifth months; 0.7 percent in the sixth; and 0.5 percent in both the seventh and eighth months of age. The purpose of the transfer matrix is to shift the total population of barrows and gilts after marketings of the last month into the current month age-group population, but before the marketing allocation among the weight groups is worked out. At 8 months of age, the pigs still in the inventory join the breeding herd in the ratio of 92 percent females to 8 percent males.

The total number of hogs marketed can be computed by the identity:

$$(6) \quad Y_t = BGS_t + SGS_t + SMALES_t$$

where:

$Y_t$ = total number of hogs marketed in month t—1,000 head.

$BGS_t$ = identified in equation 4.

$SGS_t$ = identified in equation 3.

$SMALES_t$ = number of boars sold in month t—1,000 head.

The number of boars sold is computed as the disposal of the difference between the required 8.3 percent of the breeding herd and the actual number on hand in the current month.

The identity given by equation 6 is subject to the limitation that inventory of $BGS_t$ and $SGS_t$ be capable of delivering these numbers of hogs. As far as $SGS_t$ is concerned, it is necessary to ensure that a minimum number of total females are held in inventory to breed in the current month for farrowing 4 months later.

The checking procedure becomes very complex for the $BGS_t$ inventory. Not only must $BGS_t$ as a total of all barrows and gilts of different ages be satisfied, but the inventory balance of each age group cannot be violated. Futhermore, the tolerances are much tighter than that. If too many pigs are drawn from one age group for marketing, it may result in no heavy butcher hogs being sold later on. If too few are drawn, then a large number of boars and gilts will enter the breeding herd, followed by a very small number, resulting in extreme fluctuations in the size of the breeding herd. Therefore, it is necessary to estimate the age-weight distribution associated with $BGS_t$.

Since data avaliable to support a direct approach to the problem were very limited, three alternatives were considered:

1. *Retention function*—Given time t, the total number of hogs equals the number marketed plus the number retained at the farm. Therefore, if the retention function for each age group in the BGS inventory could be generated, the problem would be solved. However, in the absence of relevant information and a sound theoretical base for such a function, this approach was dropped.

2. *Loop search allocation scheme*—The need to reconcile the number of marketed hogs over time with the inventory on hand and the number of barrows and gilts marketed led to directly determining the total number of barrows and gilts marketed by small iterative steps of selection from the inventory of each age group. On every pass, the number of barrows and gilts was drawn from the heaviest four age groups under the growing inventory on hand. In this way, a negative inventory was never reached and at the same time the different age groups were kept in relatively close ratios. Also, in each loop, a check was made to find if the total number of BGS drawn had reached the quota as estimated by equation 1. An inventory adjustment was then made. The process of looping was continued until the number as estimated by equation 1 was exceeded. At this point a movement backward was made, thus adjusting to the exact level as given by equation 1. A safety feature against an infinite loop was introduced, since the $BGS_t$ and $SF_t$ are independently estimated, with the possibility of having lagged SF underestimated for several consecutive months and BGS overestimated later on. The disadvantage of this alternative in the overall simulation of the subsector model is that hog prices are endogenous to the system and functionally related to the age-weight distribution of the numbers of barrows and gilts sold. Also, the solution to such a marketing scheme has no assurance of being unique. Therefore, this alternative was abandoned.

3. *Age-weight distribution allocation scheme*—This third approach was finally used . To disaggregate the total inventory of BGS into weight groups, it is necessary to know the relation between the age of butcher hogs and the attained weight of the hogs. Without a behavorial-decision feeding model available, an implicit feeding system unchanged with time and market conditions was assumed.

Table 8 and figure 4 show the growth function assumed and used in the subsector model. They give the expected as well as the minimum and maximum days required to qualify a hog into each of the five commercial market-weight groups. The hypothesis is that the weight distribution is some nonsymmetric distribution function which depends on the average liveweight. By using unpublished data from the major Midwest livestock markets, a picture of the real distribution over time was made (app. table 1).

Table 8—Days required for hogs to reach selected weights

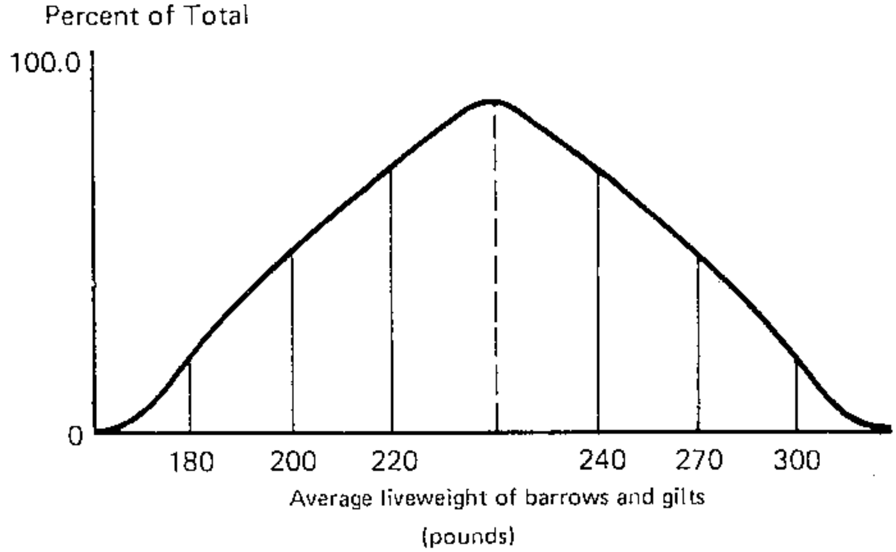
| Pounds | Expected | Minimum | Maximum |
|---|---|---|---|
| | *Days* | *Days* | *Days* |
| 180 .......... | 143 | 133 | 153 |
| 200 .......... | 155 | 144 | 166 |
| 220 .......... | 170 | 158 | 182 |
| 240 .......... | 184 | 172 | 196 |
| 270 .......... | 208 | 195 | 221 |
| 300 .......... | 233 | 219 | 247 |

Source: Estimated from graphic data similar to figure 4 and contained in unpublished report by E.C. Mill Jr., Animals Husbandry Department, Michi. State Univ., 1972. Assumes one standard deviation from the mean number of days.

With an estimate of $AVLW_t$, a first approximation was made by computing the area under the normal distribution curve corresponding to each commercial weight group. Figure 3 illustrates the sequence. Assume the standard deviation about $AVLW_t$ is 19.5 pounds. By using an algorithm (NDTR) developed by IBM, the following commercial weight groups were estimated ([5]): 180-200, 201-220, 221-240, 241-170, and 271-300 pounds per head (fig 4). The procedure to calculate these groups follows. Step one: Estimate $AVLW_t$ by equation 5 and compute the five commercial-weight groups shown in figure 4. 5 Step two: Adjust group size in proportion to the seasonal adjustment for the particular month being calculated. The estimated equations are given in the appendix and were obtained by applying ordinary least-squares procedure to the normal curve approximation and the sample values of appendix table 1.

Figure 4.

An Approximated Normal Weight Distribution of Market Barrows and Gilts




Once the number of barrows and gilts was distributed among the five weight groups, it was necessary to determine the age-inventory groups eligible for sale. To accomplish this, it was assumed that sow farrowings were uniformly distributed throughout the month. After a pig reached 4 months of age, each month's growth was divided into four time periods, and the inventory was calculated at the end of each period. The eligibility of the expanded number of groups—16—is determined with the aid of table 8, where a third of each weight group is drawn only from the expected age-weight combination, and the rest from the "expected" cell plus one standard deviation on both sides. In this way, the exact number of hogs to be drawn net of each weeks expected age-weight group is directly related to that group's size relative to that of all eligible groups. This procedure ensured inventory control constraints and seemed to resemble the real world pattern.

## Slaughtering-Processing Subsystem

With respect to inputs, the slaughtering-proc sing subsystem has interconnecting sets of behavioral relationships with the production-feeding subsystem. For output, it has similar behavioral relationships with the distribution-consumption subsystem (fig. 5). On the input side, the subsystem has an interface with the production-feeding subsystem at the live hog market, while on the output side it has an interface with the distribution-consumption subsystem at the wholesale market. In general, this subsystem is concerned with pricing and slaughtering of market hogs, breaking the carcass into primal cuts, and processing the primals into final consumer pork products. As formulated, the subsystem is a recursive set of equations.

The live hog marketing system as modeled attempts to solve two pricing problems facing the meatpacking industry: (1) determination of the price that is responsive to changes in supply and demand, and (2) establishment of payment for biological differences between market classes of hogs. A third problem—quality—is not considered. The subsystem's output, composed of fresh and processed pork cuts, is specified without regard to brand, weight, or size of the consumer cuts.

Considerable research effort was directed toward analyzing time series data to determine characteristics of demand for hogs. Usually, a year or quarter was used as the observation period, and the analyses were based on static economic theory. In recent years, economists have introduced dynamic theory into demand analyses by the use of the concept of distributed lags. The development of distributed lags as a workable econometric technique in supply and demand analysis can be attributed to the work of Nerlove (*10*) (*11*). Later, Martin developed a nonlinear distributed lag model containing two lag parameters for estimating elasticities of demand (*8*).

The structural characteristics of the hog-pork subsector as outlined above and the observed fluctuations in monthly hog prices suggested that dynamic influences

Figure 5. Systems Flow of Slaughtering-Processing Subsystem.

1 Hog supply of market groups from production-feeding subsystem

2 Estimate demand for each market hog group

3 Estimate packers' anticipated demand for six wholesale cuts

4 Compute the anticipated wholesale cut demand for six market hog classes

5 Select the minimum and maximum values from four lean wholesale cuts by market hog class

6 Compute the number of hog equivalents from the minimum and maximum values for each market hog class

7 Estimate live hog price for six market classes

8 Slaughter six market classes of hogs

9 Compute quantity of wholesale cuts from market groups

10 Estimate packers expected sales of retail and nonretail pork cuts by cut

11 Adjust expected sales of pork cuts to fresh wholesale basis

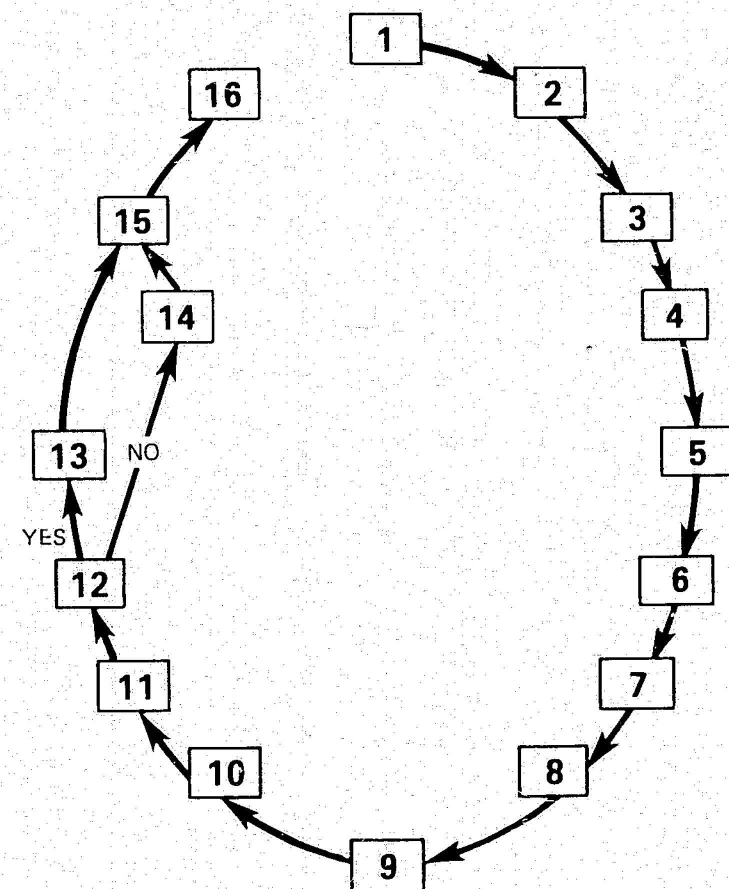
12 Will current wholesale cut production meet expected retail and nonretail pork cut sales ?

13 Compute storage quantities for wholesale cuts

14 Draw deficit quantity from storage

15 Process pork cuts into final retail and nonretail quantities

16 Transfer quantities of processed retail and nonretail pork cuts to distribution-consumption subsystem



were important determinants of hog prices. Therefore, it was imperative that a statistical technique be used that would yield consistent and unbiased estimates.

The estimation of hog prices by market classes is crucial for the system analysis. The assumption is made that the total supply of market hogs will clear the market, and be slaughtered, processed, consumed, or stored as cuts in the current period. Futhermore, the average price of barrows and gilts acts as a feedback signal in bringing forth future hog supplies as well as providing necessary quantities of pork cuts for consumption. Thus, underlying the formulation and selection of variables for the estimated equations were three basic economic hypotheses: (1) the economic cause (changes in hog supplies and pork cut sales) produces its complete effect (change in price of market hog groups) only after a lapse of time, (2) the effects of changes in the variables are spread over more than one time period (a distributed lag) and (3) different lagged coefficients are associated with the variables for hog supply and sales of pork cuts. Given these considerations, a nonstatic model incorporating distributed lags was required.

The general statistical model used to estimate all equations in the subsector model dealing with assumptions of distributed lags was Martin's two lag parameter model (*8*). The mathematical structure of this particular model is given in equation 7. The dependent variable, $Y_t$, is assumed to be a function of current and past observations of three subsets of independent variables, $X_{it-m}$, $Z_{it-m}$, and $D_{kt}$, and an error term, $e_t$ (*8*, pp. 1474-1481).

$$(7) \quad Y_t = a_o (1-\lambda)(1-\mu)(1-\beta) + \sum_{i=1}^{A} a_i X_{it}$$

$$- (\mu + \beta) \sum_{i=1}^{A} a_i X_{it-1} + \mu\beta \sum_{i=1}^{A} a_i X_{it-2}$$

$$+ \sum_{j=1}^{B} b_j Z_{jt} - (\lambda + \beta) \sum_{j=1}^{B} b_j Z_{jt-1}$$

$$+ \lambda\beta \sum_{j=1}^{B} b_j Z_{jt-2} + (\lambda + \mu + \beta) Y_{t-1}$$

$$- [(\lambda + \mu)\beta + \lambda\mu] Y_{t-2} + \lambda\mu\beta Y_{t-3}$$

$$+ \sum_{k=1}^{C} d_k D_{kt} + e_t$$

where:

$Y_{t-m}$ = the current and lagged values of the dependent variable (m=0,1,2,3).

$X_{it-m}$ = the current and lagged values of the exogenous variable associated with the lag parameter $\lambda$ (m=0,1,2).

$Z_{jt-m}$ = the current and lagged values of the exogenous variables associated with the lag parameter $\mu$ (m=0,1,2).

$D_{kt}$ = the current exogenous and/or dummy variables which are not associated with a lag.

$e_t$ = the error term.

the pure constant term.

$a_i$ = the parameters of the set of exogenous variables, $X_{it}$, (i=1, . . . , A).

$b_j$ = the parameters of the set of exogenous variables, $Z_{jt}$, (j=1, . . . , B).

$\lambda$ = the lag parameter associated with the set of exogenous variables, $X_{it}$.

$\mu$ = the lag parameter associated with the set of exogenous variables, $Z_{jt}$.

$\beta$ = the first order autocorrelation coefficient.

$d_k$ = the parameters associated with the set of exogenous variables, $D_{kt}$.

This particular estimation algorithm was used because: (1) the assumption of different lag distributions for the hog supply and pork sales variables could be made, (2) the lagged effect of selected variables could be isolated empirically, and (3) adjustments could be made for autocorrelated errors.

The economic structure of the slaughtering-processing subsystem was modeled from the viewpoint of the packer. A procedure was developed whereby consumption levels of pork cuts were translated into packer demand for market hogs (fig. 5). A data series was generated from reported pork production to approximate this demand for market hogs. The procedure for disaggregating U.S. pork production and consumption data and rectifying production and consumption of pork cut proportions was developed by Duewer in an associated study. (*3*). To develop the data series for 1965-71, the implicit assumption was made that final consumer consumption was equal to pork production.

The derived production of primal pork cuts was assumed to represent the packers' anticipated sales of primal cuts—hams, loins, bellies, ribs, butts, and picnics—for consumption as fresh or processed products. These anticipated sales of primal cuts were assumed to be a function of composite wholesale pork price, disposable personal income, zero-one monthly dummy variables, and a dummy variable for 1965 (equation 8). Only the four lean primals were estimated because packers generally buy hogs on the basis of a subjective judgment as to what the various groups of butcher hogs will yield in terms of the four lean cuts. The $j^{th}$ notation of equation 8 recognizes bellies and ribs for simplicity and consistency of subscripting in the subsector model since these two cuts are used in other phases of the model.

(8) $AQC^j_t = F(CWPP_{t-1}, DPI_t, SD, D65)$

where:

| | | |
|---|---|---|
| $AQC^j_t$ | = | anticipated packer sales of the $j_{th}$ primal cut in period t—mil. lbs.<br>j=1—hams j=5—butts<br>j=2—loins j=6—picnics |
| $CWPP_{t-1}$ | = | composite wholesale pork price lagged 1 month@\$/cwt. |
| $DPI_t$ | = | disposable personal income—\$/capita. |
| SD | = | zero-one monthly dummy variables where January served as the a priori excluded month. |
| D65 | = | dummy variable for year 1965. |

Econometrically, equation 8 was estimated as a Nerlove distributed-lag model with autoregressive errors. The mathematical structure as well as the identification of independent variables via the variable subject notation of equation 7 is given in appendix table 3.

The estimated parameters and associated statistical properties of loins are discussed and exhibited in table 9. The estimation results for the remaining lean primal cuts—ham, butts, and picnics—are given in appendix table 4. Standard statistical tests used for OLS estimation should be used with caution since the estimation of equation 8 is nonlinear in the parameter space. The significance of individual parameters may be approximated by dividing each by its standard error.

Table 9—Estimated parameters and statistical information for anticipated packer wholesale loin demand[1] ($AQC^j_t$)

| Independent variables and lagged parameters | Estimated regression parameters | Standard error of parameters |
|---|---|---|
| Constant | 214.1899 | --- |
| $CWPP_{t-1}$ | -2.1282 | 1.0757 |
| $\lambda$ | 0.0359 | 0.465 |
| $\beta$ | -0.0801 | 0.399 |
| $DPI_t$ | 0.0443 | 0.008 |
| Feb. dummy[2] | -26.7941 | 6.329 |
| Mar. dummy | 7.2408 | 8.325 |
| Apr. dummy | 0.5965 | 7.408 |
| May dummy | -25.7782 | 7.208 |
| June dummy | -34.2287 | 7.477 |
| July dummy | -39.9452 | 8.542 |
| Aug. dummy | -23.4471 | 10.205 |
| Sept. dummy | -4.4885 | 9.681 |
| Oct. dummy | 9.6399 | 8.210 |
| Nov. dummy | 6.6815 | 6.667 |
| Dec. dummy | 7.6735 | 6.238 |
| 1965 dummy | -17.9475 | 4.627 |

[1] $R^2$ = .899; F = 37.213; Mean = 209.915; D-W = 2.106; standard error of estimate = 10.545; degrees of freedom = 67. [2] January served as the a priori excluded month for equations

Using the above as a measure of significance, the lagged composite wholesale pork price, per capita disposable income, five of the seasonal variation variables, and the 1965 dummy variable were judged significant in all equations. The appropriate economic sign for CWPP and DPI were estimated in all four equations. Variables for the months—February, May, June, July, and August—as well as the 1965 dummy variable were significant in all four equations. The five monthly variables had negative signs, indicating that demand for the four pork cuts in these months was lower than in the base month, January. The remaining months displayed a mixture of positive and negative signs. The months comprising the fourth quarter exhibited positive signs for all cuts except ham, indicating anticipation of increased consumption during the Thanksgiving-Christmas-New Years holiday season. A shift in the demand curve for pork seems to have occurred between 1965 and 1966. The 1965 dummy used in the equations to reflect this shift was significant for all four cuts. The $R^2$ and D-W statistics are acceptable. The distributed lag parameters—$\lambda$,—and the autocorrelation coefficient—$\beta$—were not significantly different from zero. This would suggest linear estimation of equation 8. However, the OLS estimation of equation 8 was much poorer with respect to $R^2$, D-W, and standard error of estimate statistics. Therefore, the nonlinear Nerlove equation was used.

The economic structure of the market hog price equation was hypothesized from the viewpoint of the packer appraising a live hog market in which a predetermined supply of hogs is distributed among five market classes of barrows and gilts and one market class of cull sows and boars. In estimating prices for these alternative market groups, packers are attempting to equate the predetermined supplies with their anticipated demand for pork cuts (demand which is reflected back from the retail market to the live market). Thus, for each market group of hogs, price is assumed to be a function of hog supplies, demand for hogs, beef price, and monthly dummy variables (equation 9).

(9) $PBG^I_t = f(SBG^I_t, TBG_t, PHD^I_t, TWHD^I_t, BP_t, SD)$

where:

$PBG^I_t$ = live price of the $I^{th}$ market hog group in period t—\$/cwt. (I=1,—6).

I = 1—180- to 200-pound barrows and gilts.
I = 2—200- to 220-pound barrows and gilts.
I = 3—220- to 240-pound barrows and gilts.
I = 4—240- to 270-pound barrows and gilts.
I = 5—270-plus pound barrows and gilts.
I = 6—sows and boars.

$TBG_t$ = total supply of market hogs in period t—number/1,000 U.S. population.

$PHD_t^I$ = additional number of hogs demanded in the $I^{th}$ weight group in period t—hog equivalents/10,000 U.S. population (I-1,—6).

$TWHD_t^I$ = minimum number of hogs demand in the $I^{th}$ weight group in period t—hog equivalent/10,000 U.S. population.

$BP_t$ = choice live steer price; in period $/cwt.

SD = zero-one monthly dummy variables.

The supply of market hogs (U.S. commercial slaughter) in any given month is represented by two variables: (1) the number of hogs in each market group, and (2) total number of market hogs. These two variables are generated within the production-feeding subsystem and transferred to the slaughtering-processing subsystem. In this subsystem, the hogs are priced and slaughtered by market group.

The demand variables—$PHD^I$ and $TWHD^I$—were assumed to represent expected primal cut sales by market group classification in terms of equivalent hog numbers. The monthly data series for these variables were generated (synthesized) from reported U.S. pork production data in two phases. The basic idea was to translate consumption levels of pork cuts into packer demand for live hogs. Final consumer consumption was assumed equal to U.S. pork production in developing the data series for the 7-year period (1965-71). In the first phase, reported U.S. pork production was divided into six primal wholesale pork cuts (hams, loins, bellies, ribs, butts, and picnics) by using standard yield coefficients (*18*). To this derived production, the change in inventory of pork cuts (reported cold-storage holdings) was added or subtracted. This monthly data series was assumed to represent total U.S. consumption of primal pork cuts. The data were further disaggregated into expected primal cut sales on a market-weight classification basis as follows: (1) The total U.S. consumption of primal cuts was multiplied by the market class percentage distribution factor observed from the commercial slaughter information, and (2) then divided by individual cut yield coefficients for each of the six market groups. The completion of the first phase resulted in a monthly time series of expected primal cut sales by market groups in terms of hog numbers.

The second phase consisted of selecting or identifying the $PHD^I$ and $TWHD^I$ variables from the expected primal cut sales. The process was limited to the four lean cuts. For each cut, minimum and maximum quantities were selected for each of the market groups month by month. The minimum quantity was assumed to represent the monthly minimum expected sales of cuts—$TWHD^I$—from a particular market hog weight group. The maximum quantity minus the minimum quantity represented the additional monthly expected sales of cuts—$PHD^I$—from a specific market group. Thus, minimum expected sales of cuts—TWHD—represented the number of hogs in each weight group that the packer must buy to meet minimum demand for the four lean pork cuts. Similarly, the $PHD^I$ variable represents the additional number of hog equivalents in each market group that are required to fulfill the anticipated sales of the cut in greatest demand. The estimates for both the supply and sales variables were divided by U.S. population numbers for scaling purposes before they were entered into the estimation procedure.

Four of the six market hog price equations were estimated in the mathematical form depicted in equation 7. The exceptions (180 to 200 pound barrows and gilts, and market sows and boars) were estimated as an autoregressive Nerlove equation. The specific mathematical form and identification of variables are given in appendix tables 5 and 6. The estimated parameters and statistical properties of the equations are presented in table 10 and appendix tables 7 and 8.

Equation 9 is nonlinear in the parameter space, and, as for equation 8, caution should be observed in interpreting its statistical properties. In general, the estimation results were good. The coefficient of determination—$R^2$—was in the range of 93 to 95 percent, while standard errors of estimate were between 0.81 and 0.91, with a D-W statistic around 2.00 for all six equations.

By dividing the estimated parameter by its standard error, the relative significance of the variables can be assessed. As shown in table 10, total hog supply ($TBG_t$); minimum expected primal sales ($TWHD^I$); Choice steer price ($BP_t$); February, July, and August zero-one variables; and the $\lambda$, $\epsilon$, and $\beta$ parameters were significant in the price equation for 220- to 240-pound barrows and gilts. The appropriate economic sign was estimated for those parameters associated with supply and expected sales—packer demand—for all market hog groups of equation 9 (table 20 and appendix tables 7 and 8). The positive and highly significant autocorrelation coefficient—$\beta$—indicated serial correlation. The positive $\beta$ indicated the estimated parameters had been adjusted for positive serial correlation, which is frequently the case with economic time series data. However, the usefulness of the D-W statistic is limited as a test for serial correlation in the case of nonlinear estimation because of bias (*) in the original disturbances (14).

Changes in supply and demand are continually occurring in the hog-pork industry. The resulting change in live hog prices may not be instantaneous. The significant $\lambda$ and $\mu$ values indicated that the hypothesis of a lagged adjustment in live hog prices to changes in supply and demand could not be rejected. The time required for price to adjust to within a specified interval of a new equilibrium price level was calculated, and results are presented in table 11. The positive $\lambda$ indicated the price of 220 to 240 pound barrows and gilts underadjusted to supply changes while the negative $\mu$ indicated an overadjustment of price to changes in packer demand for live hogs. (table 11). The average

Table 10--Estimated parameters and statistical information for market price of 220 to 240 pound barrows and gilts, ($PBG_t^I$)[1]

| Independent variables and lagged parameters | Estimated regression parameters | Standard error of regression parameters |
|---|---|---|
| Constant | 7.1517 | ... |
| $SBG_t$ | -0.1005 | 0.498 |
| $TBG_t$ | -0.3628 | 0.201 |
| $TWHD_t$ | 0.0230 | 0.012 |
| $\lambda$ | 0.7003 | 0.095 |
| $\mu$ | -0.5874 | 0.124 |
| $\nu$ | 0.6857 | 0.164 |
| $BP_t$ | 0.1171 | 0.062 |
| Feb. dummy[2] | -0.8141 | 0.723 |
| Mar dummy | 1.8758 | 0.910 |
| Apr. dummy | -0.7359 | 0.908 |
| May dummy | -0.2732 | 0.659 |
| June dummy | -0.7054 | 0.800 |
| July dummy | -2.4912 | 0.763 |
| Aug. dummy | -1.6689 | 0.922 |
| Sept. dummy | -1.7531 | 1.115 |
| Oct. dummy | 0.5787 | 0.991 |
| Nov dummy | -0.6528 | 0.621 |
| Dec. dummy | 0.4883 | 0.716 |

[1] $R^2$ = .955, D-W = 2.063; F = 57.150, mean = 21.415; standard error of estimate = 0.810 degrees of freedom = 65. [2] January served as the a priori excluded month.

Table 11--Estimated time required for price of market barrows and gilts, and market sows and boars, to adjust to change in supply and demand[1]

| Market group of hogs | Calculated length of adjustment | |
|---|---|---|
| | Supply | Expected primal cut sales |
| | *Months* | *Months* |
| Barrows and gilts: | | |
| 180-200 pounds | 12.8 | N.A |
| 200-220 pounds | 5.3 | 4.4 |
| 220-240 pounds | 8.5 | 5.6 |
| 240-270 pounds | 10.9 | 5.6 |
| 270-Plus pounds | 9.7 | 1.9 |
| Sow and boars | 10.9 | N.A |
| Average, 5 groups of barrows and gilts | 9.4 | 5.1 |

[1] Based on monthly U.S. data for 1965-71.

NA = not available.

length of time required for the market price of barrows and gilts to adjust to within 95 percent of a new equilibrium level was 9.4 months after a supply change and 5.1 months after a change in expected primal cut sales. The shortest time required after a supply change was 5.3 months for the 200- to 220-pound barrows and gilts. This particular group of market hogs also gave the shortest time, 4.4 months, to adjust to a change in expected sales.

With the prices of the individual market groups developed, the subsystem proceeds with the process of slaughtering the hogs and processing the primal cuts into final consumer cuts. The quantity of green cuts is determined by applying appropriate yield coefficients to each market group. Green cuts, consisting of the six primals and trimmings, means the raw pork product before any processing or final trimming.

The quantity of green cuts to be processed into consumer pork cuts depends on packers' anticipation of retail demand. The anticipated retail demand for the eight consumer pork cuts is estimated by equation 10.

$$(10)\quad QPCD_t^I = f(WBP_t, CWPP_{t-1}, CRPP_{t-1}, RCP_t, STQGSC_t, TCKPC_t,$$

where:

$QPCD_t^I$ = anticipated quantity demanded of the $I^{th}$ retail cut in period t—mil. lbs. (retail weight).

| | |
|---|---|
| I = 1—hams | I = 6—picnics |
| I = 2—loins | I = 7—not used |
| I = 3—not used | I = 8—bacon |
| I = 4—ribs | I = 9—sausage |
| I = 5—butts | I = 10—luncheon meat |

$WBP_t$ = wholesale beef price in period t—\$/cwt.

$CWPP_{t-1}$ = composite wholesale pork price lagged 1 month—\$/cwt.

$CRPP_{t-1}$ = composite retail pork price lagged 1 month—\$/cwt.

$RCP_t$ = retail chicken price in period t—\$/cwt.

$STQGSC_t$ = total quantity of fresh pork from current slaughter in period t—lbs./capita.

$TCKPC_t$ = U.S. commercial broiler production in period t—lbs./capita.

$DPI_t$ = disposable personal income in period t—\$/capita.

SD = zero-one monthly dummy variable, where January served as the a priori excluded month.

Equation 10 was estimated as a linear function by least squares. The regression results for loins and the remaining seven consumer cuts are given in table 12 and appendix table 9.

Table 12—Estimated parameters and statistical information for packer's anticipated retail demand of loins ($QPCD_t^L$)[1]

| Independent variables and lagged parameters | Estimated regression parameters | Standard error of regression parameters |
|---|---|---|
| Constant | 25.2138 | --- |
| $WBP_t$ | 0.2924 | 0.119 |
| $CWPP_{t-1}$ | -0.0447 | 0.079 |
| $STQGSC_t$ | 34.8602 | 1.022 |
| $DPI_t$ | 0.0167 | 0.002 |
| $RCP_t$ | -0.2865 | 0.190 |
| Feb. dummy[2] | 0.1680 | 1.337 |
| Mar. dummy | 0.2401 | 1.198 |
| Apr. dummy | -9.6578 | 1.194 |
| May dummy | -9.2980 | 1.314 |
| June dummy | -8.6355 | 1.382 |
| July dummy | -5.9020 | 1.484 |
| Aug. dummy | -8.8102 | 1.277 |
| Sept. dummy | -7.1834 | 1.187 |
| Oct. dummy | -0.5031 | 1.169 |
| Nov. dummy | -4.6183 | 1.153 |
| Dec. dummy | -0.2751 | 1.152 |

[1] $R^2$ = .994; F = 737.029; mean = 195.048; D-W = 1.526; standard error of estimate = 2.141; degrees of freedom = 67. [2] January served as the a priori excluded month.

All of the independent variables listed in equation 10 were not always included in the single equation estimates of the eight consumer pork cuts. The explanatory variables producing the best fit for the anticipated retail loin demand were wholesale beef price, composite wholesale pork price, composite retail pork price, retail chicken price, per capita U.S. broiler production, per capita disposable personal income, and the 11 zero-one monthly dummy variables. Of these variables, wholesale beef price, per capita quantity of fresh pork, and per capita disposable personal income were the most significant. In general, the statistical properties of all eight equations were good, with high $R^2$ and t- statistics as well as relatively low standard error of estimates (table 12 and app. table 9). The D-W statistic was acceptable in all equations, with some serial correlation indicated. The equations exhibiting a low D-W statistic were not considered of serious enough consequence to warrant restimation.

## Distribution-Consumption Subsystem

The distribution-consumption subsystem is structured to interface with the production-feeding and the slaughtering-processing subsystem as a synchronized and integrated part of the subsector model. The objective of this subsystem is to complete the systems model and represent the organizational structure of the distribution segment of the U.S. pork subsector.

This subsystem consists of two main parts: (1) distribution of pork cuts as wholesale cuts to nonretail and retail outlets and (2) consumption of pork products assumed to occur in the institutional and household segments of the United States. The nonretail outlets in the institutional channel include hotels, restaurants, and institutions (schools, hospitals, and so on). The distribution outlet for household consumption is divided into chain supermarkets, independent supermarkets, and convenience grocers (figure 6).

In distributing the pork cuts for the various categories of consumption there are two pricing points: the wholesale market and the retail market. The total quantity of pork (supply) is in the form of the eight processed cuts from the slaughtering-processing subsystem. The wholesale pricing point determines the wholesale price for each pork cut and the quantity of each cut to be distributeed to the consumption outlets. Through the nonretail outlet, the wholesale cuts are consumed without further market action. The pork distributed through the retail channel is priced by cut for the three retail outlets.

At present, the U.S. pork distribution and consumption sector mainly operates in a free competitive market, with limited vertical integration between packers and retailers. Therefore, wholesale and retail markets serve as the points for price and quantity determination, with the packers and processors on one side and consumer of pork on the other (figure 6).

The wholesale market provides the link between this subsystem and the slaughtering-processing subsystem. The supply of pork by cuts in fresh and processed form as well as the average live market hog price is furnished by the slaughtering-processing subsystem. There are three major segments of the distribution-consumption subsystem: (1) wholesale prices by pork cuts, (2) quantity of wholesale pork by cuts and market outlets, and (3) retail pork prices by cut and retail outlet. Operation of this subsystem begins with the determination of wholesale prices and the distribution of cuts to the retail and nonretail market channels. The pork distributed to the retail sector is in turn priced by retail cut, and the quantity moving to the three retail outlets is subsequently determined. A number of variables influence the three parts of this subsystem, lagged prices, lagged quantities, and exogenous variables. For example, the wholesale price of pork cuts is affected by lagged wholesale pork prices, lagged retail pork prices, total fresh pork supply, and the monthly dummy variables.

From the three major endogenous segments, several industry statistics were derived or calculated. A composite wholesale pork price was derived from the individual wholesale pork cut prices. Per capita pork consumption by cuts and by market outlets was calculated from the quantity of pork to be consumed. Average retail pork price by cuts and a composite retail pork price by outlets and cuts were computed. Two price spread series were calculated when combined with the average market hog price—the farm-to-retail price spread and the wholesale-to-retail price spread.

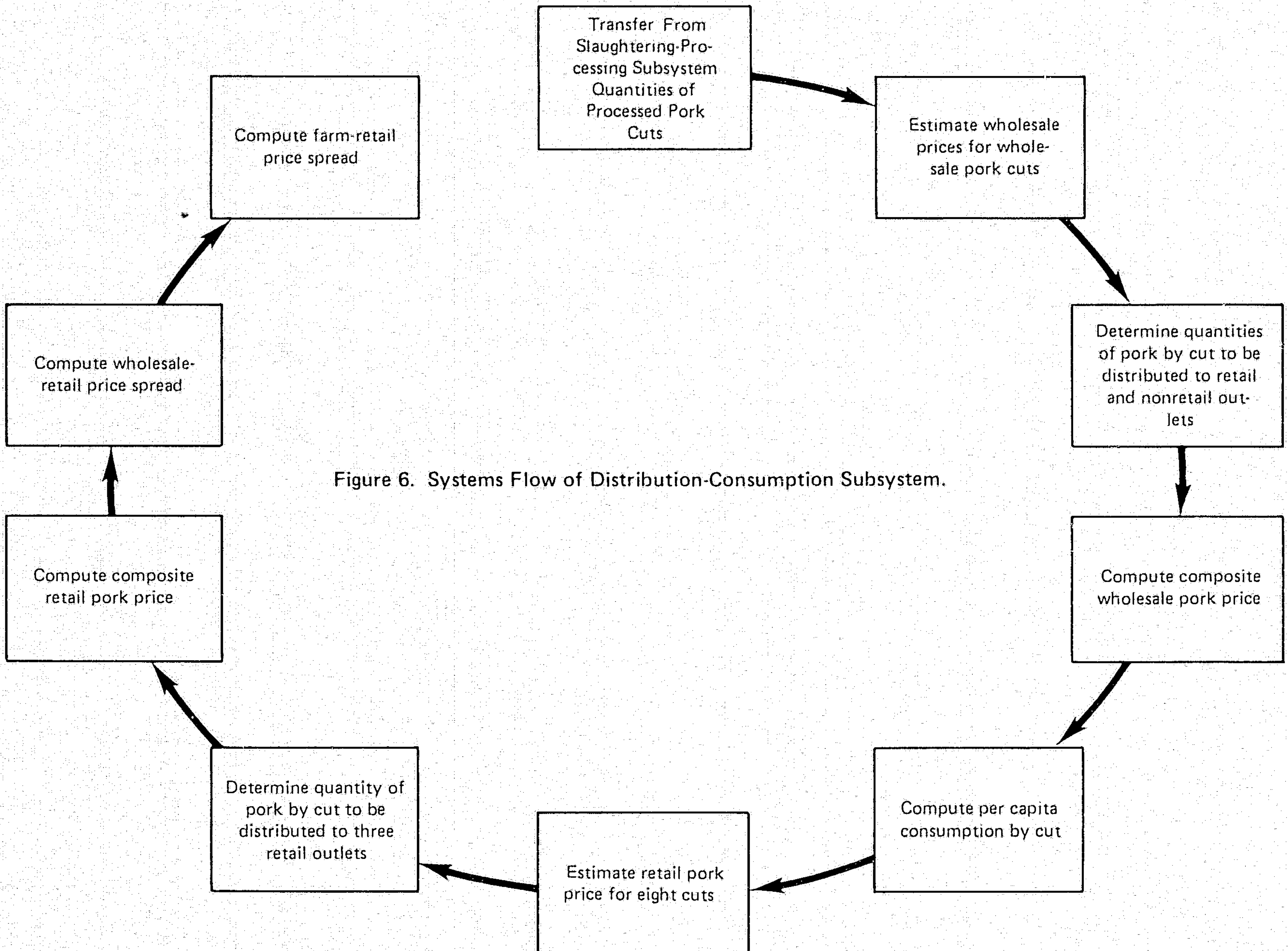



Figure 6. Systems Flow of Distribution-Consumption Subsystem.

Finally, the composite wholesale pork price and wholesale prices for hams, loins, butts, and picnics are transferred back to the slaughtering-processing subsystem. These five price variables are used in the slaughtering-processing subsystem as lagged endogeneous variables.

In mathematical form, the distribution-consumption subsystem can be delineated into two types of equations: functional forms and identities. Functional equations are used to estimate the three major endogenous variables. Two types of statistical techniques were used to estimate the functional forms: linear regression and nonlinear autoregressive regression. The remaining endogenous variables of the distribution-consumption subsystem were calculated by using identities or arithmetical equations. The nonlinear regression model is a derivation of the two-lag model used in the slaughtering-processing subsystem (equation 7). In making use of the general model in this subsystem, the $\lambda$ and $\mu$ parameters are set equal to zero, thus reducing the two-lag model to a single lagged model with a parameter, $\rho$ to account for autoregressive errors. The specific type of statistical method used to estimate the endogenous variables is presented in table 13.

Ordinarily, wholesale pork prices and quantities are determined simultaneously in the wholesale market. However, in a recursive system of equations, only unilateral causal relationships are possible. Thus, the system establishes wholesale pork prices prior to determining the quantity to be distributed to the various outlets. As modeled, the slaughtering-processing subsystem anticipates the total quantity of cuts to be processed (equation 10). This anticipated quantity, in turn, serves as a basis for the total quantity of wholes cuts available to the wholesale market. Once wholes. prices are determined by cut, the distribution of cuts retail and nonretail outlets occurs.

The wholesale prices by cuts was estimated usin linear regression technique and consisted of the follo ing variables:

$$(11)\quad WPP^j_t = f(WPP^j_{t-1}, APR^j_{t-1}, TQP^j_t, STOGS_t, RPB_t, RCP_t, BFCM_t, TCKP_t, SD, D65, FRPS_{t-1})$$

where:

$WPP^j_t$ = the wholesale price of the $j^{th}$ wholesa cut in period t—$/cwt. (j-1,2,4—6,8.10).

| | |
|---|---|
| j = 1—hams | j = 6—picnics |
| j = 2—loins | j = 7—not used |
| j = 3—bellies | j = 8—bacon |
| j = 4—ribs | j = 9—sausage |
| j = 5—butts | j = 10—luncheon meat |

$WPP^j_{t-1}$ = the lagged wholesale price of the $j^{th}$ wholesale cut@$/cwt.

$APR^j_{t-1}$ = average retail price of the $j^{th}$ processe cut lagged one period (j-1,2,4—6,8—10) $/cwt.

$TQP^j_t$ = total quantity of the $j^{th}$ processed cu available for wholesale market in perio t, (j-1,2,4—6,7—10)—mil. lbs.

Table 13—Definition of variables contained in equation for estimating wholesale pork prices and quantities, and retail pork prices, by outlets and cuts

| Statistical equation | $WPP^j_t$ | | $QP^{I,j}_t$ | $PR^{I,j}_t$ | |
|---|---|---|---|---|---|
| | Linear | | Static with autoregressive error | Static with autoregressive error | |
| Endogenous variables associated with y lags | . . . | | $TQP^j_t$ | $QPX^{I,j}_t$ | |
| Lagged dependent and other endogenous variables not associated with lags | $WPP^j_{t-m}$, $APR^j_{t-m}$, $FRPS_{t-m}$ | $TQP^j_{t-m}$, $STQGS_t$ | $WPP^j_t$ | $PR^{I,j}_{t-m}$ | |
| Exogenous variables | $BFCM_t$, $RBP_t$, Trend | $TCKP_t$, $RCP_t$ | Trend | $TCKP_t$, $RCP_t$ | $RBP_t$, $RMP_t$ |
| Dummy variables | D65, SD | | SD | D65, SD | |

| | | |
|---|---|---|
| $STQGS_t$ | = | total quantity of fresh pork available in period t from slaughter in period t—mil. lbs. |
| $RBP_t$ | = | average retail beef price in period t—c/lb. |
| $RCP_t$ | = | average retail chicken price in period t—c/lb. |
| $BFCM_t$ | = | U.S. beef consumption in period t—mil. lbs. |
| $TCKP_t$ | = | U.S. commercial broiler production in period t—mil. lbs. |
| SD | = | zero-one monthly dummy variables where January served as the a priori excluded month. |
| D65 | = | dummy variable for year 1965. |
| $FRPS_{t-1}$ | = | the farm-retail price spread lagged one period—$/cwt. |

The estimation results for the wholesale price of bellies are presented in table 14 and those for the remaining wholesale pork cuts are in appendix table 10. In general, the estimation results were acceptable. Appropriate economic signs and high t-values were indicated for the variables assumed to influence the wholesale price of pork bellies. Seasonal dummies for months May through September were all negative and significant at the 0.05 level or greater. This indicates that the price of pork bellies was depressed in this 5-month period relative to the base month, January. A 1-month lagged pork belly price was very significant, thus indicating the cyclical influence of wholesale prices. As expected, the total quantity of pork avaialble from current slaughter was significant and carried the appropriate negative sign. The total quantity of pork processed the previous month was significant, possibly indicating a proxy variable for potential pork stocks. The high $R^2$ value and significant F-statistic coupled with the satisfactory D-W statistic indicated the equation had a relatively good fit.

Table 14—Estimated coefficients and statistical information for wholesale price of pork bellies, $(WPP_t^j)$[1]

| Independent variable | Estimated regression coefficient | t-Value |
|---|---|---|
| Constant | 36.9829 | . . . |
| $WPP_{t-1}^j$ | 0.7073 | 6.317 |
| $WPP_{t-2}^j$ | -0.1819 | 2.115 |
| $TQP_{t-1}^j$ | -0.0804 | 2.744 |
| TCP | 0.2850 | 2.002 |
| STQGS | -0.0394 | 7.332 |
| BFCM | 9.7223 | 2.651 |
| TCKP | 11.0872 | 1.428 |
| Feb. dummy[2] | -3.1327 | 2.687 |
| Mar. dummy | -1.1709 | 0.987 |
| Apr. dummy | 0.6054 | 0.527 |
| May dummy | -2.6735 | 2.204 |
| June dummy | -6.2204 | 4.511 |
| July dummy | -6.5141 | 4.679 |
| Aug. dummy | -6.2584 | 5.126 |
| Sept. dummy | -2.2824 | 2.072 |
| Oct dummy | -1.4603 | 1.328 |
| Nov dummy | 2.1924 | 1.780 |
| Dec. dummy | 2.7832 | 2.622 |

[1] $R^2$ = .959; F - 83.484; mean = 52.78 D-W - 2.122; standard error of estimate = 1.8453; degrees of freedom = 41 [2] January served as the a priori excluded month.

A composite wholesale pork price is calculated by weighing the wholesale prices estimated for the individual pork cuts by the quantity processed of the respective cuts:[4]

$$(12)\quad CWPP_t - \frac{\sum_{j=1}^{10}(WPP^j * TWP_t^j)}{\sum_{j=1}^{10} TQP_t^j}$$

It is assumed that $CWPP^t$ is equal to the reported U.S. average wholesale price.

After the wholesale price is established, the quantity of each cut distributed to retail and nonretail outlets is determined. These quantities were estimated by the nonlinear autoregressive regression technique used in equation 7:[5]

$$(13)\quad QP_t^{Ij} = f(TQP_{t-1}^j, QP_{t-1}^{Ij}, WPP_t^j, SD, T)$$

$$(I=1-4); (j=1-10)$$

where:

$QP_t^{Ij}$ = the quantity of the $j^{th}$ processed cut distributed to the $I^{th}$ outlet in period t—mil. lbs.
I=1—HRI
I=2—chain supermarkets
I=3—independent supermarkets
I=4—convenience grocers.

The estimation results for equation 13 are presented in appendix table 11. A static autoregressive model was used. Estimation results were good, with $R^2$ values ranging from 0.97 to 0.99 and generally satisfactory D-W statistics. As a group, the seasonal dummy variables were very significant. Since an autoregressive error model was used, the beta coefficient accounts for the autoregressive

[4] Variables of equation 12 have been identified previously.

[5] The $j^{th}$ notation for equation 13 is the same as in equation 11. Independent variables identified in previous equations are not repeated here.

error in the residuals. It proved to be highly significant in most equations. This particular parameter is also an indication of the influence of the lagged dependent variable.

Per capita pork consumption by individual cut and on a composite basis are calculated by equations 14 and 15.

$$(14)\quad PCQP_t^j = TQP_t^j / POP$$

where:

$PCQP_t^j$ = per capita consumption of the $j_{th}$ processed cut--(lbs.), (j=1--10).

$$(15)\quad TPCQP = \sum_{j=1}^{10} PCQP^j$$

where:

TPCQP = composite per capita pork consumption--lbs.

After wholesale prices and quantities distributed to nonretail and retail outlets are determined, the system proceeds to price the pork cuts delivered to the three retail outlets. Pork cuts are distributed to the HRI channels without any further pricing. However, that portion of pork cuts delivered into retail outlets has retail prices determined by cut. Under the assumption that no storage occurs between the wholesale the retail markets, the quantity of pork distributed to each retail outlet is consumed in that amount by households.

Variables used in estimating pork retail prices by cuts are presented in equation 16. The estimation technique is the static autoregressive technique derived from equation 7.

(16)

$$PR_t^{Ij} = f(QP_t^{Ij}, QP_{t-1}^{Ij}, PR_{t-1}^{Ij}, RBP_t, RMP_t, TCKP_t, RCP_t, SD, D65)$$

The estimation results for the three retail outlets—chain, independent, and convenience—by the eight retail cuts are presented in appendix table 12. The nonlinear autoregressive model provided estimation results superior to those of a singe equation linear model. $R^2$ values ranged from 0.91 to 0.99. The equation for ham and bacon produced the lowest $R^2$ values (0.91) of the 24 single equations estimated for the retail cuts (app. table 12). Sausage and lunch meat equations yielded the highest $R^2$ values of the equation series--0.97 and 0.98, respectively.

Following the determination of retail prices, an average retail price by cut is calculated as indicated in eq. 17. Then, a composite retail pork price is computed (equation 18).[4]

$$(17)\quad APR_t^j = \frac{\sum_{I=1}^{4} (PR_t^{I,j} * QP_t^{Ij})}{\sum_{I=1}^{4} QP_t^{Ij}}$$

$$(18)\quad CRPP_t = \frac{\sum_{j=1}^{10} (APR_t^j * TQP_t^j)}{\sum_{j=1}^{10} TQP_t^j}$$

where:

$CRPP_t$ = composite retail pork price; \$/cwt.

Price spreads are estimated at two levels—wholesale-retail and farm-retail (equations 19 and 20). The two linear equations were estimated by ordinary least squares.

$$(19)\quad WRPS_t = f(WRPS_{t-1}, APR_{t-1}^j, STOGS_t, CRPP_t, CWPP_t, APBG, Trend, SD, D65, BFCM, TCKP)$$

where:

$WRPS_t$ = wholesale-retail price spread, \$/cwt.

$APR_t^j$ = average retail pork price for jth cut.
j=2—loins
j=5—butts
j=6—picnics

$$(20)\quad FRPS_t = f(FRPS_{t-1}, CRPP_t, CWPP_t, APBG_t, TCKP_t, Trend, SD)$$

where:

FRPS = farm-retail price spread@\$/cwt.

The regression results are given in appendix table 13. Estimation equations were used for these two price spread variables for the following reasons:

1. In compiling the national statistic, the U.S. Department of Agriculture accounts for price specials on a weekly basis.
2. Price specials were not a component of the subsystem model. Therefore, a single arithmatical calculation could not be done for comparison with the industry statistic.

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[4] Only those variables not identified earlier or those needed for clarification are identified.

## Simulation Results

The hog-pork systems model, together with the specifications of exogenous price and quantity input variables, was simulated on a monthly basis for January 1965 though December 1971. Lagged reported data for the period October 1964 to December 1964 were used to initialize the model. The model was completely recursive and operating on self-generated data for January 1965-December 1971. During the simulation period, the model compared simulated variables with reported variables, calculated the error in terms of absolute terms and percentages, and then proceeded to plot the simulated and reported data.

The simulation results (figs. 7-11) and validation of the model are discussed in terms of the following five variables:

1. Sow farrowings.
2. Total number of market hogs sold—that is, commercial hog slaughter.
3. Average price of market barrows and gilts.
4. Composite wholesale pork price.
5. Composite retail pork price.

These variables were selected because they are frequently used when discussing the economic structure of the hog-pork industry or the impact of demand and supply changes. The relative frequencies of simulated vs. historical for the five performance variables are presented in appendix figures 1-5.

In general, the model traces satisfactorily the time path for all five variables. As expected, the price variables displayed more variation than those for sow farrowings and market hogs sold. However, the variation was not considered serious because it was not consistently above or below the reported time path. The quantity variables—sow farrowing and total number of market hogs sold—were simulated with less variation. The annual average of the percentage monthly deviations for the 7-year period ranged from 5 percent below to just over 1 percent above the reported sow farrowings for the same period (fig. 7 and table 15). A similar percentage deviation was observed for total number of market hogs sold. The observed percentage deviation ranged from 4.75 percent below reported commercial hog slaughter to 2.13 percent above. Since this was a behavioral simulation model, no attempt was made to obtain simulated values which minimized the error.

## Validation of Model

Much has been written about procedures used to simulate economic systems. However, relatively little has been said about how to verify a simulation model. In the strictest sense, validation means to prove that a model is true. But to prove that a model is "true" requires: (1) a set of established criteria for differentiating between models which are "true" and those which are "not true", and (2) the ability to readily apply these criteria to any given model.

Naylor (*9*) outlines two general approaches to model verification—verification by forecasting and historical verification. Verification by forecasting has the disadvantage of requiring (1) great lengths of time and (2) use of only part of the information available when constructing the model. Historical verification is questionable in that it generally uses the same data that went into developing the model.

A wide variety of tests have been developed for determining whether or not the relationship between simulated and actual time paths can be attributed to chance. These techniques include Theil's inequality coefficient (equation 21), spectral analysis, factor analysis, F-Test, and others. Theil's inequality coefficient was used as the test statistic for evaluating the simulation results of this study (*24*).

$$U = \frac{\sqrt{\frac{\Sigma (P-A)^2}{n}}}{\sqrt{\frac{\Sigma A^2}{n}}} \qquad (21)$$

Table 15—Annual average monthly percentage deviations for selected variables, 1965-71

| Year | Sows farrowings | Commercial hog slaughter | Average price, market barrows and gilts | Composite wholesale pork price | Composite retail pork price |
|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| 1965 | -3.20 | 2.13 | -3.95 | -3.11 | 2.40 |
| 1966 | -0.25 | -1.98 | -0.55 | 1.03 | 0.98 |
| 1967 | -2.25 | 1.55 | -6.67 | -5.64 | 6.41 |
| 1968 | -0.66 | -4.75 | 6.41 | -1.33 | 8.66 |
| 1969 | 1.35 | -0.51 | -3.81 | -3.37 | 0.63 |
| 1970 | -2.08 | -1.31 | 3.93 | 12.62 | -4.34 |
| 1971 | -5.06 | -2.48 | 4.80 | 8.51 | 3.53 |

Figure 7. Number of sows farrowed:

-- Simulated and

— Reported

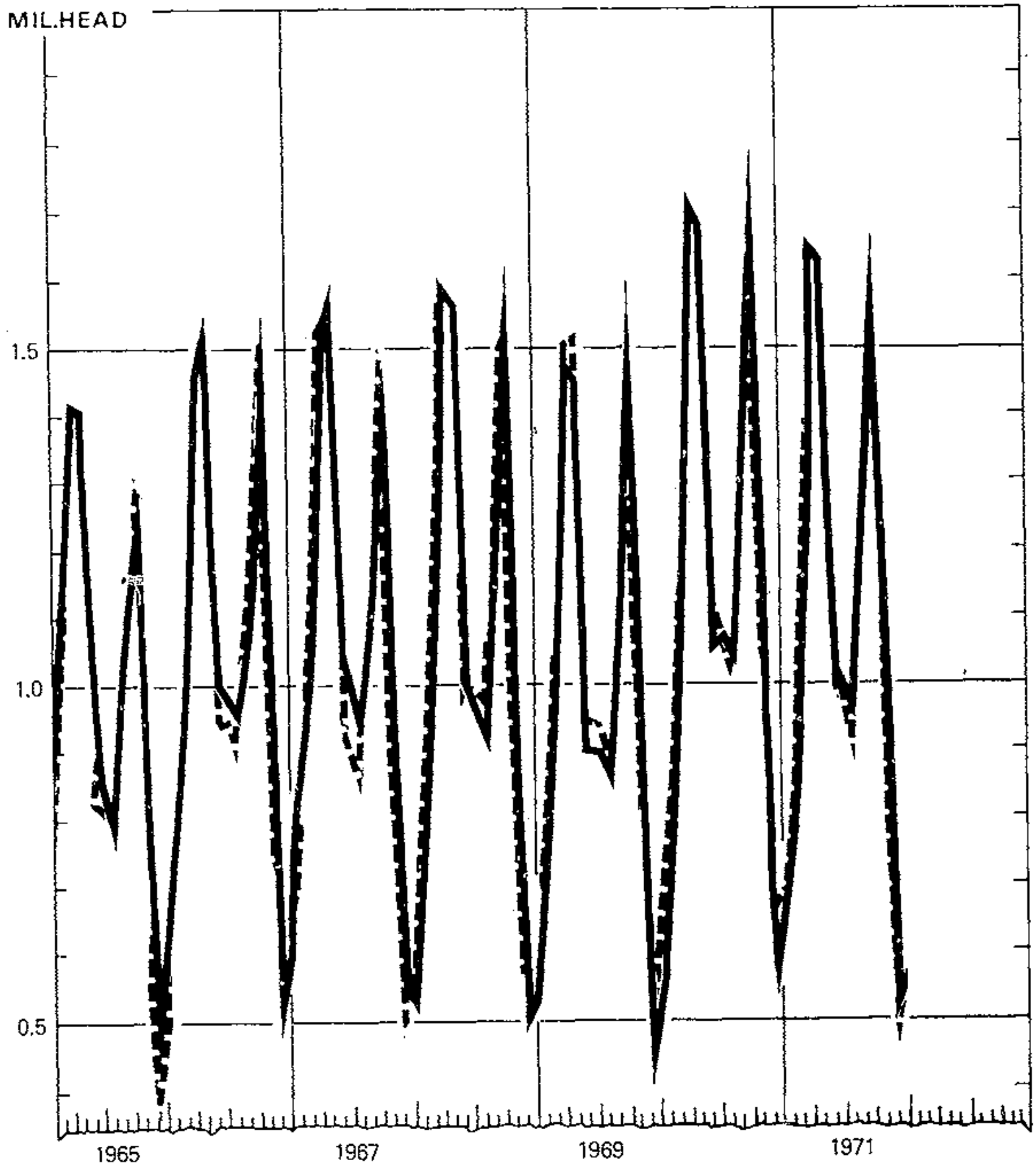


Figure 8. Commercial hog slaughter:

- - -Simulated and

——Reported

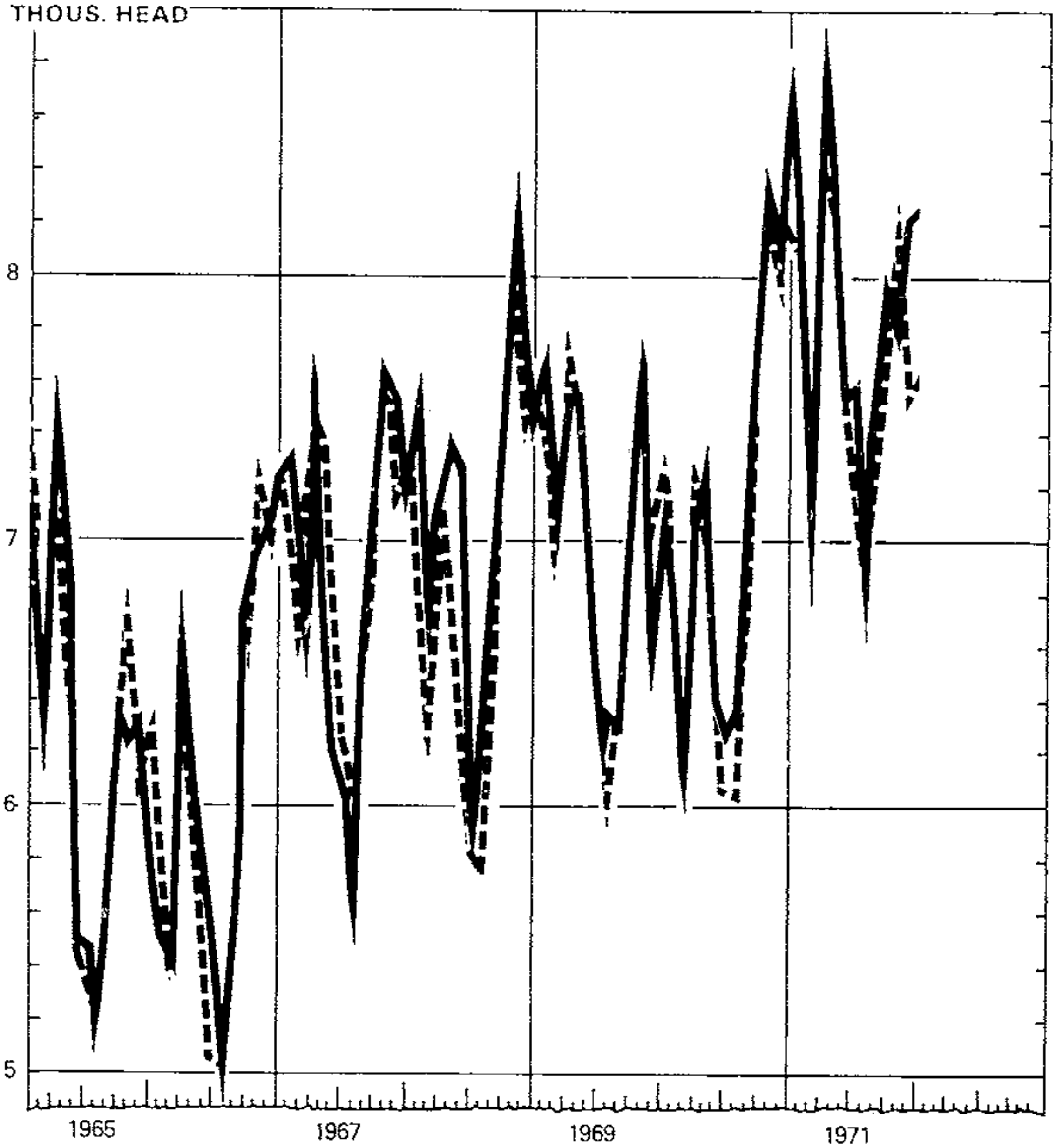


Figure 9. Average market prices of barrows and gilts:

- - - Simulated and

—— Reported

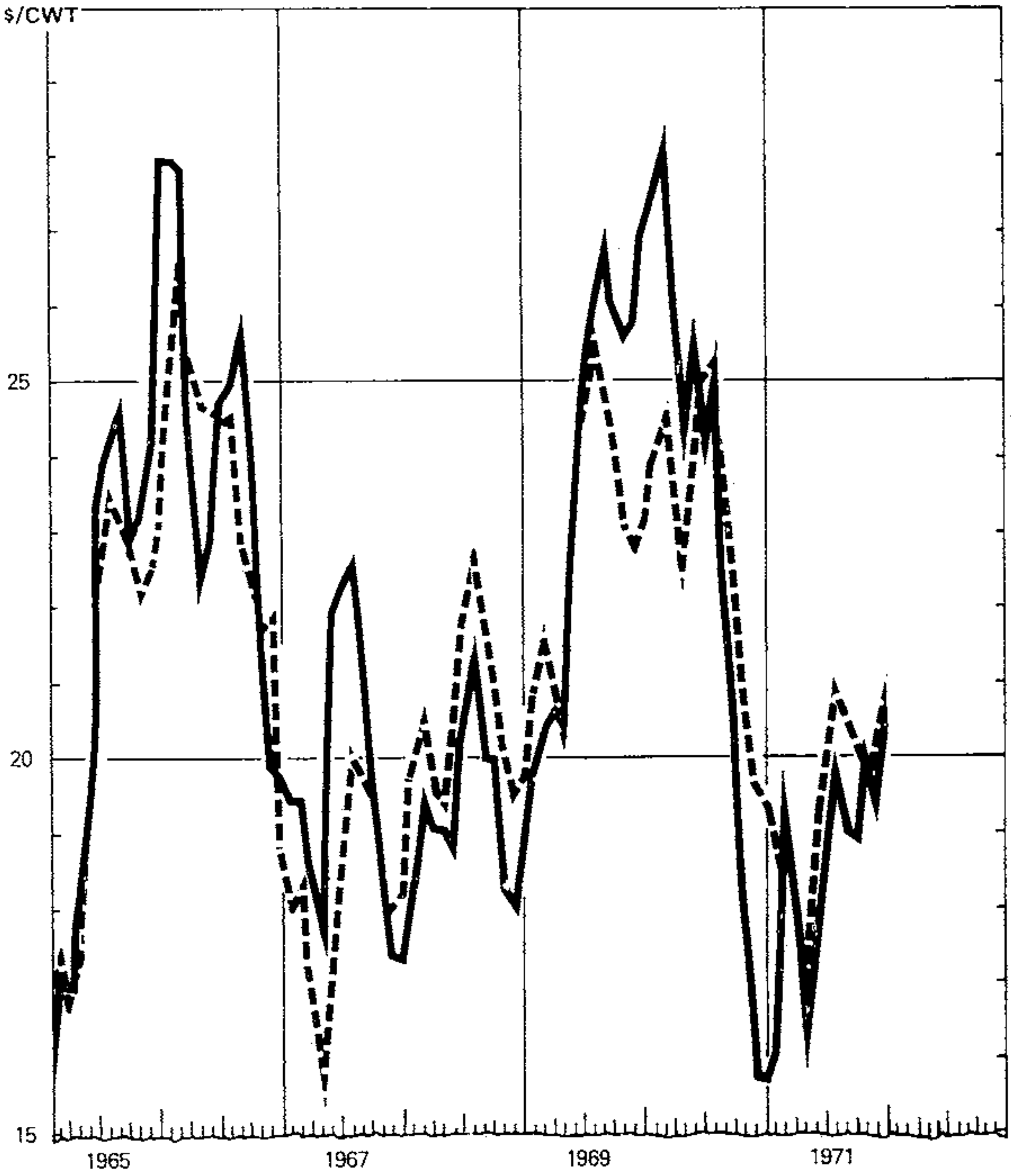


Figure 10. Composite wholesale pork price:

- - - Simulated and

— Reported

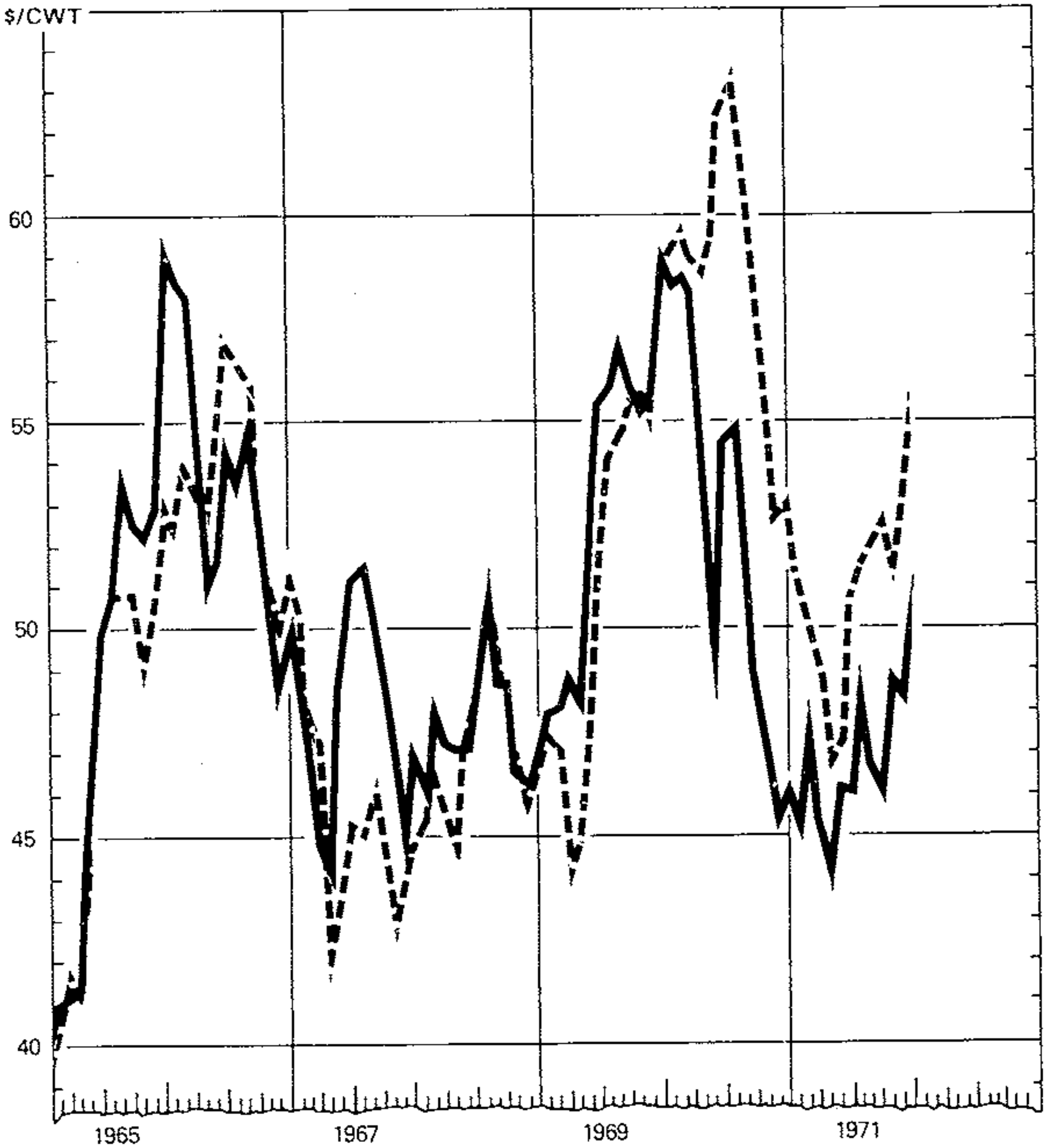
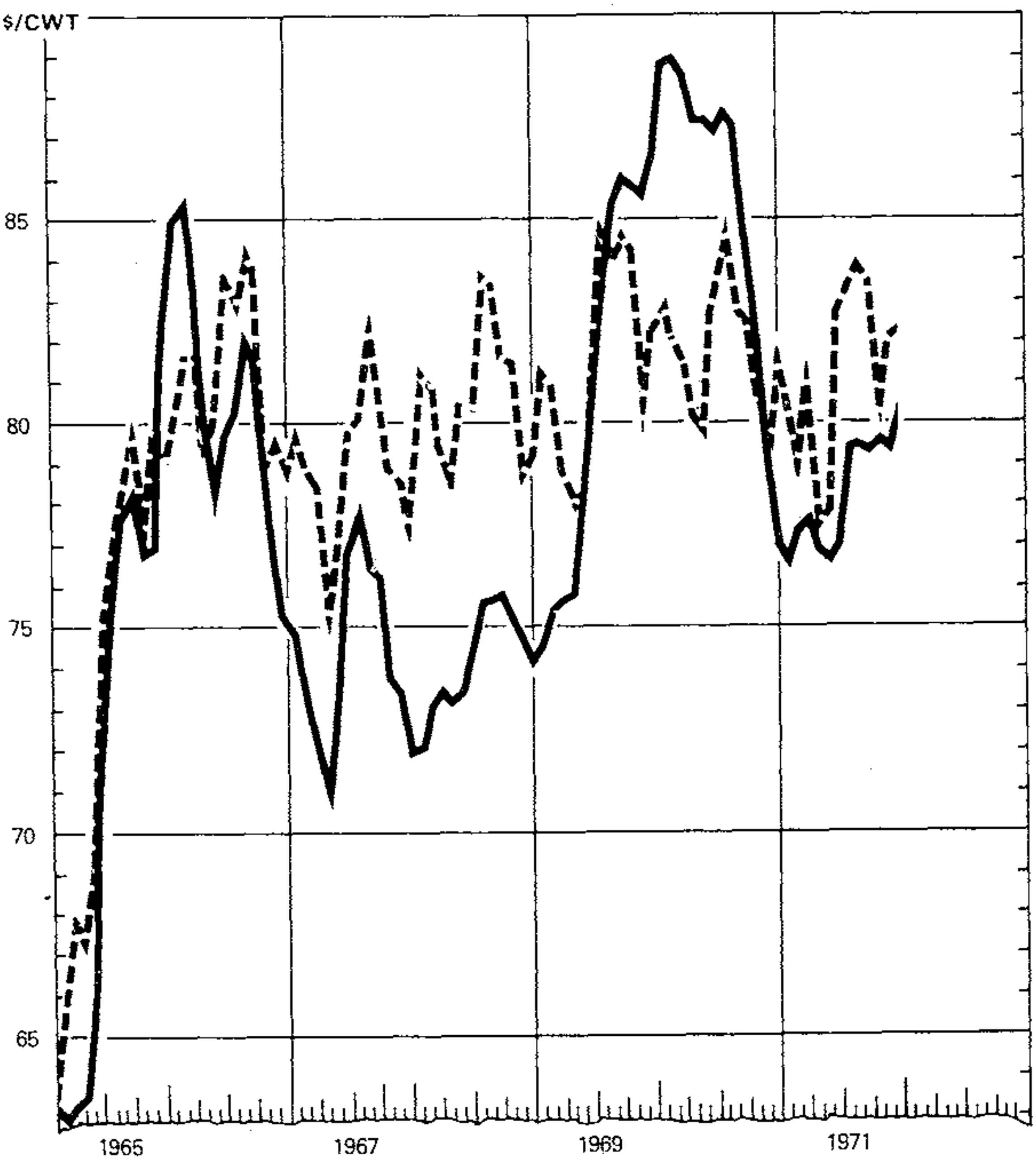


Figure 11. Composite retail pork price:

- - - Simulated and

—— Reported



The value of this statistic would be zero for a perfect simulation experiment of the historical period. The computed test statistic values for the five selected variables are shown in table 16. The U-statistic for all endogenous variables is given in appendix table 15.

Table 16—Theil's inequality coefficient for selected endogenous variables

| Variable | U-Statistics |
|---|---|
| Sows farrowings | 0.058 |
| Average price barrows and gilts | 0.102 |
| Commercial hog slaughter | 0.019 |
| Composite wholesale pork price | 0.076 |
| Composite retail pork price | 0.055 |

In view of the difficulties with criteria for verification, a measure of the degree of confinement of the model seemed more appropriate—that is, simulation of turning points on the time path of individual variables. The results showed that turning points were missed in only 8 of 84 possible times for sow farrowings and in 26 of 84 times for the composite retail price. This is not surprising, since quantity variables exhibit less variation than price variables. Also, some the the endogenous variables of the composite retail price equation were derived from other estimated equations within the model.

## Use and Limitations

On the basis of the simulation results, it can be concluded that the model provides a reasonably good explanation of the behavior of the hog-pork subsector during the period studied. For most of the endogenous variables in the model, the simulated time paths followed a pattern which closely resembled the time paths of the historical variables. However, the model failed to predict some extreme values and missed some turning points.

The primary interest was in evaluating the impact of various vertical coordination alternatives on the behavior of the hog-pork subsector. The results of these simulations are reported in another publication Effects of Changes in Vertical Coordination on Pork Production and Prices (U.S. Dept. of Agr., Econ. Res. Serv., Agr. Econ. Rpt. No. 303, Aug. 1975). However, the model should be useful in evaluating the impact of Federal Government policies on performance of the market and production sections of the hog-pork subsector. The model also may have practical or theoretical uses. As a device for simulating the aggregate behavior of the subsector, it may be useful to individual firms interested in making their own forecasts based on industry forecasts. To the extent that an individual firm's behavior follows the industry pattern, the firm could use the model for both long- and short-term forecasting.

The results presented here are conditioned by the underlying structure of the model, the limited data used, and the conceptual framework of the systems approach employed.

Data limitations affected the levels of disaggregation and aggregation, which in turn affected the functional form of specific equations. Data availability influenced the level of aggregation for equations in all three subsystems—production, slaughtering-processing, and distribution-consumption. For example, data on market hog supply by market classes were not collected. As a result, total monthly commercial hog slaughter was disaggregated into weight groups based on assumptions about the growth and fattening of market hogs. This primarily influenced the production and slaughtering-processing subsystems. Indirectly, it also influenced the distribution-consumption subsystem because quantities of wholesale and retail pork cuts were affected by the estimated distribution of hog numbers among the market weight classes.

Data availability also affected the form of specific equations. Frequently, theoretical determinants of a dependent variable could not be adequately measured by existing data series. Several examples can be cited. Changes over time in the amount of pork used in luncheon meat are likely to be influenced by changes in the relative price relationship of pork, beef, and chicken. Data series do not adequately measure the quantity of pork consumed in the form of luncheon meat. Also, changes in the demand for specific weight groups of hogs are likely to be influenced by changes in the quantity of wholesale pork cuts in storage and consumer preference for certain cuts are perceived by the meatpacker. Again, no data series adequately measures the meatpacker's purchases of specific weight classes of hogs.

In some instances, the functional form of the equation was affected by lack of data. Conceptually, one would like to fit a simultaneous system of equations for all organizational entities in the live hog market, wholesale market, and retail market. But no data were available as to quantities taken or prices paid by these entities. For example, the model does not account for the simultaneous demand for pork cuts by retail and nonretail institutions in the wholesale market, nor for the simultaneous determination of prices and quantities by the chains, independents, and convenience grocers at the retail level.

The conceptual framework employed in constructing the model does not permit simulation of the behavior of various types of hog producers or meatpackers. For some purposes, it would be more desirable to measure their response to alternative coordination possibilities than it would be to measure the aggregate response of producers, packers, and consumers. Additionally, much of the industry data series are collected annually, semiannually, or quarterly for the quantity variables and usually monthly for most of the price variables. The detailed price changes and quantity changes performed by the different types of participants in the hog-pork subsector are disguised in the aggregate data series.

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## APPENDIX

### Identification of Variables for Computer Simulation Model

MO1 = current calendar month (1-12)
MO2 = simulation month (1,-M)
TMO (I) = monthly dummy variable adjustments
I - 1-12
TMO (I) = 1 if I = MO1
TMO (I) = 0 if I = MO1
TREND = time trend (1-84)

NOTE: All variables are time subscripted t unless otherwise indicated.

### Production-Feeding Subsystem: Variable ID

W = Fourier series constant.
SF (I) = number of sows farrowing in the first time period (1,000 head).
HP (I) = average price of barrows and gilts in the first time period ($1 per cwt.).
CP = corn price; No. 2 Omaha ($1 per bu.).
GILTS = number of gilts saved for breeding (1,000 head).
BOARS = number of boars saved for breeding (1,000 head).
WPA = number of weaning pigs, 1 to 30 days of age, the current pig crop (1,000 head).
AK = number of pigs per litter.
SPPL = seasonal adjustment on the pigs per litter (AK).
HCPR = hog-corn ratio.
AVLWF = reported average liveweight (lbs.).
BGSI = reported number of barrows and gilts sold (1,000 head).
SOWSI = reported number of sows slaughtered (1,000 head).
BGS = estimated number of barrows and gilts sold (1,000 head).
SWS = reported number of sows sold (1,000 head).
BRS = reported number of boars sold (1,000 head).
TFH = total females held in breeding herd (1,000 head).
TMALES = total males held in breeding herd (1,000 head).
SFT4 = estimated number of sows farrowing at t+4 (1,000 head).
SGS = number of sows sold (1,000 head).
DMALES = number of boars required to service TFH.
TFBD = number of bred females required to yield SFT4.
SMALES = number of boars sold (1,000 head).
AVLW = average liveweight for SBG(3) (lbs.).
BGAN = number of barrows and gilts in 180-200 lb. weight group.
BGBN = number of barrows and gilts in 200-220 lb. weight group.
BGCIV = number of barrows and gilts in 240-270 lb. weight group.
BGDN = number of barrows and gilts in 270+lb. weight group.
BGEN = number of barrows and gilts in 220-240 lb. weight group.
GAMMA1 (I) = percentage of hogs in the ith weight group of all market hogs sold (I=1,-6).
I = 1 = 180-200 lbs.
I = 2 = 200-220 lbs.
I = 3 = 220-240 lbs.
I = 4 = 240-270 lbs.
I = 5 = 270 + lbs.
I = 6 = sows and boars

### Slaughtering-Processing Subsystem: Variable ID

NOTE: Time period subscript is denoted as follows:
1 = current month (t)
2 = lagged 1 month (t-1)
3 = lagged 2 months (t-2)
4 = lagged 3 months (t-3)

General rules for subscripts in this subsystem:

A. Market hog weight groups—
1 = 180-200 lbs.
2 = 200-220 lbs.
3 = 220-240 lbs.
4 = 240-270 lbs.
5 = 270 + lbs.
6 = sows and boars

B. Fresh or processed wholesale cuts—
*6 fresh (green cuts)*
1 = hams
2 = loins
3 = bellies
4 = ribs
5 = butts
6 = picnics
7 = trimmings

*8 processed cuts*
1 = hams
2 = loins
3 = not used
4 = ribs
5 = butts
6 = picnics
7 = not used
8 = bacon
9 = sausage
10 = luncheon meat

AQG (I,I) = anticipated demand for the ith wholesale cut (mil. lbs.).

GAMMA 2 (I,1,-18) = regression coefficients for AQG (I,1) estimated equation.

CWPP (I) = composite wholesale pork price in the ith time period, I=1,-3, composite of the nine wholesale prices ($/cwt.).

WBP (I) = wholesale beef price in the ith time period, I=1,2, ($/cwt.).

DPI = disposable personal income ($ per capita).

AQGC (I,J) = anticipated demand of the jth cut in the ith market hog weight group (I=1,-6), (J=1-6) (lbs./hog).

THETA 1 (I,J) = cut-out coefficient for the jth wholesale cut in the ith market hog weight group (I=1,6) (J=1,-7).

SBGN (I,I) = number of market hogs in the ith weight group (I=1-6) (1,000 head).

TBGN (I) = total number of market hogs in the ith time period (I=1,-3) (1,000 head).

SBG (I,J) = number of market hogs in the ith weight group for jth time period (I=1,-6), (J=1-3): (no./1,000 U.S population).

TBG (I) = total number of market hogs in the ith time period (I=1-3) (no./1,000 U.S. population)...................

TWHD (I,J) = minimum number of hogs demanded in the ith weight group for jth time period (I=1-6), (J=1-3) (hog equivalents 10,000 U.S. population).

PHD (I,J) = additional number of hogs demanded in the ith weight group for jth time period (I=1-6), (J=1-3) (hog equivalent/10,000 U.S. population).

PBG (I,J) = live hog price of the ith market weight group in the jth time period (I=1-6) (J=1-4) ($/cwt.).

GAMMA 3 (I) = regression coefficients for PBG(I,1) estimated equation (I=1-20).

BP = choice live steer price ($/cwt.).

APBG (I) = average price barrows and gilts in the ith time period ($/cwt.).

QGS (I,J) = quantity of the jth wholesale green cut from the ith market hog weight group (I=1-6) (J=1-7) (mil. lbs.).

TQGS (J) = total quantity of the jth wholesale green cut from current slaughter (J=1-7) (mil. lbs.).

STQGS (I) = total quantity of fresh pork from current slaughter in the ith time period (I=1,2) (mil. lbs.).

QPCD (I,J) = anticipated quantity demanded of the ith processed cut in the jth time period (I=1,-10 but ≠3 or 7) (j=1-2) (mil. lbs.).

THETA 3 (I) = regression coefficient for QPCD (I,1) estimated equation (I=1,10 but ≠3 or 7).

WBP (I) = wholesale beef price in the ith time period (I=1,2) ($/cwt.).

TCKC (I) = per capita chicken consumption in the ith time period (I=1,2) (lbs.).

RCP = retail chicken price ($/cwt.).

CRPP (I) = composite retail price of pork in the ith time period (I=1,2) ($/cwt.)

QPCDF (J) = quantity demanded of the jth processed cut in green cut equivalents, (J=110) (mil. lbs.).

TCKP (I) = U.S. commercial broiler production in the ith time period (mil. lbs.).

QGCP (J) = quantity of the jth green cut from current slaughter for processing, (J=1,10) (mil. lbs.).

QGCPS (J) = quantity of the jth green cut from storage for processing (J=1,10) (mil. lbs.).

SQG (I,J) = quantity of the ith cut in storage in the jth time period (I,1-7) (J=1,2) (mil. lbs.).

DSTOR (J) = maximum storage quantity of the jth cut (J=1,7 (mil. lbs.).

PIPE (J) = minimum storage quantity of the jth cut (J=1,-7) (mil. lbs.).

QPS (J) = quantity of the jth cut processed (J=1, 10) (mil. lbs.).

## Distribution-Consumption Subsystem: Variable ID

NOTE: Same rules for subscripting of cuts apply in this subsystem as in the Slaughtering-Processing subsystem.

DPM (I) = days per month in the ith month (I=1, 12).

DUMPR (J) = 1965 dummy variable for the jth cut (J=1,10).

WPP (I,J) = wholesale price of the ith cut in the jth time period (I=1,10) (J-1,3) ($/cwt.).

RA (I,) = regression coefficients for the WPP (I,J) estimated equation (I=1,10).

QP (I,J.K) = quantity of the jth processed cut for the ith outlet in the Kth time period (I=1,4), (J=1,10), (K-1,2) (mil. lbs.).

DELTA1 (I,J) = regression coefficients for the QP (I,J, 1) estimated equation (I=1,5) (J=1, 10).

TQP (I,J) = total quantity of the ith cut processed in the jth time period (I=1,10) (J=1,2) (mil. lbs.).

FRPS (I) = farm-retail price spread in the ith time period (I=1,2)($/cwt.).

APR (I,J) = average retail price of the ith cut in the jth time period; averaged over the three retail outlets (I=1,10) (J=1,2) ($/cwt.)

TREND = time trend with first simulation month = 1 and continuing.

PCQP (J) = per capita supply quantity of the jth processed cut (J=1,10) (lbs.).

TPCQP = per capita pork supply quantity (lbs.).

RMP (I) = U.S. red meat production in the ith time period (10 mil. lbs.).

PPD (I) = U.S. commercial poultry production in the ith time period (10 mil. lbs.).

QPX (I,J,K) = quantity of the jth processed cut for the ith outlet in the kth time period adjusted to days in month (I=1,5) (J=1,10) (K=1,2) (mil. lbs.).

PS (I) I = 1. wholesale-retail price spread ($/cwt.).

I = 2. farm-retail price spread ($/cwt.).

RB (I) = regression coefficient for the ith price spread series (I=1,2).

Appendix table 1--Market barrows and gilts: Weight group percentages, seven Midwest markets

| Sample Month and Year | 180-200 pounds | 201-220 pounds | 221-240 pounds | 241-270 pounds | 271-plus pounds |
|---|---|---|---|---|---|
| | | | Percentage | | |
| Jan. 70 | 2.39 | 23.51 | 35.03 | 28.06 | 8.31 |
| Feb. | 5.10 | 25.66 | 34.66 | 27.14 | 5.90 |
| Mar. | 3.22 | 25.71 | 39.33 | 25.77 | 4.87 |
| Apr. | 2.61 | 16.86 | 32.71 | 35.11 | 10.47 |
| May | 2.94 | 17.08 | 30.86 | 33.83 | 11.51 |
| June | 4.62 | 20.95 | 33.04 | 25.31 | 12.44 |
| July | 5.55 | 33.40 | 40.71 | 15.63 | 3.35 |
| Aug. | 8.59 | 36.85 | 37.80 | 14.90 | 1.76 |
| Sept. | 5.57 | 28.85 | 43.43 | 17.61 | 3.79 |
| Oct. | 3.66 | 23.97 | 39.26 | 27.40 | 5.19 |
| Nov. | 3.58 | 22.48 | 38.90 | 27.13 | 6.22 |
| Dec. | 5.16 | 23.23 | 35.45 | 25.47 | 8.02 |
| Jan. 71 | 4.97 | 24.78 | 32.27 | 28.42 | 6.96 |
| Feb. | 6.42 | 27.54 | 38.57 | 21.04 | 4.97 |
| Mar. | 4.95 | 27.24 | 42.96 | 20.25 | 3.31 |
| Apr. | 2.19 | 23.08 | 33.65 | 29.40 | 8.65 |
| May | 2.83 | 17.99 | 39.04 | 28.80 | 8.49 |
| June | 4.98 | 21.90 | 34.28 | 28.17 | 7.52 |
| July | 6.88 | 30.47 | 36.88 | 21.29 | 2.68 |
| Aug. | 6.82 | 32.31 | 38.99 | 17.66 | 3.77 |
| Sept. | 6.08 | 31.86 | 42.03 | 16.32 | 3.25 |
| Oct. | 1.97 | 27.33 | 41.61 | 26.01 | 2.64 |
| Nov. | 2.49 | 19.46 | 40.15 | 29.78 | 6.89 |
| Dec. | 4.62 | 26.14 | 35.67 | 25.01 | 7.01 |
| Jan. 72 | 4.18 | 25.43 | 35.33 | 26.10 | 6.93 |
| Feb. | 4.66 | 24.99 | 40.99 | 23.74 | 4.51 |
| Mar. | 3.33 | 22.06 | 40.63 | 27.14 | 5.48 |
| Apr. | 2.51 | 22.73 | 35.22 | 30.53 | 7.05 |
| May | 2.56 | 19.02 | 38.87 | 29.46 | 7.49 |
| June | 3.04 | 23.55 | 35.17 | 27.20 | 8.02 |

Source: Unpublished data obtained from Market News Branch, Livestock Division, Agr. Mktg. Serv., U.S. Dept. of Agr., Washington, D.C. Seven markets include Indianapolis, Kansas City, Omaha, National Stock Yards, St. Louis, Sioux City, South St. Joseph, and South St. Paul.

Appendix table 2--Estimation equations for the weight groups as fractions of total barrows and gilts sold

| Independent Variable | 180-200 Pound | | 200-220 Pounds | | 240-270 Pounds | | 270 Plus | |
|---|---|---|---|---|---|---|---|---|
| | Regression Coefficient | Significance Level | Regression Coefficient | Significance Level | Regression Coefficient | Significance Level | Regression Coefficient | Significance Level |
| Constant | 0.036 | <0.0005 | 0.153 | 0.0005 | 0.103 | 0.025 | 0.023 | 0.001 |
| Normal 2/ Equivalent | 0.572 | <0.0005 | 0.569 | <0.0005 | 0.387 | 0.002 | 0.874 | 0.005 |
| Jan. Dummy 3/ Feb. Dummy | -0.014 | 0.016 | | | | | | |
| March Dummy | -0.018 | 0.003 | | | | | -0.014 | -0.101 |
| April Dummy | -0.025 | <0.005 | -0.033 | 0.02 | 0.054 | 0.006 | 0.019 | 0.036 |
| May Dummy | -0.014 | 0.018 | -0.036 | 0.02 | 0.024 | 0.226 | | |
| June Dummy | | | | | | | 0.016 | 0.072 |
| July Dummy | | | 0.055 | <0.005 | -0.053 | 0.007 | -0.021 | 0.019 |
| August Dummy | | | 0.045 | 0.006 | -0.041 | 0.070 | | |
| Sept. Dummy | -0.015 | 0.015 | | | 0.040 | 0.065 | | |
| Oct. Dummy | -0.030 | <0.005 | | | 0.029 | 0.098 | -0.012 | 0.154 |
| Nov. Dummy | -0.019 | 0.002 | -0.027 | 0.045 | 0.020 | 0.233 | | |
| $R^2$ | 0.871 | | 0.904 | | 0.857 | | 0.867 | |
| F-Value | 20.471 | | 36.972 | | 18.254 | | 25.907 | |
| D-W Statistic | 1.58 | | 1.95 | | 1.74 | | 1.47 | |

1/ The fraction for the 220-240 pound barrows and gilts class was calculated as the residual.
2/ The equivalent fraction computed as area under the normal distribution curve.
3/ The month of December was a priori deleted. Zero coefficients have been omitted.

Appendix table 3--Identification of variables in equation for anticipated packer sales of the four lean primal cuts--hams, loins, butts, and picnics

| | Dependent variable | Constant | Independent variable subset X | | Lagged dependent variable | | Independent variable subset D | Error term |
|---|---|---|---|---|---|---|---|---|
| Nerlove structure of statistical model: Equation 7 | $Y_t =$ | $a_0(1-\lambda)(1-\beta)$ | $+\sum a_i X_{it}$ | $-\beta \sum a_i X_{it-1}$ | $+(\lambda+\beta)Y_{t-1}$ | $-(\lambda\beta)Y_{t-2}$ | $+\sum d_k D_{kt}$ | $+ e_t$ |
| Variables of $AQG_t^j$ (j=1,2, 5,6) 8 | $AQG_t^j$ | | $CWPP_{t-1}$ | $CWPP_{t-2}$ | $AQG^j_{t-1}$ | $AQG^j_{t-2}$ | $DPI_t$<br>SD<br>D65 | |

Appendix table 4--Estimated parameters and statistical information for anticipated packer sales of hams, butts, and picnics ($AQG^j_t$)

| Independent variables and lagged parameters | Hams | | Butts | | Picnics | |
|---|---|---|---|---|---|---|
| | Estimated regression parameters | Standard error of parameters | Estimated regression parameter | Standard error of parameter | Estimated regression parameter | Standard error of parameter |
| Constant | 209.7266 | --- | 93.5131 | --- | 107.8019 | --- |
| $CwPP_{t-1}$ | -1.8378 | 1.207 | -0.9395 | 0.461 | -1.0762 | 0.569 |
| $\lambda$ | 0.1668 | 0.480 | 0.0117 | 0.469 | 0.0770 | 0.457 |
| $\beta$ | -0.0602 | 0.430 | -0.0643 | 0.409 | -0.0754 | 0.399 |
| $DPI_t$ | 0.0441 | 0.011 | 0.0191 | 0.003 | 0.0228 | 0.004 |
| Feb. Dummy* | -32.2995 | 9.372 | -11.4193 | 2.747 | -13.249 | 3.450 |
| Mar. Dummy | -17.0244 | 8.072 | 2.9599 | 3.387 | 6.0669 | 4.418 |
| Apr. Dummy | 3.1833 | 8.970 | 1.0244 | 3.014 | 0.3179 | 4.074 |
| May Dummy | -49.9868 | 9.448 | -11.2277 | 3.008 | -13.4504 | 3.901 |
| June Dummy | -66.4667 | 8.416 | -15.9047 | 3.076 | -18.0661 | 4.081 |
| July Dummy | -57.1867 | 9.376 | -18.0323 | 3.531 | -19.5823 | 4.694 |
| Aug. Dummy | -52.0988 | 10.535 | -10.7862 | 4.126 | -11.0808 | 5.437 |
| Sept. Dummy | -12.2503 | 10.895 | -1.6223 | 3.840 | -0.3826 | 5.239 |
| Oct. Dummy | 6.4708 | 10.220 | 3.9384 | 3.291 | 6.7965 | 4.444 |
| Nov. Dummy | -28.1700 | 9.683 | 1.4563 | 2.833 | 3.3555 | 3.614 |
| Dec. Dummy | -38.0472 | 8.176 | 1.5913 | 2.746 | 4.1230 | 3.408 |
| D65 Dummy | -17.7546 | 6.526 | -7.8199 | 2.050 | -9.9492 | 2.560 |
| $R^2$ | .871 | | .893 | | .896 | |
| Mean | 240.279 | | 89.805 | | 112.632 | |
| F | 28.151 | | 34.828 | | 36.018 | |
| D-W | 2.043 | | 2.103 | | 2.137 | |
| Standard Error of Estimation | 15.025 | | 4.678 | | 5.805 | |

*January served as the excluded a priori month.

Appendix Table 5--Identification of economic variables in statistical model of price of market 180-200 pound barrows and gilts and market sows and boars

| | Dependent Variable | Constant | Independent Variable Subset X | | Lagged Dependent Variable | | Independent Variable Subset D | Error Term |
|---|---|---|---|---|---|---|---|---|
| Nerlove Structure of Statistical Model: Equation 7 | $Y_t$ | $= a_0(1-\lambda)(1+\beta) +$ | $\sum_{i=1}^{A} a_i X_{it}$ | $-\beta \sum_{i=1} a_i X_{it-1}$ | $+(\lambda+\beta)Y_{t-1}$ | $-(\lambda\beta)Y_{t-2} +$ | $\sum_{k=1}^{C} d_k D_{kt} +$ | $e_t$ |
| Economic Variable of $PBG_t^1$ Equation: Equation 9 | $PBG_t^1$ | | $TBG_t$ | $TBG_{t-1}$ | $PBG_{t-1}^1$ | $PBG_{t-2}$ | $PHD_t^1$<br>$TWHD_t^1$<br>$SBG_t^1$<br>$BP_t$<br>SD | |
| Economic Variable for $PBG_t^6$ Equation: Equation 9 | $PBG_t^6$ | | $TBG_t$ | $TBG_{t-1}$ | $PBG_{t-1}^6$ | $PB_{t-2}^6$ | $TWHD_t^6$<br>$BP_t$<br>SD | |

Appendix table 6--Identification of economic variables in statistical model of price of barrows and gilts

| Item | Dependent Variable | Constant | Independent Variable Subset X | | | Independent Variable Subset Z |
|---|---|---|---|---|---|---|
| Two Parameter Lag Structure Of Statistical Model: Equation 7 | $Y_t$ | $= a_o(1 - \lambda)(1 - \mu)(1 - \beta)$ | $+ \sum_{i=1}^{A} a_i X_{it}$ | $- (\mu + \beta) \sum_{i=1}^{A} a_i X_{it-1}$ | $+ \mu\beta \sum_{i=1}^{A} a_i X_{it-2}$ | $+ \sum_{j=1}^{B} b_j Z_{jt}$ |
| Economic Variable of $PBG_t^I$ Equation: I-2,5 | $PBG_t^I$ | | $SBG_t^I$ <br> $TBG_t$ | $SBG_{t-1}^I$ <br> $TBG_{t-1}$ | $SBG_{t-2}^I$ <br> $TBG_{t-2}$ | $PHD_t^I$ <br> $TWHD_t^I$ |

Continued

Appendix table 6--Identification of economic variables in statistical model of price of barrows and gilts--Continued

| Item | Independent Variable Subset Z Cont'd | | Lagged Dependent Variable | | | Independent Variable Subset D | Error Term |
|---|---|---|---|---|---|---|---|
| Two Parameter Lag Structure Of Statistical Model: Equation 7 | $(\lambda + \mu) \sum_{j=1}^{B} b_j Z_{jt-1}$ + | $\lambda\mu \sum_{j=1}^{B} b_j Z_{jt-2}$ + | $($ [illegible] $+ \mu +$ [illegible] $) Y_{t-1}$ − | $[(\lambda + \mu)\mu + \lambda\mu] Y_{t-2}$ + | $\lambda\mu\mu Y_{t-3}$ + | $\sum_{k=1}^{C} d_k D_{kt}$ + | $e_t$ |
| Economic Variable of $PBG_t^I$ Equation: I-2,5 | $PHD_{t-1}^I$<br>$TWHD_{t-1}^I$ | $PHD_{t-2}^I$<br>$TWHD_{t-2}^I$ | $PBG_{t-1}^I$ | $PBG_{t-2}^I$ | $PBG_{t-3}^I$ | $BP_t$<br>SD | |

Appendix table 7--Estimated parameters and statistical information for price of 180- to 200-pound barrow gilts and market sows and boars

| Independent Variable And Lagged Parameters | 180-200 Pound Barrows and Gilts | | Market Sows And Boars | |
|---|---|---|---|---|
| | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter |
| Constant | 10.8794 | --- | 6.0391 | --- |
| $TBG_t$ | -0.3480 | 0.058 | -0.2612 | 0.067 |
| $\lambda$ | 0.7919 | 0.047 | 0.7599 | 0.66 |
| $\beta$ | 0.0411 | 0.123 | 0.3553 | 0.131 |
| $PHD_t$ | 0.2769 | 0.255 | --- | --- |
| $TWHD_t$ | 0.0444 | 0.076 | 0.0814 | 0.096 |
| $BP_t$ | 0.1573 | 0.050 | 0.0963 | 0.046 |
| Feb. Dummy* | -1.9950 | 0.698 | -0.3413 | 0.548 |
| Mar. Dummy | -1.5687 | 0.579 | -0.9628 | 0.629 |
| Apr. Dummy | -1.0562 | 0.558 | -1.8150 | 0.497 |
| May Dummy | -0.2813 | 0.621 | -1.3649 | 0.601 |
| June Dummy | -1.3938 | 0.645 | -1.8005 | 0.717 |
| July Dummy | -2.7197 | 0.801 | -1.9328 | 0.775 |
| Aug. Dummy | -4.0820 | 1.094 | -1.1672 | 0.641 |
| Sept. Dummy | -2.5646 | 0.851 | -1.2855 | 0.576 |
| Oct. Dummy | 0.0954 | 0.557 | -0.9164 | 0.543 |
| Nov. Dummy | -0.5929 | 0.503 | -2.1774 | 0.541 |
| Dec. Dummy | -0.3493 | 0.713 | -1.1195 | 0.516 |
| $R^2$ | .947 | | .933 | |
| Mean | 21.470 | | 18.025 | |
| F | 68.779 | | 58.435 | |
| D-W | 2.002 | | 2.018 | |
| Standard Error of Estimation | 0.885 | | 0.916 | |

*January served as the *a priori* excluded month.

Appendix table 8--Estimated parameters and statistical information for price of 200-220, 240-270, and 270-plus pound market barrows and gilts

| Independent Variable And Lagged Parameter | 200-220 Pound Market Barrows and Gilts | | 240-270 Pound Market Barrows and Gilts | | 270-Plus Market Barrows and Gilts | |
|---|---|---|---|---|---|---|
| | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter |
| Constant | 4.5290 | --- | 8.6694 | --- | 6.4235 | --- |
| $SBC_t$ | -0.2129 | 0.169 | -0.2920 | 0.229 | -0.9502 | 0.387 |
| $TBG_t$ | -0.2973 | 0.047 | -0.2814 | 0.094 | -0.2149 | 0.068 |
| $TWHD_t$ | 0.0363 | 0.010 | 0.0149 | 0.019 | 0.0249 | 0.051 |
| λ | 0.5717 | 0.111 | 0.7613 | 0.078 | 0.7346 | 0.098 |
| μ | -0.5125 | 0.103 | -0.5873 | 0.135 | -0.5456 | 0.137 |
| β | 0.8316 | 0.114 | 0.5920 | 0.168 | 0.6466 | 0.190 |
| $BP_t$ | 0.0368 | 0.041 | 0.1294 | 0.059 | 0.1053 | 0.054 |
| Feb. Dummy* | -0.9695 | 0.484 | -1.1827 | 0.771 | -1.3929 | 0.732 |
| Mar. Dummy | -0.9533 | 0.455 | -2.1062 | 0.633 | -2.8901 | 0.779 |
| April Dummy | --- | --- | -1.5222 | 0.784 | -1.6626 | 0.785 |
| May Dummy | --- | --- | 0.1856 | 0.894 | 0.0792 | 0.921 |
| June Dummy | --- | --- | -1.4308 | 0.734 | -1.0536 | 0.589 |
| July Dummy | -1.3249 | 0.590 | -2.6840 | 1.139 | -2.4178 | 1.042 |
| Aug. Dummy | -0.4992 | 0.668 | -3.3978 | 1.284 | -3.1165 | 0.952 |
| Sept. Dummy | --- | --- | -2.4291 | 1.115 | -2.1215 | 0.839 |
| Oct. Dummy | --- | --- | -0.5946 | 0.824 | -1.4954 | 0.764 |
| Nov. Dummy | --- | --- | -0.7066 | 0.855 | -1.7167 | 0.595 |
| Dec. Dummy | --- | --- | 0.0186 | 0.665 | -0.1315 | 0.688 |
| $R^2$ | .942 | | .952 | | .950 | |
| Mean | 21.803 | | 20.790 | | 20.204 | |
| F | 105.486 | | 52,364 | | 55.610 | |
| D-W | 1.990 | | 2.020 | | 1.993 | |
| Standard Error or Estimation | 0.879 | | 0.845 | | 0.857 | |

*January served as *a priori* excluded month.

Appendix table 9--Estimated parameters and statistical information for packers' anticipated retail demand for hams, ribs, butts, picnics, bacon, sausage, and luncheon meat ($QPCD^j_t$)

| Independent Variables And Lagged Parameter | Hams | | Ribs | | Butts | |
|---|---|---|---|---|---|---|
| | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter |
| Constant | -21.7415 | --- | 0.7121 | --- | -5.8798 | --- |
| $WBP_t$ | --- | --- | --- | --- | 0.1105 | 0.046 |
| $CWPP_{t-1}$ | --- | --- | --- | --- | -0.0114 | 0.030 |
| $CRPP_{t-1}$ | -0.4186 | 0.189 | -0.1028 | 0.051 | --- | --- |
| $RCP_t$ | --- | --- | --- | --- | -0.1596 | 0.073 |
| $STQCSC_t$ | 40.7927 | 2.927 | 8.5491 | 0.799 | 11.0516 | |
| $TCKPC_t$ | --- | --- | --- | --- | --- | --- |
| $DPI_t$ | 0.0279 | 0.003 | 0.0069 | 0.009 | 0.0055 | 0.006 |
| Feb. Dummy * | 2.0951 | 3.983 | 0.0416 | 1.087 | -0.0540 | 0.516 |
| Mar. Dummy | 27.2333 | 3.584 | 0.2435 | 0.978 | 0.2496 | 0.463 |
| Apr. Dummy | -15.6231 | 3.555 | -3.0995 | 0.970 | -3.5641 | 0.461 |
| May Dummy | 5.2322 | 3.820 | 1.9161 | 1.042 | -2.9433 | 0.507 |
| June Dummy | 16.6062 | 4.097 | 4.5587 | 1.118 | -2.0560 | 0.534 |
| July Dummy | 6.2626 | 4.414 | 0.7690 | 1.204 | -1.4735 | 0.573 |
| Aug. Dummy | 17.5415 | 3.867 | 1.9120 | 1.055 | -2.4975 | 0.493 |
| Sept. Dummy | 2.0958 | 3.621 | -1.7071 | 0.988 | -2.6009 | 0.458 |
| Oct. Dummy | 4.5629 | 3.726 | 1.8666 | 1.017 | 0.0231 | 0.451 |
| Nov. Dummy | 26.3370 | 3.602 | -3.0167 | 0.983 | -0.5269 | 0.445 |
| Dec. Dummy | 45.8767 | 3.590 | -2.7133 | 0.979 | 1.0501 | 0.445 |
| $R^2$ | .971 | | .934 | | .992 | |
| Mean | 245.937 | | 56.422 | | 63.116 | |
| F | 166.587 | | 70.175 | | 517.274 | |
| D-W | 1.819 | | 1.068 | | 1.762 | |
| Standard Error of Estimate | 6.647 | | 1.814 | | 0.827 | |

*January served as *a priori* excluded month.

Continued

Appendix table 9--Estimated parameters and statistical information for packers' anticipated retail demand for hams, ribs, butts, picnics, bacon, sausage, and luncheon meat ($QPCD^J_t$)--Continued

| Independent Variables And Lagged Parameter | Picnics | | Bacon | | Sausage | | Lunch Meat | |
|---|---|---|---|---|---|---|---|---|
| | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter | Estimated Regression Parameter | Standard Error of Parameter |
| Constant | -3.9577 | --- | 19.0577 | --- | 10.5322 | --- | 44.6863 | --- |
| $WBP_t$ | 0.0841 | 0.034 | 0.6724 | 0.287 | 0.2218 | | 0.5000 | 0.264 |
| $GWPP_{t-1}$ | -0.0849 | 0.023 | --- | --- | -0.4102 | | --- | --- |
| $CRPP_{t-1}$ | --- | --- | -0.4442 | 0.149 | --- | --- | -0.7665 | 0.159 |
| $RCP_t$ | -0.0791 | 0.055 | --- | --- | --- | --- | | |
| $STQGSC_t$ | 9.0185 | 0.295 | 21.3821 | 2.357 | 17.5871 | 1.705 | 9.0221 | 2.460 |
| $TCKPC_t$ | --- | --- | --- | --- | 0.5382 | 0.304 | 0.8636 | 0.453 |
| $DPI_t$ | 0.0044 | 0.0004 | 0.160 | 0.046 | 0.0083 | 0.002 | 0.0101 | 0.004 |
| Feb. | -0.5114 | 0.387 | -11.6679 | 3.094 | -6.3416 | 1.952 | -1.606 | 2.955 |
| Mar. | -0.4635 | 0.347 | -10.7214 | 2.785 | -7.545 | 1.679 | -3.7015 | 2.590 |
| Apr. | -2.5106 | 0.345 | -17.7405 | 2.758 | -12.3053 | 1.658 | -15.918 | 2.538 |
| May | -2.6617 | 0.380 | -11.7687 | 2.933 | -12.2770 | 2.088 | -11.661 | 2.908 |
| June | -2.2651 | 0.399 | 2.5247 | 3.162 | -7.8358 | 2.377 | -9.9761 | 3.422 |
| July | -2.1786 | 0.429 | 16.5978 | 3.406 | -4.4739 | 2.366 | -8.4763 | 3.433 |
| Aug. | -2.5901 | 0.369 | 11.8359 | 2.984 | -8.4891 | 2.137 | -9.0851 | 3.133 |
| Sept. | -2.4207 | 0.343 | 6.4206 | 2.796 | -8.0842 | 1.701 | -5.6987 | 2.599 |
| Oct. | -0.5790 | 0.338 | 0.8755 | 2.874 | -7.7584 | 1.728 | -0.8784 | 2.679 |
| Nov. | -1.0524 | 0.333 | -7.8226 | 2.784 | -7.7483 | 1.895 | -1.3846 | 2.999 |
| Dec. | 0.0144 | 0.334 | -10.3480 | 2.770 | -3.8501 | 1.708 | -4.3106 | 2.673 |
| $R^2$ | .993 | | .940 | | .964 | | .889 | |
| Mean | 51.958 | | 168.165 | | 121.274 | | 101.878 | |
| F | 575.431 | | 70.763 | | 111.277 | | 33.556 | |
| D-W | 1.620 | | 1.514 | | 1.749 | | 1.860 | |
| Standard Error of Estimate | 0.620 | | 5.128 | | 3.079 | | 4.718 | |

Appendix table 10--Estimated regression coefficients and statistical information for wholesale price, by pork cut, $WPP^j_t$

| Independent Variable | Hams | Loins | Bellies | Ribs | Butts | Picnics | Bacon | Sausage | Lunch Meat |
|---|---|---|---|---|---|---|---|---|---|
| | Equation and Dependent Variable | | | | | | | | |
| | WPP (1) | WPP (2) | WPP (3) | WPP (4) | WPP (5) | WPP (6) | WPP (8) | WPP (9) | WPP (10) |
| (1): | | | | | | | | | |
| 1. Constant | 21.177215 | 49.985712 | 36.982912 | 27.952577 | 28.857743 | 7.798343 | 38.231029 | 9.405038 | -7.081807 |
| 2. $WPP^1_{t-1}$ | 0.803818 | 0.124799 | --- | --- | --- | 0.053059 | 0.048624 | --- | --- |
| | (6.740) | (1.179) | | | | (0.884) | (0.552) | | |
| 3. $WPP^2_{t-1}$ | --- | 0.260542 | --- | --- | --- | --- | --- | 0.051017 | --- |
| | | (2.539) | | | | | | (0.589) | |
| 4. $WPP^3_{t-1}$ | --- | --- | 0.707345 | --- | --- | --- | 0.694134 | --- | --- |
| | | | (6.317) | | | | (5.392) | | |
| 5. $WPP^4_{t-1}$ | --- | --- | --- | 0.583258 | --- | --- | --- | --- | --- |
| | | | | (3.416) | | | | | |
| 6. $WPP^5_{t-1}$ | --- | --- | --- | --- | 0.560205 | --- | --- | --- | --- |
| | | | | | (6.208) | | | | |
| (2): | | | | | | | | | |
| 7. $WPP^6_{t-1}$ | --- | --- | --- | --- | --- | 0.724613 | --- | 0.355379 | --- |
| | | | | | | (6.345) | | (2.379) | |
| 8. $WPP^8_{t-1}$ | --- | --- | --- | --- | --- | --- | --- | --- | 0.110902 |
| | | | | | | | | | (2.760) |
| 9. $WPP^9_{t-1}$ | --- | --- | --- | --- | --- | --- | --- | 0.753424 | --- |
| | | | | | | | | (6.172) | |
| 10. $WPP^{10}_{t-1}$ | --- | --- | --- | --- | --- | --- | --- | --- | 0.475304 |
| | | | | | | | | | (3.937) |
| 11. $WPP^1_{t-2}$ | -0.030231 | --- | --- | --- | --- | --- | --- | --- | --- |
| | (-0.246) | | | | | | | | |
| (3): | | | | | | | | | |
| 12. $WPP^2_{t-2}$ | --- | 0.223822 | --- | --- | --- | --- | --- | --- | --- |
| | | (1.851) | | | | | | | |
| 13. $WPP^3_{t-2}$ | --- | --- | -0.181898 | --- | --- | --- | -0.113888 | --- | --- |
| | | | (-2.115) | | | | (-1.028) | | |
| 14. $WPP^4_{t-2}$ | --- | --- | --- | -0.087014 | --- | --- | --- | --- | --- |
| | | | | (-0.584) | | | | | |
| 15. $WPP^5_{t-2}$ | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 16. $WPP^6_{t-2}$ | --- | --- | --- | --- | --- | 0.013753 | --- | --- | --- |
| | | | | | | (0.130) | | | |
| (4): | | | | | | | | | |
| 17. $WPP^9_{t-2}$ | --- | --- | --- | --- | --- | --- | --- | 0.068357 | --- |
| | | | | | | | | (0.523) | |
| 18. $WPP^{10}_{t-2}$ | --- | --- | --- | --- | --- | --- | --- | --- | 0.103795 |
| | | | | | | | | | (0.842) |
| 19. $APR^1_{t-1}$ | -0.221846 | -0.482039 | --- | --- | --- | --- | --- | --- | --- |
| | (-2.156) | (-3.261) | | | | | | | |
| 20. $APR^2_{t-1}$ | --- | -0.246605 | --- | --- | --- | --- | --- | --- | --- |
| | | (-1.846) | | | | | | | |
| 21. $APR^4_{t-1}$ | --- | --- | --- | -0.022807 | --- | --- | --- | --- | --- |
| | | | | (-0.087) | | | | | |

Continued

Appendix table 10--Estimated regression coefficients and statistical information for wholesale price, by pork cut, $WPP_t^J$-- Continued

| Independent Variable | Hams | Loins | Bellies | Ribs | Butts | Picnics | Bacon | Sausage | Lunch Meat |
|---|---|---|---|---|---|---|---|---|---|
| | Equation and Dependent Variable | | | | | | | | |
| | WPP (1) | WPP (2) | WPP (3) | WPP (4) | WPP (5) | WPP (6) | WPP (8) | WPP (9) | WPP (10) |
| (5): | | | | | | | | | |
| 22. $APR_{t-1}^5$ | --- | 0.598872 (3.190) | --- | --- | --- | --- | --- | --- | --- |
| 23. $APR_{t-1}^6$ | --- | --- | --- | --- | --- | -0.113969 (-1.112) | --- | --- | --- |
| 24. $APR_{t-1}^9$ | --- | --- | --- | --- | --- | --- | --- | -0.473157 (-4.404) | --- |
| 25. $APR_{t-1}^{10}$ | --- | --- | --- | --- | --- | --- | --- | --- | 0.044291 (0.462) |
| 26. $TQP_t^I$ | 0.069[illegible] (1.6[illegible]5) | --- | --- | --- | --- | --- | --- | --- | --- |
| (6): | | | | | | | | | |
| 27. $TQP_t^4$ | --- | --- | --- | -0.221977 (-1.395) | --- | --- | --- | --- | --- |
| 28. $TQP_t^6$ | --- | --- | --- | -0.633788 (-1.489) | --- | --- | --- | --- | --- |
| 29. $TWP_t^8$ | --- | --- | --- | --- | --- | --- | -0.094579 (-1.885) | --- | --- |
| 30. $TWP_t^9$ | -0.12866[illegible] (-1.580) | --- | --- | --- | --- | --- | --- | --- | --- |
| 31. $TWP_t^{10}$ | --- | 0.113941 (2.305) | --- | --- | --- | 0.067354 (2.215) | --- | --- | --- |
| (7): | | | | | | | | | |
| 32. $TWP_{t-1}^5$ | --- | --- | --- | --- | -0.245475 (2.548) | --- | --- | --- | --- |
| 33. $TWP_{t-1}^8$ | --- | --- | -0.080425 (-2.744) | -0.019551 (-0.471) | --- | --- | --- | --- | --- |
| 34. TREND | --- | --- | --- | 0.069455 (1.183) | --- | --- | --- | --- | --- |
| 35. $KBP_t$ | --- | --- | --- | --- | 0.289070 (3.564) | --- | --- | 0.236395 (4.029) | 0.200596 (3.618) |
| 36. $RCP_t$ | 0.344563 (2.080) | 0.128650 (0.652) | 0.284972 (2.002) | 0.301676 (1.457) | | 0.190581 (1.641) | --- | | |
| (8): | | | | | | | | | |
| 37. $STOGS_t$ | -0.022969 (-2.487) | -0.044482 (-7.682) | -0.039372 (-7.332) | 0.010448 (0.562) | --- | -0.018035 (-5.032) | -0.021379 (-3.145) | -0.012708 (-2.298) | -0.002041 (-0.513) |
| 38. $BFCM_t$ | --- | 0.529844 (0.133) | 9.722345 (2.651) | 5.267283 (1.068) | --- | --- | 6.514959 (1.696) | --- | 3.239052 (1.062) |
| 39. $TCKP_t$ | 25.056671 (2.928) | 38.007216 (3.459) | 11.087169 (1.428) | 28.823273 (2.337) | -4.156011 (0.510) | 16.327782 (2.559) | 16.705914 (1.776) | 17.486956 (2.083) | --- |
| 40. $APR_{t-1}^8$ | --- | --- | --- | --- | --- | --- | 0.046146 (0.492) | --- | --- |
| 40. $FRPS_{t-1}$ | | | | | -0.483920 (3.888) | | | | |

Continued

Appendix table 10--Estimated regression coefficients and statistical information for wholesale price, by pork cut, $WPP_t^j$-- Continued

| Independ-end Variable | Hams | Loins | Bellies | Ribs | Butts | Picnics | Bacon | Sausage | Lunch Meat |
|---|---|---|---|---|---|---|---|---|---|
| | Equation and Dependent Variable | | | | | | | | |
| | WPP (1) | WPP (2) | WPP (3) | WPP (4) | WPP (5) | WPP (6) | WPP (8) | WPP (9) | WPP (10) |
| 41. D65 | --- | --- | --- | --- | -0.957259 | 0.964225 | 1.080671 | -1.990544 | --- |
| | | | | | (0.971) | (1.596) | (1.260) | (-2.066) | |
| 42. Feb. | 2.344133 | -1.658192 | -3.132746 | -0.765128 | -0.379073 | -1.697255 | -3.049859 | 0.473228 | 1.35419 |
| Dummy | (1.457) | (-1.077) | (-2.687) | (-0.489) | (0.290) | (-2.036) | (-2.220) | (0.438) | (1.205) |
| 43. Mar. | 1.137006 | -3.389175 | -1.170876 | 0.923838 | -4.976964 | -2.108946 | -0.513604 | 0.789374 | 1.750977 |
| Dummy | (6.121) | (-2.209) | (-0.987) | (0.563) | (3.446) | (-2.601) | (-0.442) | (0.740) | (1.753) |
| 44. April | -0.180318 | -4.456131 | 0.605352 | -0.339858 | -2.727146 | -1.162574 | -2.073228 | -0.546219 | 1.513608 |
| Dummy | (-0.109) | (-2.740) | (0.527) | (-0.170) | (2.386) | (-1.169) | (-1.515) | (-0.549) | (1.478) |
| 45. May | 0.179368 | -4.296985 | -2.673500 | -0.192595 | -1.645964 | -1.556257 | -3.415824 | -0.601829 | 1.254134 |
| Dummy | (0.093) | (-2.402) | (-2.204) | (-0.097) | (1.209) | (-1.327) | (-2.118) | (-0.492) | (1.246) |
| 46. June | -1.961997 | -4.317855 | -6.220354 | -0.111838 | -0.648234 | -2.291837 | -3.906984 | -2.207251 | 1.131525 |
| Dummy | (-0.973) | (-2.198) | (-4.511) | (-0.053) | (0.407) | (-1.686) | (-2.240) | (-1.604) | (1.015) |
| 47. July | -2.623963 | -5.074273 | -6.514141 | -3.254732 | -1.674107 | -3.149817 | -3.491439 | -2.487291 | 0.506858 |
| Dummy | (-1.349) | (-2.523) | (-4.679) | (-1.687) | (1.083) | (-2.350) | (-1.812) | (-1.799) | (0.439) |
| 48. Aug. | -1.858231 | -8.788908 | -6.258405 | -3.371116 | -3.963100 | -3.982625 | -3.923058 | -1.045148 | 1.578934 |
| Dummy | (-0.938) | (-4.251) | (-5.126) | (-1.585) | (2.480) | (-3.160) | (-2.267) | (-0.823) | (1.522) |
| 49. Sept. | -0.595824 | -4.848471 | -2.282412 | -5.194161 | -3.733577 | -1.756937 | -2.092562 | 0.078980 | -0.422321 |
| Dummy | (-0.383) | (-2.666) | (-2.072) | (-2.814) | (2.593) | (-1.878) | (-1.584) | (0.071) | (-0.444) |
| 50. Oct. | 3.809592 | -3.893218 | -1.460263 | -5.882236 | -1.718133 | -1.064461 | -1.773306 | -0.033899 | 0.882943 |
| Dummy | (2.485) | (-2.286) | (-1.328) | (-3.499) | (1.352) | (-1.271) | (-1.365) | (-0.029) | (0.874) |
| 51. Nov. | 4.851917 | -2.418541 | 2.192407 | 0.899503 | -1.177189 | 1.140961 | 0.637779 | -0.301301 | -0.107425 |
| Dummy | (2.504) | (-1.532) | (1.780) | (0.520) | (0.930) | (1.467) | (0.518) | (-0.248) | (-0.102) |
| 52. Dec. | 7.321616 | -1.263554 | 2.783238 | 0.563905 | 0.272631 | 0.316039 | 2.139146 | -0.387393 | 2.104509 |
| Dummy | (3.158) | (-0.987) | (2.622) | (0.420) | (0.232) | (0.447) | (1.845) | (-0.356) | (1.987) |
| $R^2$ | 0.889 | 0.922 | 0.959 | 0.930 | 0.890 | 0.919 | 0.955 | 0.902 | 0.933 |
| D-W | 2.055 | 2.190 | 2.122 | 2.174 | 2.286 | 1.961 | 1.815 | 2.036 | 2.054 |

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut and outlet (t values appear in parentheses below the parameter)

| | | QP (1,1) | QP(2,1) | QP (3,1) | QP (4,1) | QP (1,2) | QP(2,2) | QP (3,2) |
|---|---|---|---|---|---|---|---|---|
| Constant | | -18.220367 | -5.516621 | -7.353348 | -0.151991 | -8.578818 | 0.417888 | 4,149454 |
| (I,J,1) | | | | | | | | |
| TQP (1,1) | X | 0.506850 | 0.100924 | 0.071221 | 0.001376 | -0.182871 | | |
| DELTAI(I,T,2) | | (17.89.2) | (6.4198) | (3.8292) | (3.8131) | (10.5168) | | |
| TQP (2,1) | | | | | | 0.874241 | 0.290506 | |
| (I,J,3) | | | | | | (15.0219) | (20.2089) | |
| TQP (4,1) | | | 0.596645 | 0.429254 | 0.007998 | | | |
| (I,J,4) | | | 9,8979) | (6.2365) | (5.6476) | | | |
| TQP (5,1) | | | | 0.469221 | 0.008539 | | | |
| (I,J,5) | | | | (5.0607) | (4.6890) | | | |
| TQP (8,1) | | | | | | -0.102825 | | |
| (I,J,7) | | | | | | (4.6021) | | |
| TQP (10,1) | | | 0.067684 | 0.095360 | 0.001697 | -0.155106 | | |
| (I,J,9) | | | (2.6099) | (4,1340) | (3.6863) | (6.1682) | | |
| B | | 0.503156 | 0.158097 | 0.115645 | 0.236180 | 0.329126 | 0.529318 | 0.334929 |
| (I,J,6) | | (4.7212) | (1.2601) | (0.8948) | (1.8836) | (2.6937) | (4.9733) | (2.8582) |
| WPP (1,1) | D | 0.072012 | -0.007886 | -0.024519 | 0.000316 | | | |
| (I,J,11) | | (0.8147) | (0.2428) | (0.8189) | (0.5671) | | | |
| WPP (2,1) | | | | | | 0.070887 | -0.0024784 | -0.016690 |
| (I,J,11) | | | | | | (2.6187) | (0.8558) | (0.5041) |
| WPP (4,1) | | | | | | | | |
| (I,J,11) | | | | | | | | |
| WPP (5,1) | | | | | | | | |
| (I,J,11) | | | | | | | | |
| T | | -0.071432 | 0.087828 | -0.044006 | 0.000343 | -0.023333 | 0.051736 | -0.040595 |
| (I,J,12) | | (2.7811) | (5.5499) | (4.2046) | (2.0918) | (2.8043) | (3.8658) | (3.6169) |
| Mo (2) | | 11.133048 | -0.990895 | 0.160283 | 0.003318 | 0.863014 | 0.675011 | 1.062991 |
| (I,J,13) | | (4.9412) | (1.6405) | (0.2349) | (0.2349) | (0.2614) | (0.9715) | (0.8550) |
| Mo (3) | | 17.436829 | -2.452408 | -1.023444 | -0.020884 | 0.986047 | 2.541568 | 2.978211 |
| (I,J,14) | | (6.1130) | (2.8915) | (1.2269) | (1.1980) | (0.7646) | (3.0037) | (2.6391) |
| Mo (4) | | -37.447617 | 18.354919 | 22.779282 | 0.424741 | 10.831221 | -5.686108 | -6.427267 |
| (I,J,15) | | (20.8280) | (24.3216) | (27.6449) | (28.9120) | (10.2658) | (7.1608) | (6.1895 |

Continued

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut and outlet (t values appear in parentheses below the parameter)--Continued

| | | QP(1,1) | QP(2,1) | QP(3,1) | QP(4,1) | QP(1,2) | QP(2,2) | QP(3,2) | QP(4,2) |
|---|---|---|---|---|---|---|---|---|---|
| Mo(5) | D | -5.822684 | 11.768222 | 18,561859 | 0.291884 | 7.268606 | 1.105525 | 0.131169 | 0.013016 |
| (I,J,16) | | (1,0086) | (5.0789) | (7.0124) | (5.8612) | (3.1660) | (0.7912) | (0.0680) | (0.3861) |
| Mo(6) | | -8.278242 | 11.730661 | 19.27236 | 0.307183 | 6.364818 | 1.961681 | 1,844204 | 0.038902 |
| (I,J,17) | | (1.5973) | (6.1141) | (7.6474) | (6.5385) | (2.7476) | (1.7517) | (1.215) | (1.4595) |
| Mo(7) | | 3.119831 | 7.831004 | 12.846868 | 0.187360 | 12.069186 | -2.404087 | -2.843505 | -0.052713 |
| (I,J,18) | | (0.6213) | (4.1928) | (5.1553) | (4.0366) | (5.6472) | (2.5543) | (2.3064) | (2.4114) |
| Mo(8) | | 1.460057 | 6.865937 | 12.959002 | 0.200289 | 12.064814 | -0.853297 | -1.482720 | -0.023225 |
| (I,J,19) | | (0.3584) | (4.7668) | (7.0198) | (5.7038) | (4.1643) | (0.7140) | (0.9248) | (0.8185) |
| Mo(9) | | -6.537216 | 9.546175 | 14.00266 | 0.221371 | 12.175147 | -3.362363 | -4.539361 | -0.079297 |
| (I,J,20) | | (1.8342) | (7.7416) | (8.6307) | (7.2270) | (4.1828) | (2.8165) | (2.9095) | (2.8481) |
| Mo(10) | | 14.611181 | -1.588245 | 0.691515 | -0.028500 | -14.503273 | 8.850367 | 0.186781 | 0.186781 |
| (I,J,21) | | (3.4242) | (1.0727) | (0.4074) | (0.8917) | (6.1137) | (5.0380) | (5.5149) | (4.0524) |
| Mo(11) | | 16.729324 | 0.752391 | 3.278429 | 0.046161 | -3.140769 | 3.954645 | 6.565447 | 0.106393 |
| (I,J,22) | | (5.7682) | (0.8223) | (4.0430) | (2.5850) | (3.2930) | (6.1997) | (9.5640) | (8.1776) |
| Mo(12) | | 16.219696 | 0.362121 | 2.948939 | 0.038252 | -3.781747 | 4.199112 | 6.913476 | 0.112422 |
| (I,J,23) | | (5.9038) | (0.3082) | (2.7368) | (1.7532) | (3.5391) | (6.8856) | (11.1618) | (9.3423) |
| $R^2$ | | 0.9902 | 0.9928 | 0.9939 | 0.9942 | 0.9935 | 0.9923 | 0.9920 | 0.9925 |
| D-W | | 2.08282 | 1.9194 | 2.0119 | 2.0933 | 1.9011 | 2.1001 | 2.0191 | 2.0719 |

Continued

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut and outlet (t values appear in parentheses below the parameter)--Continued

| | QP (4,2) | QP (1,4) | QP (2,4) | QP (3,4) | QP (4,4) | QP (1,5) | QP (2,5) | QP (3,5) | QP (4,5) |
|---|---|---|---|---|---|---|---|---|---|
| Constant | -0.044899 | -3,691405 | 0.601671 | 0.958946 | 0 008963 | -1.758526 | -0.222059 | 3.039920 | 0.026850 |
| (I,J,1) | | | | | | | | | |
| TQP (1,1) | | | | | | -0.052520 | | 0.0399234 | |
| DELTAI(I,T,2) | | | | | | (12.3546) | | (8.8931) | |
| TQP (2,1) | 0.006483 | | | | | -0.058316 | | | |
| (I,J,3) | (21.6631) | | | | | (4.3495) | | | |
| TQP (4,1) | | 0.756009 | 0.026639 | 0.020354 | 0.000416 | | | | |
| (J,I,4) | | (41.6569) | (3.5254) | (2.5556) | (2.6696) | | | | |
| TQP (5,1) | | | 0.072718 | 0.098107 | 0.001822 | 0.896183 | 0.232634 | 0.189674 | 0.006314 |
| (J,I,5) | | | (9.7999) | (12.8498) | (12.3025) | (20.9312) | (22.5011) | (9.5625) | (22.0342) |
| TQP (8,1) | | | | | | -0.038504 | | | |
| (J,I,7) | | | | | | (6.9867) | | | |
| TQP (10,1) | | | 0.017542 | 0.019775 | 0.000399 | -0.047538 | 0.042052 | | |
| (J,I,9) | | | (8.9592) | (8.4014) | (9.2191) | (8.2190) | (8.7290) | | |
| B | 0.422786 | 0.467833 | 0.981219 | 0.305012 | 0.419566 | 0.388660 | 0.969862 | 0.258626 | 0.295968 |
| (J,I,10) | (3.7324) | (4.0878) | (23.8749) | (2.4539) | (3.4717) | (3.2841) | (24.1651) | (2.1771) | (2.5597) |
| WPP (1,1) | | | | | | | | | |
| (I,J,11) | | | | | | | | | |
| WPP(2,1) | -0.000466 | | | | | | | | |
| (I,J,11) | (0.7612) | | | | | | | | |
| WPP (4,1) | | 0.018121 | -0.000843 | -0.001324 | -0.000005 | | | | |
| (I,J,11) | | (1.5239) | (0.3441) | (0.4771) | (0.1253) | | | | |
| WPP(5,1) | | | | | | 0.009503 | -0.002963 | -0.002963 | -0.000112 |
| (I,J,11) | | | | | | (1.6996) | (0.5142) | (1.2041) | (0.6236) |
| T | 0.000298 | -0.011602 | | -0.006191 | | -0.005268 | | -0.013889 | 0.000101 |
| (I,J,12) | (1.7804) | (2.8785) | | (4.3097) | | (2.8489) | | (4.6958) | (.8399) |
| Mo(2) | 0.018733 | 1.175674 | -0.721902 | -0.318462 | -0.007464 | 0.588649 | 0.090000 | -0.724265 | -0.004862 |
| (I,J,13) | (1.0244) | (4.6150) | (10.5158) | (4.0464) | (4.6013) | (3.2841) | (0.5842) | (4.0357) | (1.1697) |
| Mo(3) | 0.057470 | -0.375232 | -0.266660 | 0.086106 | -0.000493 | 0.502246 | 0.872696 | -0.999649 | 0.005840 |
| (I,J,14) | (2.9338) | (1.5490) | (3.4485) | (1.3540) | (0.3651) | (2.0209) | (4.8083) | (4.8281) | (1.3578) |
| Mo(4) | -0.121550 | 2.854744 | -1.543464 | -1.231857 | -0.024840 | 3.369794 | -1.362780 | -2.215962 | -0.041651 |
| (I,J,15) | (6.6829) | (11.3746) | (21.4438) | (13.4791) | (13.4730) | (21.0944) | (8.5839) | (15.9634) | (10.6117) |

Continued

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut and outlet (t values appear in parentheses below the parameter)--Continued

| | | QP(1,4) | QP(2,4) | QP(3,4) | QP(4,4) | QP(1,5) | QP(2,5) | QP(3,5) | QP(4,5) |
|---|---|---|---|---|---|---|---|---|---|
| Mo(5) | D | 2.282324 | -0.527862 | -0.748736 | -0.013902 | 2.146414 | 0.713793 | -1.743444 | -0.012879 |
| (I,J,16) | | (7.2028) | (8.0854) | (7.9956) | (8.6912) | (4.7008) | (4.4108) | (6.4267) | (1.7702) |
| Mo(6) | | 2.007889 | -0.439416 | -0.605183 | -0.011648 | 1.947727 | 0.765621 | -1.437459 | -0.005447 |
| (I,J,17) | | (5.3544) | (6.5657) | (6.9843) | (7.6064) | (4.3013) | (4.8791) | (5.3478) | (0.9335) |
| Mo(7) | | 1.153051 | -0.466125 | -0.609306 | -0.011676 | 3.150031 | -0.174250 | -1.693753 | -0.02150 |
| (I,J,18) | | (2.7939) | (5.5804) | (8.3678) | (8.8417) | (7.6758) | (1.1227) | (7.9380) | (4.2180) |
| Mo(8) | | 1.671023 | -0.535752 | -0.559232 | -0.011537 | 3.085966 | 0.446495 | -2.064565 | -0.016052 |
| (I,J,19) | | (5.1529) | (7.9554) | (8.2673) | (9.4315) | (5.5282) | (2.6315) | (7.8135) | (2.7384) |
| Mo(9) | | 0.987221 | -0.660281 | -0.747727 | -0.015151 | 3.209171 | -0.197853 | -1.994678 | -0.029064 |
| (I,J,20) | | (2.8466) | (8.0811) | (11.9556) | (12.6507) | (5.6635) | (1.1500) | (8.0251) | (5.1617) |
| Mo(10) | | 1.235710 | -0.538505 | -0.649745 | -0.013372 | -2.28167 | 2.277323 | 0.717458 | 0.018083 |
| (I,J,11) | | (4.0524) | (7.7532) | (8.8899) | (10.0540) | (3.8030) | (12.1792) | (2.9068) | (2.6127) |
| Mo(11) | | -0.353328 | -0.451739 | -0.009389 | 0.333167 | 0.591173 | 0.591173 | -0.783547 | 0.007471 |
| (I,J,12) | | (0.8456) | (4.3195) | (5.5709) | (6.1283) | (1.3571) | (3.9296) | (3.4194) | (2.0197 |
| Mo(12) | | 0.294069 | -0.422939 | -0.384336 | -0.008686 | 0.141874 | 0.685401 | -0.932046 | 0.010224 |
| (I,J,13) | | (1.2387) | (6.0840) | (5.7707) | (6.7472) | (5.5343) | (4.4151) | (3.9676) | (2.7283) |
| $R^2$ | | 0.9928 | 0.9942 | 0.9946 | 0.9951 | 0.9946 | 0.9947 | 0.9952 | 0.9910 |
| D-W | | 2.0234 | 2.1668 | 1.8758 | 1.8546 | 1.9611 | 2.4877 | 2.1668 | 2.0823 |

Continued

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut and outlet (t values appear in parentheses below the parameters)--Continued

| DELTAI (I,J,K) | | QP(1,8) | QP(2,8) | QP(3,8) | QP(4,8) | QP(1,9) | QP(2,9) | QP(3,9) | QP(4,9) | QP(1,10) | QP(2,10) | QP(3,10) | QP(4,10) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K = 1 Constant | | 4.659046 | -4.902735 | -3.918501 | -0.068039 | -8.319912 | 5.557776 | 8.455599 | 0.818548 | 0.813124 | -0.428440 | -0.440596 | 0.698991 |
| 2 TQP(1,1) | X | -1.173261 | | | | | | | | -0.132532 | | | 0.016031 |
| | | (10.1515) | | | | | | | | (11.9940) | | | (11.4441) |
| 3 TQP(5,1) | | | | | | -0.661746 | | | | | | | |
| | | | | | | (7.5754) | | | | | | | |
| 4 TQP(8,1) | | 0.759138 | 0.171678 | 0.200488 | 0.008049 | | | | | -0.195675 | | | 0.022871 |
| | | (30.0301) | (9.1542) | (9.3875) | (9.0946) | | | | | (12.1314) | | | (11.6356) |
| 5 TQP(9,1) | | -0.318677 | | | | 0.843668 | 0.244924 | 0.298512 | 0.032885 | | | | |
| | | (7.8922) | | | | (18.4706) | (17.8199) | (20.4273) | (19.2672) | | | | |
| 6 TQP(10,1) | ↓ | -0.118425 | | | | -0.172548 | | | | 0.903769 | 0.051830 | 0.040504 | 0.010522 |
| | | (4.6055) | | | | (7.1670) | | | | (45.0844) | (7.1639) | (4.2633) | (4.3478) |
| 7 $\beta$ | | 0.686498 | 0.100018 | 0.106175 | 0.068302 | 0.454400 | 0.332663 | 0.173230 | 0.256506 | 0.463752 | -0.023432 | 0.044036 | 0.476957 |
| | | (6.9432) | (1.4502) | (1.5845) | (1.0346) | (3.88[illegible]7) | (2.8699) | (1.4624) | (2.1811) | (4.0142) | (0.8331) | (1.5611) | (4.1903) |
| 8 TQP(1,1) | D | | 0.119900 | 0.142748 | 0.005940 | | | | | | | 0.064952 | |
| | | | (11.8536) | (12.4167) | (12.6857) | | | | | | | (13.2610) | |
| 9 TQP(5,1) | | | | | | | | | | | 0.253806 | | |
| | | | | | | | | | | | (14.9484) | | |
| 10 TQP(8,1) | | | | | | | | | | | 0.052437 | 0.087942 | |
| | | | | | | | | | | | (7.3486) | (11.2336) | |
| 11 WPP(1,1) | | -0.048505 | | | | | | | | | | | -0.003968 |
| | | (1.0829) | | | | | | | | | | | (1.2675) |
| 12 WPP(8,1) | | 0.034222 | -0.005937 | 0.008077 | -0.000720 | | | | | | | | |
| | | (1.1207) | (0.1866) | (0.2243) | (0.4692) | | | | | | | | |
| 13 WPP(4,1) | | | | | | -0.001472 | -0.012936 | -0.009201 | -0.001223 | | | | |
| | | | | | | (0.0510) | (0.5948) | (0.3850) | (0.4487) | | | | |
| 14 WPP(10,1) | ↓ | | | | | | | | | -0.041479 | -0.022967 | 0.002138 | -0.000014 |
| | | | | | | | | | | (2.3916) | (1.5386) | (0.1123) | (0.005725 |

Continued

Appendix table 11--Estimated parameters for wholesale quantities of pork distributed to retail and nonretail outlets, by cut outlet (t values appear in parentheses below the parameters)--Continued

| DELTAI (I,J,K) | | AP(1,8) | AP(2,8) | AP(3,8) | AP(4,8) | AP(1,9) | AP(2,9) | AP(3,9) | AP(4,9) | AP(1,10) | AP(2,10) | AP(3,10) | AP(4,10) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K = 15 T | D ↓ | | 0,052853 | -0.024787 | 0.000867 | -0.009114 | 0.040338 | -0.007867 | 0.002258 | | 0.040903 | -0.014204 | |
| | | | (4.0559) | (2.4605) | (1.6901) | (1.1604) | (4.5020) | (1.0792) | (2.7237) | | (6.3770) | (1.9502) | |
| 16 Mo(2) | | -3.824865 | 0.798242 | 1.227550 | 0.029440 | 2.147616 | -0.846842 | -0.147747 | -0.057796 | 1.264068 | 0.104835 | 0.125374 | -0.201587 |
| | | (3.3774) | (1.1154) | (1.4162) | (0.8509) | (4.1398) | (1.5315) | (0.2669) | (0.8661) | (1.5522) | (0.5614) | (0.5431) | (2.1534) |
| 17 Mo(3) | | -0.991610 | -0.653921 | -0.402619 | -0.0405.( | -0.282580 | 1.404904 | 2.463301 | 0.234206 | 2.517497 | 0.744398 | -0.314261 | -0.237986 |
| | | (0.7082) | (0.8448) | (0.4324) | (1.0770) | (0.3082) | (2.9041) | (5.0381) | (4.0063) | (2.5617) | (3.8393) | (0.7213) | (1.9725) |
| 18 Mo(4) | | -12.606320 | 4.651780 | 5.888854 | 0.226652 | 24.212723 | -10.451139 | -11.112752 | -1.130563 | 0.612967 | 0.068053 | 0.264015 | -0.116937 |
| | | (16.3574) | (8.2313) | (8.7484) | (8.3224) | (20.6167) | (15.4941) | (15.4415) | (15.4792) | (0.9334) | (0.3801) | (1.1939) | (1.5247) |
| 19 Mo(5) | | -3.665093 | 3.124223 | 4.142309 | 0.153750 | 12.325455 | -6.011622 | -7.840174 | -0.824493 | 3.230269 | 0.297379 | -0.510896 | -0.409553 |
| | | (2.3708) | (5.6241) | (6.3005) | (5.7269) | (7.1128) | (6.9265) | (7.2462) | (7.0151) | (3.8958) | (1.6785) | (2.2188) | (4.3427) |
| 20 Mo(6) | | -2.237982 | 1.464172 | 2.260351 | 0.076332 | 11.898990 | -6.319307 | -8.020718 | -0.855792 | 4.357778 | 0.224627 | -1.365579 | -0.519328 |
| | | (1.6619) | (2.9993) | (5.8907) | (3.2423) | (7.6426) | (8.0369) | (8.2534) | (8.0783) | (6.9256) | (1.1286) | (5.9353) | (7.1161) |
| 21 Mo(7) | | -11.632910 | 4.896282 | 6.343328 | 0.246310 | 7.478582 | -4.654475 | -6.028453 | -0.634958 | -2.518065 | 2.312738 | 1.506473 | 0.328260 |
| | | (10.8431) | (8.3412) | (9.1913) | (8.8366) | (5.1564) | (5.8361) | (6.1781) | (5.9435) | (5.2718) | (9.1790) | (5.6460) | (5.5397) |
| 22 Mo(8) | | -7.925900 | 4.766389 | 6.328539 | 0.243257 | 8.659907 | -4.204174 | -5.092379 | -0.553967 | 0.131232 | 3.032072 | 1.477706 | 0.032306 |
| | | (4.2842) | (9.7208) | (10.8934) | (10.4615) | (9.2979) | (6.6413) | (6.6453) | (6.5803) | (0.1327) | (13.8399) | (6.6474) | (0.2721) |
| 23 Mo(9) | | -9.159710 | 6.495649 | 8.442656 | 0.334430 | 11.073309 | -4.968255 | -5.817170 | -0.646067 | -1.963930 | 2.800255 | 2.449975 | 0.285819 |
| | | (5.1896) | (14.9471) | (16.9090) | (16.4719) | (13.3036) | (9.1318) | (9.0610) | (9.0563) | (2.1591) | (15.2706) | (11.9114) | (2.6243) |
| 24 Mo(10) | | 8.255666 | -0.177824 | 0.693390 | 0.012618 | 4.677826 | -1.293535 | -1.500503 | -0.162552 | 6.100170 | -0.911468 | -0.929573 | -0.707191 |
| | | (4.1609) | (0.4075) | (1.4081) | (0.6245) | (4.4043) | (2.2307) | (2.1756) | (2.1248) | (5.2960) | (5.6323) | (4.5858) | (4.8771) |
| 25 Mo(11) | | -1.373717 | -1.207733 | -0.412666 | -0.047639 | 6.099052 | -2.170521 | -1.729699 | -0.233984 | 3.937970 | -0.355241 | -1.484043 | -0.447811 |
| | | (0.9788) | (1.8427) | (0.5454) | (1.5621) | (9.1117) | (5.3142) | (3.9762) | (4.6290) | (4.5550) | (2.1162) | (5.4626) | (4.1256) |
| 26 Mo(12) | | -1.224770 | -1.601076 | -0.964975 | -0.066777 | 5.844336 | -2.440387 | -2.054065 | -0.271203 | 3.491158 | 0.260115 | -1.553729 | -0.347927 |
| | | (0.8962) | (2.0933) | (1.1039) | (.18785) | (9.4585) | (6.1529) | (4.8865) | (5.5378) | (3.8558) | (1.4272) | (4.3625) | (2.9761) |
| $R^2$ | | 0.9782 | 0.9925 | 0.9895 | 0.9916 | 0.9884 | 0.9895 | 0.9891 | 0.9893 | 0.9886 | 0.9963 | 0.9937 | 0.9935 |
| D-W | | 2.0445 | 1.3558 | 1.3107 | 1.2795 | 1.6747 | 1.9392 | 1.9409 | 1.9540 | 2.1473 | 1.6851 | 1.2442 | 2.0777 |

Appendix table 12--Estimated parameters of retail pork prices, by cut and outlet

| Equation name and no. | | $QP_t^{ij}$ Own quantity | $RBP_t$ Beef price | $RCP_t$ Poultry price | $RMP_t$ Red meat produce | TCKP Poultry produce | β Auto-correlations |
|---|---|---|---|---|---|---|---|
| Ham Chain Price | 1 | -0.190121 | | 0.092557 | 0.057767 | | 0.947779 |
| | | (0.1357) | | (0.2194) | (0.0364) | | (0.0447) |
| Ham Ind. Price | 2 | -0.219481 | | 0.114154 | 0.074723 | | 0.938737 |
| | | (0.1161) | | (0.2179) | (0.0365) | | (0.0462) |
| Ham Conv. Price | 3 | -11.455462 | | 0.113440 | 0.073682 | | 0.943141 |
| | | (6.6297) | | (0.2296) | (0.0390) | | (0.0456) |
| Loin Chain Price | 4 | -0.514582 | | | 0.080913 | 0.146590 | 0.962720 |
| | | (0.1681) | | | (0.0422) | (0.0755) | (0.0316) |
| Loin Ind. Price | 5 | -0.421922 | | | 0.078907 | 0.145342 | 0.938600 |
| | | (0.1452) | | | (0.0435) | (0.0766) | (0.0392) |
| Loin Conv. Price | 6 | -24.094574 | | | 0.082628 | 0.156301 | 0.950621 |
| | | (8.2130) | | | (0.456) | (0.0800) | (0.0357) |
| Rib Chain Price | 7 | -4.141293 | | 0.255093 | 0.097857 | | 0.973477 |
| | | (1.2198) | | (0.2154) | (0.0366) | | (0.0268) |
| Rib Ind. Price | 8 | -3.866458 | | 0.273290 | 0.112043 | | 0.955362 |
| | | (1.0404) | | (0.2134) | (0.0373) | | (0.0344) |
| Rib. Conv. Price | 9 | -205.465100 | | 0.275932 | 0.108265 | | 0.965355 |
| | | (59.3315) | | (0.2259) | (0.0394) | | (0.0304) |
| Butts Chain Price | 10 | -2.075989 | | 0.170603 | 0.148697 | | 0.982724 |
| | | (0.4718) | | (0.1846) | (0.0341) | | (0.0345) |
| Butts Ind. Price | 11 | -1.897387 | | 0.195482 | 0.162016 | | 0.947069 |
| | | (0.3905) | | (0.1826) | (0.0337) | | (0.0434) |
| Butts Con. Price | 12 | -105.903700 | | 0.202864 | 0.167865 | | 0.966345 |
| | | (22.4834) | | (0.1923) | (0.0360) | | (0.0394) |
| Picnic Chain Price | 13 | -0.687902 | | 0.316373 | 0.059152 | | 0.932259 |
| | | (0.3442) | | (0.1720) | (0.0284) | | (0.0364) |
| Picnic Ind. Price | 14 | -0.535162 | | 0.318943 | 0.054841 | | 0.923224 |
| | | (0.2949) | | (0.1734) | (0.0287) | | (0.0391) |
| Picnic Conv. Price | 15 | -38.938004 | | 0.332995 | 0.059256 | | 0.927150 |
| | | (20.7526) | | (0.1815) | (0.0301) | | (0.0378) |
| Bacon Chain Price | 16 | -0.674129 | | 0.231104 | 0.111297 | | 0.931742 |
| | | (0.2342) | | (0.3261) | (0.0545) | | (0.0468) |
| Bacon Ind. Price | 17 | -0.571185 | | 0.249601 | 0.110250 | | 0.926278 |
| | | (0.2017) | | (0.3276) | (0.0550) | | (0.0469) |
| Bacon Conv.Price | 18 | -14.549573 | | 0.260287 | 0.117768 | | 0.927713 |
| | | (5.0651) | | (0.3436) | (0.0576) | | (0.0471) |
| Sausage Chain Price | 19 | -0.454320 | 0.349784 | 0.244879 | 0.057618 | | 0.964447 |
| | | (0.1765) | (0.0982) | (0.1497) | (0.0230) | | (0.0385) |
| Sausage Ind. Price | 20 | -0.375683 | 0.344838 | 0.242158 | 0.057182 | | 0.964416 |
| | | (0.1586) | (0.0991) | (0.1507) | (0.0246) | | (0.0396) |
| Sausage Conv. Price | 21 | -3.490165 | 0.369176 | 0.252277 | 0.058397 | | 0.964536 |
| | | (1.4532) | (0.1038) | (0.1579) | (0.0250) | | (0.0393) |
| Lunch Meat Chain Price | 22 | -0.177186 | 0.225462 | 0.221448 | 0.049267 | -0.079512 | 0.969380 |
| | | (0.1654) | (0.0762) | (0.1146) | (0.0199) | (0.0390) | (0.0173) |
| Lunch Meat Ind. Price | 23 | -0.138409 | 0.225031 | 0.219907 | 0.047881 | -0.080648 | 0.968224 |
| | | (0.1401) | (0.0762) | (0.1147) | (0.0199) | (0.0390) | (0.0176) |
| Lunch Meat Conv. Price | 24 | -0.549370 | 0.235734 | 0.228656 | 0.049897 | -0.083357 | 0.968390 |
| | | (0.5635) | (0.0806) | (0.1213) | (0.0210) | (0.0415) | (0.0177) |

Continued

Appendix table 12--Estimated parameters of retail pork prices, by cut and outlet--Continued

| Equation Name and Number | | DUMMIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec |
| Ham Chain Price | 1 | -1.799729 | -1.069483 | -0.996820 | -1.323294 | 0.673961 | -1.772569 | -0.281355 | -1.263749 | -1.715735 | -0.247329 | 0.552971 |
| | | (1.2434) | (1.4346) | (2.9509) | (1.2118) | (1.3533) | (1.0665) | (1.3430) | (1.2922) | (1.0103) | (1.5372) | (1.3299) |
| Ham Ind. Price | 2 | -1.944324 | -0.141128 | 0.815436 | -0.591666 | 1.53310 | -1.614889 | 0.633138 | -0.424520 | -1.415904 | 0.762343 | 1.372417 |
| | | (1.3639) | (1.5929) | (3.1680) | (1.3386) | (1.5120) | (1.0152) | (1.5132) | (1.4420) | (0.9782) | (1.7058) | (1.4617) |
| Ham Conv. Price | 3 | -1.403852 | -0.507937 | 0.245541 | -0.918173 | 1.270241 | -1.819970 | 0.301360 | -0.733667 | -1.663007 | 0.418798 | 1.123125 |
| | | (1.3835) | (1.6132) | (3.2782) | (1.3379) | (1.5245) | (1.0887) | (1.5205) | (1.4528) | (1.0378) | (1.7306) | (1.4854) |
| Loin Chain Price | 4 | 1.511875 | 0.646692 | -6.560368 | 1.193018 | 2.580726 | 0.318533 | -1.460804 | -1.370745 | 4.937091 | 1.465798 | 1.729649 |
| | | (1.4469) | (1.7979) | (1.5257) | (1.6987) | (1.8774) | (1.5396) | (1.8454) | (1.4496) | (3.4292) | (1.8038) | (1.5390) |
| Loin Ind. Price | 5 | 2.405797 | 1.556997 | -5.607962 | 1.956342 | 3.361498 | 1.162212 | -0.544688 | -0.556844 | 5.598352 | 2.341757 | 2.544542 |
| | | (1.6796) | (2.0816) | (1.4238) | (1.8544) | (2.0336) | (1.6203) | (2.0324) | (1.6363) | (3.7550) | (2.1215) | (1.8126) |
| Loin Conv. Price | 6 | 2.085253 | 1.131806 | -6.375149 | 1.653898 | 3.115737 | 0.775998 | -1.049917 | -0.933797 | 5.536715 | 2.035686 | 2.281694 |
| | | (1.6638) | (2.0697) | (1.5426) | (1.8841) | (2.0758) | (1.6638) | (2.0562) | (1.6405) | (3.8385) | (2.0980) | (1.7876) |
| Rib Chain Price | 7 | 0.419409 | 0.595814 | -5.782538 | 0.649524 | 3.128622 | 0.007896 | 0.270227 | -2.012171 | -3.873835 | -0.951312 | 0.329656 |
| | | (1.0760) | (0.9666) | (2.2889) | (1.0893) | (1.0372) | (1.1785) | (1.0061) | (1.0797) | (1.0069) | (0.9693) | (0.9873) |
| Rib Ind. Price | 8 | 1.325302 | 1.720232 | -5.565854 | 1.477776 | 3.98116 | 0.823789 | 1.343463 | -1.062638 | -2.642220 | 0.182664 | 1.216653 |
| | | (0.9810) | (1.0113) | (2.0682) | (0.9921) | (0.9598) | (1.0576) | (0.9385) | (0.9843) | (1.0733) | (1.0114) | (0.9403) |
| Rib Conv. Price | 9 | 0.937732 | 1.226202 | -5.877607 | 1.144845 | 3.764072 | 0.463470 | 0.878112 | -1.574645 | -3.412341 | -0.409011 | 0.831677 |
| | | (1.0722) | (1.0348) | (2.3118) | (1.0868) | (1.0422) | (1.1710) | (1.0135) | (1.0781) | (1.0930) | (1.0370) | (1.0066) |
| Butts Chain Price | 10 | 1.624944 | 1.122435 | -4.331820 | 2.364011 | 4.164929 | 2.845720 | 3.323825 | -0.350121 | 7.752876 | 2.537832 | 2.669733 |
| | | (0.9786) | (1.2291) | (1.0942) | (0.9813) | (1.0040) | (0.8671) | (1.0155) | (0.9577) | (2.1229) | (1.2915) | (1.0729) |
| Butts Ind. Price | 11 | 3.036215 | 5.705358 | -3.455027 | 3.579465 | 5.384296 | 3.937345 | 4.797447 | 1.018414 | 9.701348 | 4.320599 | 4.193202 |
| | | (1.1054) | (1.4020) | (0.9353) | (1.0905) | (1.1252) | (0.9142) | (1.137) | (1.0514) | (2.2682) | (1.4729) | (1.2204) |
| Butts Conv. Price | 12 | 2.584862 | 5.359914 | -4.131908 | 3.275589 | 5.156605 | 3.652154 | 4.428846 | 0.490366 | 9.527299 | 3.812738 | 3.758452 |
| | | (1.1031) | (1.4034) | (1.0533) | (1.1000) | (1.1316) | (0.9340) | (1.1469) | (1.0660) | (2.3483) | (1.4726) | (1.2163) |
| Picnic Chain Price | 13 | 0.266770 | -0.162072 | -0.203241 | -0.136841 | 1.080078 | 0.928037 | 0.767719 | 0.728999 | 1.607610 | 1.309035 | 0.463197 |
| | | (0.7966) | (0.8575) | (0.7469) | (0.8073) | (0.7674) | (0.7851) | (0.7873) | (0.8620) | (0.9526) | (0.8971) | (0.7929) |
| Picnic Ind. Price | 14 | 0.457565 | 0.010134 | -0.021546 | 0.107877 | 1.287597 | 1.125759 | 0.957191 | 0.885259 | 1.750572 | 1.467605 | 0.640646 |
| | | (0.8382) | (0.9297) | (0.7695) | (0.7868) | (0.7726) | (0.7955) | (0.8401) | (0.9278) | (1.0352) | (0.9762) | (0.8429) |
| Picnic Conv. Price | 15 | 0.389517 | 0.088298 | -0.108468 | 0.002267 | 1.255860 | 1.089512 | 0.913237 | 0.849579 | 1.762243 | 1.459335 | 0.585430 |
| | | (0.8589) | (0.9403) | (0.7964) | (0.8396) | (0.8074) | (0.8292) | (0.8556) | (0.9420) | (1.0466) | (0.9863) | (0.8591) |
| Bacon Chain Price | 16 | 1.197117 | 2.305901 | 1.560078 | 1.977606 | 4.774769 | 5.201463 | 4.269128 | 3.583832 | -5.063715 | 1.68384 | 2.790154 |
| | | (1.7213) | (2.0286) | (1.7990) | (1.6722) | (1.7589) | (2.2418) | (1.9037) | (1.8649) | (1.6417) | (2.1320) | (1.8378) |
| Bacon Ind. Price | 17 | 1.721071 | 2.922522 | 2.135285 | 1.598378 | 5.374310 | 5.766291 | 4.971011 | 4.250655 | -4.325423 | 2.331984 | 3.366364 |
| | | (1.8546) | (2.2082) | (1.9474) | (1.7983) | (1.9028) | (2.4149) | (2.0845) | (2.0213) | (1.5626) | (2.3293) | (1.9855) |
| Bacon Conv. Price | 18 | 1.53056 | 1.802198 | 1.994643 | 2.459312 | 5.374326 | 5.829816 | 4.921712 | 4.175228 | -4.888109 | 2.186239 | 3.291179 |
| | | (1.8805) | (2.2305) | (1.9722) | (1.8252) | (1.9271) | (2.4535) | (2.1025) | (2.0484) | (1.6752) | (2.3458) | (2.0136) |
| Sausage Chain Price | 19 | -1.187803 | -2.063418 | -8.244716 | -2.383562 | -2.028908 | -1.359656 | -1.373788 | -2.641674 | -0.838876 | -3.551276 | -2.955355 |
| | | (0.8144) | (0.6863) | (2.4534) | (0.8276) | (0.8153) | (0.7030) | (0.7386) | (0.7949) | (0.7287) | (0.6868) | (0.739) |
| Sausage Ind. Price | 20 | 1.777903 | -1.673341 | -7.778102 | -1.985131 | -1.638722 | -0.981471 | 0.975233 | -2.266269 | -0.488404 | -3.165864 | -2.594463 |
| | | (0.7565) | (0.6872) | (2.4630) | (0.7693) | (0.7590) | (0.6963) | (0.6890) | (0.7409) | (0.8132) | (0.6834) | (0.7011) |
| Sausage Conv. Price | 21 | 2.052387 | -1.947368 | -8.259539 | -2.268354 | -1.889155 | -1.218807 | -1.197643 | -2.529214 | -0.703365 | -3.518913 | -2.893136 |
| | | (0.8219) | (0.7176) | (2.5859) | (0.8367) | (0.8236) | (0.7316) | (0.7463) | (0.8038) | (0.8086) | (0.7162) | (0.7540) |
| Lunch Meat Chain Price | 22 | 0.502561 | 1.455377 | 1.072618 | 1.591329 | 1.990356 | 1.659085 | 2.673980 | 0.665028 | 1.639008 | 0.599825 | 0.831563 |
| | | (0.5396) | (0.6603) | (0.7658) | (0.7632) | (0.8584) | (0.8607) | (0.8272) | (0.6204) | (0.8142) | (0.6129) | (0.5421) |
| Lunch Meat Ind. Price | 23 | 0.583637 | 1.519756 | 1.181867 | 1.680237 | 2.080424 | 1.707002 | 2.762739 | 0.744530 | 1.769400 | 0.656297 | 0.892946 |
| | | (0.6051) | (0.6992) | (0.7353) | (0.7646) | (0.8624) | (0.8993) | (0.8435) | (0.6404) | (0.7691) | (0.6623) | (0.5727) |
| Lunch Meat Conv. Price | 24 | 0.601123 | 1.584802 | 1.216936 | 1.735269 | 2.161137 | 1.769475 | 2.875198 | 0.770386 | 1.828596 | 0.689961 | 0.931542 |
| | | (0.6362) | (0.7331) | (0.7855) | (0.8068) | (0.9095) | (0.9416) | (0.8869) | (0.6732) | (0.8239) | (0.6979) | (0.6024) |

Continued

Appendix table 12--Estimated parameters of retail pork prices, by cut and outlet--Continued

| Equation Name and Number | | 1965 Dummy | Constant | $R^2$ | Durbin-Watson |
|---|---|---|---|---|---|
| Ham Chain Price | 1 | 1.457629<br>(0.6755) | 4.394650 | 0.9100 | 1.6938 |
| Ham Ind. Price | 2 | 1.385193<br>(0.6431) | 4.196970 | 0.9120 | 1.7193 |
| Ham Conv. Price | 3 | 1.472851<br>(0.6943) | 4.413339 | 0.9113 | 1.7134 |
| Loin Chain Price | 4 | | 3.022997 | 0.9408 | 1.5378 |
| Loin Ind. Price | 5 | | 4.208594 | 0.9403 | 1.5680 |
| Loin Conv. Price | 6 | | 3.784664 | 0.9404 | 1.5562 |
| Rib Chain Price | 7 | | 2.698295 | 0.9536 | 1.8052 |
| Rib Ind. Price | 8 | | 2.954039 | 0.9551 | 1.7633 |
| Rib Conv. Price | 9 | | 2.888651 | 0.9540 | 1.780 |
| Butts Chain Price | 10 | 0.961001<br>(0.5809) | -1.148357 | 0.9478 | 1.4601 |
| Butts Ind. Price | 11 | 0.788906<br>(0.5241) | -0.644826 | 0.9504 | 1.5505 |
| Butts Conv. Price | 12 | 0.875452<br>(0.5836) | -1.169025 | 0.9494 | 1.5183 |
| Picnic Chain Price | 13 | | 2.024258 | 0.9273 | 2.1369 |
| Picnic Ind. Price | 14 | | 2.154676 | 0.9265 | 2.1311 |
| Picnic Conv. Price | 15 | | 2.209477 | 0.9268 | 2.1320 |
| Bacon Chain Price | 16 | 1.844529<br>(0.9509) | 3.651814 | 0.9172 | 1.8230 |
| Bacon Ind. Price | 17 | 1.922082<br>(0.9053) | 3.413120 | 0.9168 | 1.8238 |
| Bacon Conv. Price | 18 | 1.966253<br>(0.9732) | 3.739574 | 0.9170 | 1.8247 |
| Sausage Chain Price | 19 | 1.008748<br>(0.4974) | 3.415465 | 0.9735 | 1.8784 |
| Sausage Ind. Price | 20 | 1.039734<br>(0.4784) | 3.036424 | 0.9731 | 1.8679 |
| Sausage Conv. Price | 21 | 1.083827<br>(0.5118) | 3.345042 | 0.9733 | 1.8707 |
| Lunch Meat Chain Price | 22 | | 0.713479 | 0.9891 | 1.5465 |
| Lunch Meat Ind. Price | 23 | | 0.698752 | 0.9891 | 1.5398 |
| Lunch Meat Conv. Price | 24 | | 0.747657 | 0.9890 | 1.5388 |

Appendix table 13--Estimated regression coefficients for wholesale, retail, and farm-retail price spreads ($WRPS_t$, $FRPS_t$)

| Item | Wholesale-Retail Price Spread (WRPS) | | Farm-Retail Price Spread (FRPS) | |
|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value |
| Constant | -5.7252 | --- | -7.8622 | --- |
| $WRPS_{t-1}$ | -0.0063 | 0.010 | --- | |
| $FRPS_{t-1}$ | --- | --- | 0.1067 | 1.700 |
| $APR^2_{t-1}$ | 0.0692 | 1.635 | --- | --- |
| $APR^5_{t-1}$ | 0.0359 | 0.630 | --- | --- |
| $APR^6_{t-2}$ | 0.0264 | 1.122 | --- | --- |
| BFCM | -0.5334 | 0.315 | --- | --- |
| TCKP | -0.1899 | 0.034 | 4.0539 | 1.330 |
| STQGS | -0.0022 | 0.541 | --- | --- |
| $CRPP_t$ | 0.4351 | 3.713 | 0.9030 | 1.271 |
| $CWPP_t$ | -0.0138 | 0.092 | -0.0769 | 0.631 |
| APBC | -0.8123 | 4.247 | -1.3897 | 9.297 |
| Trend | --- | --- | -0.0115 | 1.233 |
| Feb. Dummy* | 0.1575 | 0.321 | -0.0913 | --- |
| Mar. Dummy | 0.4852 | 1.004 | 0.2606 | 0.635 |
| Apr. Dummy | -0.0872 | 1.623 | -0.7285 | 1.750 |
| May Dummy | -0.3966 | 0.633 | -1.1526 | 2.770 |
| June Dummy | -0.2407 | 0.313 | -1.1688 | 2.750 |
| July Dummy | -0.3107 | 0.370 | -1.0349 | 2.494 |
| Aug. Dummy | 0.0644 | 0.076 | -0.9331 | 2.109 |
| Sept. Dummy | -0.1294 | 0.208 | -0.6918 | 1.623 |
| Oct. Dummy | -0.0029 | 0.005 | -0.6879 | 1.640 |
| Nov. Dummy | -0.7910 | 1.452 | -0.5391 | 1.198 |
| Dec. Dummy | -1.1959 | 2.081 | -0.3618 | 0.798 |
| D65 | 0.4518 | 0.873 | --- | --- |
| $R^2$ | .91 | | | |
| D-W | 1.729 | | | |

*January served as a priori excluded month.

Appendix table 14.--Monthly percentage deviation of selected variables for simulated results

| Year | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total | Ann. Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Sows Farrowings | | | | | | | |
| 1965 | -3.64 | -4.25 | -1.81 | 0.96 | -8.73 | -5.39 | -1.11 | 2.42 | 4.41 | -1.81 | -16.98 | -11.04 | -38.37 | -3.20 |
| 1966 | -2.24 | 7.08 | 1.75 | -1.54 | -7.14 | -4.18 | -7.60 | 6.06 | 4.83 | 4.78 | 1.73 | -6.57 | -2.96 | -0.25 |
| 1967 | -2.90 | 6.14 | 1.70 | 0.83 | -11.38 | -6.26 | -6.74 | 2.28 | 1.12 | -6.22 | -17.06 | 9.45 | -27.04 | -2.25 |
| 1968 | 0.49 | -4.15 | 0.08 | 0.20 | -0.45 | 2.18 | 3.62 | -4.67 | -3.46 | -3.12 | -6.69 | 5.10 | -7.86 | -0.66 |
| 1969 | -1.94 | -10.10 | 2.20 | 5.33 | 4.94 | 4.61 | 2.34 | -5.06 | -2.10 | 1.69 | 7.50 | 6.82 | 16.22 | 1.35 |
| 1970 | -3.18 | -9.93 | -3.66 | -2.78 | 5.79 | 1.58 | -1.39 | -8.23 | -11.62 | -2.47 | 11.74 | 1.66 | -25.01 | -2.08 |
| 1971 | -8.38 | -16.84 | -5.68 | -0.58 | -3.16 | -0.17 | -6.08 | -9.83 | -2.52 | -7.04 | -6.95 | 5.52 | -60.71 | -5.06 |
| | | | | | Total Number Market Hogs Sold--Commercial Hog Slaughter | | | | | | | | | |
| 1965 | 6.51 | 3.9 | -3.91 | 5.30 | 2.84 | -1.07 | 1.32 | 3.49 | -3.31 | 8.52 | -4.16 | 8.29 | 25.59 | 2.13 |
| 1966 | 2.52 | -1.28 | -2.25 | -4.27 | 6.15 | -2.25 | 1.96 | -4.00 | -4.56 | 4.74 | -3.54 | -0.74 | -23.70 | -1.98 |
| 1967 | -4.35 | -0.19 | -1.83 | 9.35 | 9.54 | 2.98 | 8.37 | -4.24 | -0.97 | 0.11 | -4.28 | 2.03 | 18.56 | 1.55 |
| 1968 | -9.50 | -6.09 | -3.58 | [illegible] | -13.42 | -7.1[illegible] | -7.29 | -4.98 | -0.81 | -5.37 | 0.14 | 0.77 | -57.03 | -4.75 |
| 1969 | -4.65 | -3.32 | 2.67 | -1.83 | 3.75 | -0.31 | -5.76 | 1.79 | -4.13 | -3.04 | 8.71 | 1.81 | -6.16 | -.51 |
| 1970 | 1.52 | 5.75 | 5.50 | -4.41 | 6.59 | -3.25 | -4.98 | 1.05 | -2.71 | -1.54 | -2.23 | -7.57 | -15.67 | -1.31 |
| 1971 | -2.16 | 6.65 | -4.95 | -2.67 | -6.63 | -8.35 | 0.23 | -4.10 | -4.79 | 5.36 | -8.04 | -7.70 | -29.78 | -2.48 |
| | | | | | | Average Price Market Barrows and Gilts | | | | | | | | |
| 1965 | -0.06 | 2.50 | -6.98 | -3.02 | -3.24 | -4.86 | -3.05 | -5.93 | -0.48 | -5.12 | -7.51 | -16.68 | -47.43 | -3.95 |
| 1966 | -10.59 | -4.74 | 5.17 | 10.94 | 6.39 | -1.04 | -2.25 | -11.03 | -4.16 | 0.98 | 10.13 | -4.21 | -6.64 | -.55 |
| 1967 | -2.95 | -5.83 | -9.28 | -11.53 | -21.52 | -16.13 | -11.64 | -6.47 | -0.95 | 1.55 | 3.75 | 5.71 | -80.03 | -6.67 |
| 1968 | 8.46 | 6.26 | 2.20 | 1.58 | 7.72 | 6.80 | 5.78 | 8.50 | 5.82 | 9.15 | 8.65 | 5.16 | 76.88 | 6.41 |
| 1969 | 3.22 | 5.98 | 0.19 | -0.77 | -3.45 | -2.74 | -1.98 | -6.80 | -6.53 | -9.15 | -11.65 | -14.00 | -45.68 | -3.81 |
| 1970 | -12.51 | -12.85 | -9.58 | -5.59 | 1.90 | 4.27 | 0.66 | 7.89 | 9.32 | 15.47 | 24.87 | 23.33 | 47.16 | 3.93 |
| 1971 | 15.50 | -2.22 | 3.04 | 2.84 | 5.67 | 8.24 | 5.42 | 8.42 | 6.98 | -0.64 | 3.85 | 0.48 | 57.57 | 4.80 |
| | | | | | | Composite Wholesale Pork Price | | | | | | | | |
| 1965 | -1.78 | -0.07 | 0.73 | -0.58 | -2.18 | -2.56 | -0.88 | -5.25 | -3.43 | -5.98 | -5.11 | -10.26 | -37.35 | -3.11 |
| 1966 | -10.32 | -4.61 | -2.51 | 2.81 | 4.40 | 5.24 | 5.73 | 2.47 | 2.27 | 1.72 | 2.79 | 2.32 | 12.26 | 1.02 |
| 1967 | 3.23 | 1.94 | 2.00 | -3.92 | -11.90 | -11.59 | -12.46 | -8.71 | -7.86 | -8.00 | -5.44 | -5.02 | -67.73 | -5.64 |
| 1968 | -1.12 | -3.15 | -3.88 | -5.55 | 0.31 | -0.88 | -0.41 | 2.04 | -1.56 | 1.31 | -1.23 | -1.88 | -15.98 | -1.33 |
| 1969 | 1.39 | -2.30 | -5.61 | -6.22 | -7.42 | -6.79 | -3.00 | -3.67 | -0.67 | 0.95 | -1.55 | -2.76 | -40.43 | -3.37 |
| 1970 | 1.57 | 2.15 | 2.25 | 8.60 | 21.78 | 14.61 | 15.53 | 16.06 | 19.92 | 17.83 | 15.97 | 15.22 | 151.39 | 12.62 |
| 1971 | 14.34 | 4.40 | 8.40 | 6.33 | 2.79 | 9.95 | 6.32 | 11.70 | 14.38 | 5.37 | 9.05 | 9.10 | 102.13 | 8.51 |
| | | | | | | Composite Retail Pork Price | | | | | | | | |
| 1965 | -0.16 | 3.92 | 2.11 | 5.66 | 3.91 | 3.65 | 1.82 | 0.77 | 2.23 | 0.20 | 3.44 | -3.77 | 28.78 | 2.40 |
| 1966 | -5.83 | -4.43 | -2.39 | -0.46 | 2.87 | 5.00 | 2.83 | 2.77 | 2.45 | 0.36 | 3.90 | 4.75 | 11.82 | 0.98 |
| 1967 | 7.02 | 7.89 | 8.81 | 5.83 | 4.96 | 3.72 | 3.22 | 7.75 | 5.80 | 6.92 | 7.30 | 7.67 | 76.89 | 6.41 |
| 1968 | 12.73 | 10.33 | 8.01 | 6.94 | 9.49 | 7.99 | 10.50 | 9.94 | 7.51 | 8.37 | 5.57 | 6.55 | 103.93 | 8.66 |
| 1969 | 8.89 | 7.11 | 4.22 | 2.70 | 0.34 | 0.11 | 1.46 | -1.53 | -1.68 | -2.59 | -6.39 | -5.12 | 7.52 | 0.63 |
| 1970 | -6.66 | -8.00 | -8.14 | -8.39 | -9.03 | -4.64 | -3.43 | -4.89 | -2.12 | -2.08 | -0.38 | 5.66 | 52.10 | -4.34 |
| 1971 | 4.77 | 1.53 | 3.95 | 0.76 | 1.65 | 6.99 | 5.16 | 5.77 | 5.32 | 0.66 | 3.51 | 2.37 | 42.34 | 3.53 |

Appendix table 15--Theil's inequality coefficient for endogenous variables of hog-pork subsector model

| Variable | μ-Statistic | Variable | μ-Statistic | Variable | μ-Statistic |
|---|---|---|---|---|---|
| SBG(1) | 0.175 | WPP(1) | 0.119 | QP(2.1) | 0.135 |
| SBG(2) | 0.099 | WPP(2) | 0.128 | QP(2.2) | 0.061 |
| SBG(3) | 0.065 | WPP(3) | 0.183 | QP(2.4) | 0.173 |
| SBG(4) | 0.089 | WPP(4) | 0.091 | QP(2.5) | 0.065 |
| SBG(5) | 0.236 | WPP(5) | 0.217 | QP(2.6) | 0.045 |
| SBG(6) | 0.109 | WPP(6) | 0.138 | QP(2.8) | 0.490 |
| PBG(1) | 0.072 | WPP(8) | 0.169 | QP(2.9) | 0.191 |
| PBG(2) | 0.105 | WPP(9) | 0.354 | QP(2.10) | 0.348 |
| PBG(3) | 0.108 | WPP(10) | 0.045 | QP(3.1) | 0.097 |
| PBG(4) | 0.084 | APR(1) | 0.529 | QP(3.2) | 0.045 |
| PBG(5) | 0.098 | APR(2) | 0.198 | QP(3.4) | 0.071 |
| PBG(6) | 0.128 | APR(4) | 0.124 | QP(3.5) | 0.051 |
| PHD(1) | 0.206 | APR(5) | 0.176 | QP(3.6) | 0.050 |
| PHD(2) | 0.139 | APR(6) | 0.444 | QP(3.8) | 0.111 |
| PHD(3) | 0.122 | APR(8) | 0.578 | QP(3.9) | 0.122 |
| PHD(4) | 0.127 | APR(9) | 0.296 | QP(3.10) | 0.090 |
| PHD(5) | 0.242 | APR(10) | 0.436 | QP(4.1) | 0.076 |
| PHD(6) | 0.159 | TQP(1) | 0.076 | QP(4.2) | 0.045 |
| TWHD(1) | 0.184 | TQP(2) | 0.045 | QP(4.4) | 0.068 |
| TWHD(2) | 0.106 | TQP(4) | 0.137 | QP(4.5) | 0.051 |
| TWHD(3) | 0.070 | TQP(5) | 0.045 | QP(4.6) | 0.044 |
| TWHD(4) | 0.089 | TQP(6) | 0.045 | QP(4.8) | 0.109 |
| TWHD(5) | 0.240 | TQP(8) | 0.180 | QP(4.9) | 0.128 |
| TWHD(6) | 0.124 | TQP(9) | 0.147 | QP(4.10) | 0.227 |
| | | TQP(10) | 0.156 | QP(5.1) | 0.076 |
| | | | | QP(5.2) | 0.045 |
| | | | | QP(5.4) | 0.070 |
| | | | | QP(5.5) | 0.044 |
| | | | | QP(5.6) | 0.045 |
| | | | | QP(5.8) | 0.108 |
| | | | | QP(5.9) | 0.126 |
| | | | | QP(5.10) | 0.175 |

END