



A dynamic price and supply model of the U.S. pork industry
by Cecil Dee Black

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Applied Economics
Montana State University
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Abstract:

A rational distributed lag model of prices and supplies is estimated for the farm, slaughter, and retail levels of the U.S. pork industry. The rational lags are estimated for estimation of nonstochastic difference equations. Estimation of nonstochastic difference equations allows for precision of the disturbance process from the systematic portion of the regression equations. Short, intermediate, and long term supply elasticities and price flexibilities are calculated to measure dynamic responsiveness within the industry. Interpretations and implications of the regression results are given in the body of the thesis.

The flexibility of the rational generating function permitted the measurement of biological and economic factors in the market. On the supply side, the ratio of hog prices to corn prices had a significant influence on farrowing and slaughtering decisions. However, the supply elasticities were relatively small, reflecting high investment costs in confinement technology. On the price side, the dynamics were less pronounced since pricing decisions are closely tied to short term wholesale pricing.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

June 1984

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ABSTRACT

A rational distributed lag model of prices and supplies is estimated for the farm, slaughter, and retail levels of the U.S. pork industry. The rational lags are estimated for estimation of nonstochastic difference equations. Estimation of nonstochastic difference equations allows for preclusion of the disturbance process from the systematic portion of the regression equations. Short, intermediate, and long term supply elasticities and price flexibilities are calculated to measure dynamic responsiveness within the industry. Interpretations and implications of the regression results are given in the body of the thesis.

The flexibility of the rational generating function permitted the measurement of biological and economic factors in the market. On the supply side, the ratio of hog prices to corn prices had a significant influence on farrowing and slaughtering decisions. However, the supply elasticities were relatively small, reflecting high investment costs in confinement technology. On the price side, the dynamics were less pronounced since pricing decisions are closely tied to short term wholesale pricing.

CHAPTER 1

INTRODUCTION

The U.S. pork economy has been characterized by change, much of it credited to technological advancements and market reorganization. The resultant system is a complex network of markets, whereby consumers, retailers, agribusiness firms, and producers interact to establish market prices and quantities. Some of the important technical and economic changes that have occurred within the production and marketing sectors of pork include¹:

Enabling Factors:

1. The enlargement of grain farms associated with crop technology, thus, increasing domestic feed supplies,
2. Animal technology—antibiotics, genetics (leaner hogs), and specialized buildings and equipment.
3. Changed producer perceptions toward hog production enterprises,
4. Economics of size in farming operations.
5. Credit availability for needed financing.

Motivating Factors:

1. On the average, hog-corn ratios over the 1970-1982 time period have been favorable to expand sow herds. However, they have also demonstrated considerable variation.
2. Incentives from income tax rules have promoted fast growth of larger operations.

¹ U.S., Congress, Senate. Committee on Agriculture, Nutrition, and Forestry, Farm Structure, Committee Print, 96th Cong., 2nd Session, April 1980.

3. Anticipated further inflation as a motivator of growth now.
4. Improvement in consumer demand as attitudes towards pork products have improved.

Much of the structural change in the hog industry was a mere reflection of overall changes in postwar U.S. agriculture. Hog enterprises kept pace with the general increase in the size of farms and the substitution of capital for labor to reduce unit costs of production. Thus came the growth of large commercial farrowing and finishing operations. Within the realm of hog production, confinement buildings, mechanized handling of feed, water and wastes, and ventilation have become standard practices. Within the realm of hog marketing, more efficiency has been gained through increased direct sales to packers, horizontal specialization in packing plants, selling hogs on a carcass grade and weight basis, and advertising and promotion of pork products.

The importance of marketing hog and pork products is revealed in dollars generated. In 1982, farm sales were 136.2 billion dollars, of which 70.2 billion dollars was based directly on livestock production.² Revenues generated by individual livestock production species were: beef and dairy 48.2 billion dollars, pork 10.6 billion dollars, poultry 9.2 billion dollars, sheep and lamb .4 billion dollars, and other livestock 1.5 billion dollars.³

Statement of the Problem

Dynamic behavior in production, marketing, and consumption characterizes the total pork industry. Each level of the market independently exhibits its own characteristics and also interacts with other market levels in the industry (i.e., packers interacting with producers and retailers). These interactions significantly influence the variation in pork

² Addition of individual totals will not equal sector total due to rounding.

³ U.S. Department of Agriculture. Economic Research Service. "Indicators of the Farm Sector: Income and Balance Sheet Statistics." Statistical Bulletin ECIFS 2-2. Washington, D.C.: Government Printing Office. 1982.

demand, supply, and prices. Quantification of such demand and supply behavior in the pork industry would give a better understanding of the industry's economic forces and would also aid in forecasting important variables in the industry. Such information can lead to a more efficient allocation of resources in both hog production and marketing decisions.

Objectives

The major objectives of this research are:

1. To formulate a dynamic econometric model depicting the production, processing, and retail structure of the hog-pork economy. Emphasis is on specifying market price and supply equations.
2. To statistically estimate the parameters of the conditional probability distributions above by an appropriate regression method.
3. To assess the distributed lag effects (short, intermediate, and long term impacts) on the dependent variables from changes in economic and technical variables in the pork industry.

Procedures

The hog-pork market structure is represented by behavioral supply and price equations, formulated by economic theory, a priori knowledge of the livestock industry, and previous research. The model includes supply and price equations at the market levels of the producer, processor, and retailer. The sample period includes the years 1969 through 1982. The units of observation are defined on a semiannual period, which is consistent with the semiannual production period of market hogs. The structural parameters of the model are estimated by a nonlinear least squares algorithm, incorporating both nonstochastic difference equations and serial correlation in the error structure.

The distributed lag patterns of the endogenous variables assist in assessing the time path behavior of market price and supplies. They are calculated from a mathematical algorithm that estimates the partial derivatives of the equations both period by period and cumulatively, jointly using the parameters of the exogenous regressors and difference equations.

The following is a discussion of market structure and practices in the pork industry. This information is an important input in formulating the economic model to be presented in Chapter 2.

Dynamics of the Pork Industry

Many factors, individually and collectively, determine the supply and demand for pork at the farm, processor and retailer levels. Overall, the social, economic and technical factors that affect primary and derived demand and primary and derived supply interact to determine equilibrium consumption, production, prices and marketing margins.

Over time, changes in consumer preferences have led to more consumption of lean pork with a marked decrease in lard consumption. Pork production in 1960 yielded 10,863 million pounds of meat and 2,419 million pounds of lard, while 15,719 million pounds of meat and 1,155 million pounds of lard were produced in 1981.⁴ Per capita consumption of all meats in the United States increased by 25.76 pounds from 1960 to 1981, with the bulk of the change attributed to increased beef and poultry consumption. Poultry itself has experienced a 34 percent increase in per capita consumption since 1967. Pork and mutton and lamb consumption levels have remained relatively constant. Per capita pork consumption in 1969 was 65 pounds and decreased to 62.7 pounds in 1982.⁵

⁴ National Pork Producers Council. Pork Industry Statistics. Des Moines, Iowa, 1982.

⁵ U.S. Department of Agriculture. Economic Research Service. Livestock and Meat Statistics. Bulletin No. 522. Supp., 1982.

Because of increased consumer demand for lean meat, pork production trends have been toward hogs that consist of a higher lean to fat ratio. These hogs are being produced on fewer farms with increased technological and production capabilities (i.e., confinement operations). During the 1970 to 1982 period the average dressed weight of hogs decreased 7.6 percent, the number of hogs slaughtered increased 12.2 percent, and meat produced increased 21.3 percent.⁶ Therefore, the increased pork production (i.e., meat) is due more to hog type than animal size or number slaughtered.

Based on time series data, hog prices received by farmers have been characterized by large fluctuations (shown in Table 1). These price fluctuations reflect changes in market supply and demand conditions. The demand side changes include: (1) population size, (2) the level of inflation, (3) the level of consumer income and income distribution, (4) prices and availability of substitutes, and (5) consumer habits and preferences. Supply side changes include: (1) technology, (2) product substitutes, and (3) production and marketing factor costs (including interest).

Marketing margins change over time as a result of changes in the determinants of the demand for and the supply of marketing services. Changes in marketing margins shift either the primary or derived demand curves, depending upon the nature of the change (i.e., introduction of a new service or a cost change for existing services). A change in the cost of existing marketing services impacts both the retail and producer levels. For example, a wage increase in meat packing industry has the effect of decreasing both derived demand (downward shift) and derived supply (backward shift). All other factors held constant, the result is an increase in retail price and a decrease in farm price. The magnitude of change at each level is dependent upon the relative slopes of the primary supply and demand curves (Tomek and Robinson).

⁶ Ibid.

Table 1. Summary Statistics of Pork Prices and Supplies, 1969 through 1982.*

Year	Barrow & Gilt Slaughter Price (\$/hundred wt.)	Barrow & Gilt Slaughter Supply (thous. of head)	Sow Slaughter Price (\$/hundred wt.)	Sow Slaughter Supply (thous. of head)	Retail Price (\$/hundred wt.)	Retail Supply (mil. of lbs.)
1969	23.21	70342	20.14	5010	73.26	7433.8
1970	46.88	71086	19.51	4937	78.94	7609.95
1971	36.25	81026	15.11	5354	69.94	8605.0
1972	26.04	74685	22.44	4704	81.36	7961.2
1973	39.86	67586	35.03	4272	106.94	7220.3
1974	35.51	70723	29.63	5256	98.33	7784.9
1975	48.42	61327	42.89	3708	131.73	6537.8
1976	44.69	65540	38.14	3359	136.55	6909.7
1977	40.80	69542	38.44	4056	124.22	6719.2
1978	48.00	69581	42.80	3911	141.88	6755.1
1979	43.42	78776	37.60	4648	145.30	7676.5
1980	39.51	85654	35.27	5214	138.05	8317.9
1981	44.85	82072	40.68	4608	152.10	8066.3
1982	54.20	74412	46.93	3959	173.21	7305.4

*U.S. Averages, taken from monthly U.S.D.A. data.

General Market Structure

The U.S. pork industry can be separated into several sectors: (1) production of breeding stock, (2) production of market hogs, (3) slaughter and processing, and (4) retailing of the final product. The majority of hog production occurs within the Midwest, close to the major source of feed (i.e., corn). Oftentimes the production of breeding stock and the production of market hogs are pursued simultaneously. These are referred to as farrow to finish operations. In some cases the functions are performed separately (i.e., strictly feeder pig production and strictly finishing operations). Within recent years technological advances have made confinement operations more prominent. The result has been a decrease in the number of producers with increases in average size and productivity of those remaining. Confinement operations are more capital intensive because of reduced labor requirements, and since there has been a growing market for lean pork, the result has been efficient production of the slaughter hog.

Slaughtering and processing are the next stages in the pork marketing channel. Their principal function is to slaughter, process and package fresh and cured meats. Hog slaughtering and processing plants are located throughout the U.S., but the volume of slaughter is largest in the North-Central states. This location coincides with greatest concentration of hog production.

Since the early 1920s, the market concentration of meat packing firms has declined. This has been reflected by changes in firm size in the national market. On a regional level, the market may indeed be classified as imperfect competition. Size structure refers to the volume of slaughter held by one firm or several firms relative to total slaughter. The factors that account for declining concentration include: (1) new firms have entered and are slaughtering increasing portions of livestock produced, (2) small firms that remained in the industry have experienced more rapid growth than the remaining larger firms, (3) increased

species specialization by slaughtering and processing firms (attributed to technical efficiency), and (4) federal inspection and grading of carcasses have enabled small firms to compete more effectively with larger firms. The combination of increased farm size and structural changes at the slaughter levels has been to reduce the importance of terminal markets and, to a certain extent, local auctions. This has led to a greater percentage of direct producer to packer sales rather than local auction market transactions. Currently, direct sales constitute more than 70 percent of total national hog sales (Sheperd and Futress, 1982).

Processors sell pork to retailers in a more highly processed form compared to beef, lamb and mutton, and poultry. On a regional basis, the structure of most retail markets is classified as monopolistic competition (Holdren, 1964). Retailers sell in local markets where the market is delimited by time and space, producing a certain amount of isolation from direct price competition and, thus, relying more upon non-price competition.

Many market participants in the livestock-meat economy have voiced concern over the structure and conduct within the food industry. Small retailers argue that large processors have undue market power, while small processors maintain they are at the mercy of large retailers. Consumers feel they are being exploited and are impotent in implementing corrective measures. Farmers feel that since they are the smallest and least organized institution in the food industry, they lack bargaining power and have limited marketing alternatives. Both consumers and producers have expressed concern over middlemen functions due to the increasing size of marketing margins. However, Tomek and Robinson indicate that the size of the margin itself does not automatically imply inefficiencies or profiteering in the marketing sector.

The next chapter presents a review of the literature relevant to the estimation of supply and prices in the pork industry. Also, a discussion of distributed lag models and the formulation of the hog-pork model for this thesis will be presented. The empirical results

are presented in Chapter 3. The final chapter summarizes the accomplishments of this work and directives for further study. Appendix A presents the raw data used in estimating the models.

CHAPTER 2

LITERATURE REVIEW, THEORY, AND MODEL SPECIFICATION

The first section of this chapter describes previous econometric models of the pork industry. Development of distributed lag theory will be discussed in the second section of this chapter. The final section of this chapter presents the model specification to be estimated in this work.

Review of Literature

Many studies have addressed the problem of accurately modeling the livestock-meat industry. With respect to pork, much of the previous research was devoted to explanation of the hog cycle and its hypothesized length. A majority of previous models specified a recursive set of equations to account for the delayed interaction between price and quantities, i.e., a Cobweb framework. However, Jelavich (1973) presented an alternative approach to the Cobweb theorem in explaining hog cycles via distributed lags (discussed later).

Harlow (1962) estimated a quarterly statistical model that explained variations in the supplies and prices of hogs. The endogenous variables explained in the model were: (1) the number of sows farrowing, (2) number of hogs slaughtered, (3) quantity of pork produced, (4) cold storage holdings, (5) retail price of pork, and (6) prices received by farmers for hogs. The model was specified as a recursive system of equations. He assumed that prices and quantities were not jointly dependent, which, if they were, would warrant use of a simultaneous equation's estimator. Harlow's model was statistically significant based on the explained variation in each dependent variable (the R^2 's exceeded .90) and the significance level of the estimated coefficients.

Crom (1971) estimated, by ordinary least squares, a quarterly model of the beef and pork sectors based on 1955-68 data. The pork sector consisted of behavioral and identity equations within a recursive framework. Sow farrowing numbers represented a herd inventory equation, and was specified with a lag on the dependent variable and with lagged explanatory variables. The hog-corn price ratio explained approximately two-thirds of the variance in sow farrowing numbers. Lagged sows farrowing, pigs saved per litter, and a lagged hog-corn price ratio were utilized to estimate a commercial hog slaughter equation. Equations for pork imports and exports were also constructed and hypothesized to be functions of wholesale pork price and lagged per capita supply. Net imports and ending stocks were added to domestic pork production, then divided by population, to derive contemporaneous per capita pork consumption. This variable, along with per capita non-fed beef supply, consumer income, and a trend variable depicting consumer tastes and preferences, was specified in a retail pork price equation. Ending stocks were determined simultaneously with retail prices. Live hog prices were specified as a function of wholesale price and by-product values.

Research has shown that U.S. pork production is cyclical in nature. The hog-corn ratio generally has been used as the appropriate measure of profitability in the hog production sector (Breimeyer, 1959). The biology of hog production yields lagged responses, for instance an increase in returns (i.e., via a higher hog-corn ratio) results in increased farrowings, which in turn generates increased pork production, but the increased output does not reach the market until one to two years later. Increased production then impacts the hog-corn ratio causing it to decrease, and consequently, gross returns decrease leading to an industry contraction of the sow herd.

Early research explained cycles in pork production and prices through use of the Cobweb theorem. Dean and Heady (1958) specified farrowings as a function of the hog-corn ratio lagged one year, however, Breimeyer (1959) and Harlow (1962) suggested that the

cycle was longer. Breimeyer indicated lagged hog-corn ratios of one and two years were more meaningful, and Harlow rationalized that price during one year may affect production decisions during the next two to three years. This hypothesis was instrumental in Harlow's observation of the four year hog cycle.

Jelavich (1973) presented a distributed lag harmonic motion model as an alternative to the Cobweb theorem. The author's primary criticism of previous hog-pork industry Cobweb models was the assumption that farmers expected current prices to remain unchanged into the next production period. His work resulted in a distributed lag technique for estimating harmonic motion within the hog industry. Hog-corn ratios and commercial hog slaughter were estimated using lag specification. He determined that both equations were cyclical in nature with the length of the cycles not significantly different from four years. His contribution was the concept that distributed lag equations can assist in determining the true lags involved in time series data, i.e., properly declining weights on past values of the independent variables.

Heinen (1975) estimated an econometric model based on annual data from 1950 to 1959. Heinen's model included six endogenous variables: (1) farm price of pork, (2) retail price of pork, (3) pork imports, (4) total supply of pork, (5) total production of pork, and (6) the total number of hogs slaughtered. The final model estimates obtained by OLS resulted in significant parameters of the theoretically correct sign. Prediction interval tests along with short- and long-run response coefficients were also presented. One method employed to evaluate the forecasting accuracy of the model was prediction interval tests for observations outside the sample. These interval tests were reported for the 1970-73 period, a time of considerable fluctuation in both prices and quantities.

Heinen also applied an alternative evaluation of model performance, the Chow test.¹ This procedure tested whether or not unexplained shifts or structural change occurred

¹ See Heinen (1975), p. 374) for a detailed description and use of the Chow test.

during the 1970-73 period. Extremely low values of the test statistic revealed that structural change was not evident.

Shonkwiler and Spreen (1982) presented a systematic approach for specifying lead-lag relationships between hog slaughter and the hog-corn ratio. Their dynamic regression approach was considered to be another alternative procedure for analyzing the U.S. hog market. This process allowed explicit tests of causal relationships between variables by use of transfer functions, and in specific circumstances provided a means of identifying the proper distributed lag forms.

They indicated that the general nature of lag relationships may be described by theory and observation. Particularly, the dynamic regression technique should allow the data to determine the length of the lag. The dynamic regression techniques applied to post-war hog market data (1946-1979) showed a dampening oscillating cycle of 3.047 years. In order to verify this cycle length, analysis of monthly data was also conducted. The cycle length of 3.047 years was again supported.

The length of the cycle calculated by the transfer function approach was shorter than the four year cycles obtained in earlier research. However, Shonkwiler and Spreen's sample period included more recent data than earlier studies. The authors suggest that the adoption of hog confinement operations and the increasing size of present confinement operations may have tempered the length of the hog cycle.

Distributed Lag Theory

Dependent variables often respond to changes in independent variables over several time periods. This delayed reaction suggests that lagged explanatory variables should be included in the model specification, resulting in a dynamic model. There are several reasons why such a lag structure is necessary. On the demand side, consumer attitudes, information dispersion, and habits and customs are impediments to quick adjustment. On the supply

side biological production periods, technology, and producer attitudes serve as constraints to immediate output response.

Some theoretical justifications for specifying distributed lag models are the "partial adjustment" and "adaptive expectations" hypotheses. The partial adjustment model is utilized in situations where the adjustment process does not take place instantaneously. This delayed reaction may be due to such factors as biological and/or technical constraints, customs, or rigidities within the industry. The adaptive expectations model is appropriate in situations where the level of a decision variable is a function of the expected level of an independent variable. The latter is usually represented by a weighted structure on previous levels of experience in forecasting the independent variable (Kmenta, 1971). In developing a model to explain the hog-pork industry, the use of either of these hypotheses can be justified. For example, in the situation where the number of sows farrowing is the decision variable, the partial adjustment model is appropriate since both biological as well as physical factors (i.e., sow replacement intervals and farrowing capacity) influence the producer adjustment process. The adaptive expectations model is also appropriate in that decisions regarding sow herd size are made on the basis of producers' expectations of returns in market hog production (i.e., future slaughter price and feed costs). Oftentimes the two hypotheses can be combined into one model, called the compound geometric model (Kmenta, 1971).

A distributed lag model with one dependent variable Y and one independent (exogenous) variable X can be written as:

$$Y_t = \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \dots + e_t \quad (1)$$

where e_t is the classical additive disturbance term. In this model the effect of a change in the explanatory variable (X) on the dependent variable (Y) is spread over an infinite time period. As long as the summation of the β coefficients is finite, the lag effects of the

explanatory variable upon the dependent variable would asymptotically dissipate, thus allowing the dependent variable (Y) to achieve a new equilibrium.

The model above cannot be estimated directly due to an infinite number of coefficients, thus resulting in a problem with degrees of freedom. Also, multicollinearity among the lagged variables would reduce the precision of the parameter estimates. However, the model can be estimated by reducing it to a first order difference equation with a contemporaneous independent variable through the Koyck transformation (Kmenta, 1971).

Finite lag structures are also used in dynamic models. These structures indicate that after a certain time period lag coefficients assume a zero value. A finite distributed lag equation can be written as:

$$Y_t = \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + e_t \quad (2)$$

in which all lag coefficients higher than β_2 are assumed to be zero. This model presents several statistical problems. If the lag structure is high, multicollinearity between the lagged exogenous variables can exist, resulting in small values of coefficient estimates relative to their standard errors. Choice of the lag interval is often arbitrary and without theoretical basis, which may or may not allow for complete dissipation of distributed lag effects. Several alternatives have been suggested to handle the statistical problems in both finite and infinite lag models. Rucker (1980) provides detailed descriptions of these alternative distributed lag model specifications, including the advantages and disadvantages of each.

Finite lag structures are often utilized to approximate infinite lag structures. Jorgenson (1966) presented an application by which infinite lag structures may be approximated by estimating a reduced number of parameters. He defined the function as a rational distributed lag "if and only if it may be written with a finite number of lags in both dependent and independent variables" (p. 138). Jorgenson demonstrated that finite distributed lag functions, the Koyck geometric function, and Solows' Pascal distributed lag function are all special cases of rational distributed lags.

The class of functions represented by Jorgenson's rational distributed lag is subject to the constraint that the sequence of the β_i coefficients have a rational generating function. This generating function, represented by $R(L)$, is written as a polynomial in the lag operator ℓ :

$$R(L) = r_0 + r_1 \ell + r_2 \ell^2 + \dots \quad (3)$$

Since this generating function is assumed to be rational it may be written as:

$$R(L) = \frac{\alpha(L)}{\lambda(L)} \quad (4)$$

where $\alpha(L)$ and $\lambda(L)$ are polynomials in L of order m and n , respectively:

$$\alpha(L) = \alpha_0 + \alpha_1 \ell + \dots + \alpha_m \ell^m \quad (5)$$

$$\lambda(L) = \lambda_0 + \lambda_1 \ell + \dots + \lambda_N \ell^N \quad (6)$$

These polynomials have no characteristic roots in common, therefore, they may be represented only in ratio form. Normalization of λ_0 at unity is done without loss of generality. Since the sequence β_i has a rational generating function we may write:

$$Y_t = R(L)X_t + e_t = \frac{\alpha(L)}{\lambda(L)} X_t + e_t \quad (7)$$

where L is the lag operator and $L^k X_t = X_{t-k}$. Multiplication of both sides of Equation (7) by $\lambda(L)$ yields:

$$\lambda(L)Y_t = \alpha(L)X_t + \lambda(L)e_t \quad (8)$$

Expansion of the polynomial terms yields:

$$(1 + \lambda_1 \ell + \dots + \lambda_N \ell^N) Y_t = (\alpha_0 + \alpha_1 \ell + \dots + \alpha_m \ell^m) X_t + V_t \quad (9)$$

where $V_t = \lambda(L)e_t = \sum_{i=0}^N \lambda_i e_{t-i}$ and is autocorrelated. The final specification of the rational distributed lag function is:

$$Y_t + \lambda_1 Y_{t-1} + \dots + \lambda_N Y_{t-N} = \alpha_0 + \alpha_1 X_{t-1} + \dots + \alpha_m X_{t-m} + e_t + \lambda_1 e_{t-1} + \dots + \lambda_N e_{t-N} \quad (10)$$

which transforms Equation (8) into an n th order difference equation with an n th order moving average error structure. Jorgenson showed that a rational lag model can approximate any arbitrary law function to a desired degree of accuracy given sufficiently high values of M and N .

There are different views of how to specify the proper order on lag structures in empirical work. One view is that presented by Griliches (1967), where he concluded that relatively small changes in parameter estimates imply a variety of possible shapes for the lag distributions. This group, of which Nerlove is a member, argues that time series data is always inexact in nature, therefore only rough approximations of lag distributions are all that can be expected from the data. They propose that the shapes of distributed lag be based upon economic theory. However, the evolution of dynamic theory is not yet complete (for a discussion of development of dynamic theory relevant to this problem see Nerlove (1972) and Sims (1974)). An alternative view is supported by Shonkwiler and Spreen (1982) who suggest that the data, in combination with dynamic regression techniques, may itself demonstrate the true distributed lag relationships in the market.

Stochastic and Nonstochastic Difference Equations

Burt (1978) discussed some of the major problems associated with estimating dynamics in agricultural supply response. He discussed the problems with models that rely upon relevant information through complete specification and a historical data series. He suggested that low order difference equations can accomplish the same objective as a model laden with many lagged exogenous variables. He offered a pragmatic justification for the use of difference equations: (1) a complete series of historical data for exogenous

variables is not required, (2) the number of model parameters to be estimated is reduced, (3) a static industry structure is not required, therefore the data sample can be enlarged, and (4) the problem of lag specification can be minimized. Burt concluded that a low order difference equation in conjunction with small order lags on the independent variables can satisfactorily capture the effects of technological, economic, and biological factors that characterize agricultural supply response.

An estimation approach suggested by Burt is nonstochastic difference equations. A first order stochastic difference equation is:

$$Y_t = \alpha + \beta X_{t-1} + \lambda Y_{t-1} + e_t \quad (11)$$

This equation contains two stochastic elements, the lagged dependent variable Y_{t-1} and the random error term e_t . Equation (11) can be written as nonstochastic:

$$Y_t = \alpha + \beta X_{t-1} + \lambda E(Y_{t-1}) + u_t \quad (12)$$

where $u_t = \rho e_{t-1} + e_t$ and $E(Y_{t-1}) = Y_{t-1} - u_{t-1}$ (i.e., the lagged dependent variable is minus its non-systematic component).

Every statistical regression equation contains a stochastic disturbance term. However, whether an equation is viewed as stochastic or nonstochastic is resolved by the manner in which the lagged dependent variable enters the equation. As shown in Equation (11), a stochastic difference equation utilizes the observed value of the lagged dependent variable, while in Equation (12), a nonstochastic difference equation uses the expected value of the lagged dependent variable. Thus, the systematic part of Equation (12) is purely exogenous even when serial correlation exists in the error structure.

The autoregressive error structure in Equation (12) and/or the lagged expectation of the dependent variable present estimation problems for ordinary least squares (OLS) due to nonlinearities in the parameters. Since the parameters in the hog-pork model will be estimated within the framework of a nonstochastic rational lag structure, a nonlinear

least squares algorithm (maximum likelihood under normality) will be used. In the absence of serious specification error, consistent and asymptotically efficient parameter estimates should result.

Model Development

The adjustment of supplies and prices at all market levels in the hog-pork industry is hypothesized to be a distributed lag process. Beginning with the supply side, at the farm level, sow farrowing numbers represent the herd base from which pig crops are generated. Pig crops and sow inventories represent the quantity of hogs available for slaughtering and processing. This quantity is considered primary supply. Since the overall model is a system of market equations, market behavior at the slaughter level is described as a jointly dependent relationship between slaughter supply and slaughter prices of barrows and gilts.

The supply of processed pork products in the wholesale market is hypothesized to be a function of the numbers of barrows, gilts and sows slaughtered and average dressed weights. Producers tend to finish market hogs at weights desired by packers, consequently, the average dressed weights have varied little over the sample period.

Cold storage holdings are also specified in the model and are estimated at the end of each semiannual production period. The quantity of pork in storage is postulated to be a function of the quantity of wholesale pork produced and retail price, the latter giving the signal whether to add to or subtract from storage. The summation of wholesale pork production, pork cold storage holdings, and pork imports represents the total supply of pork available at the retail market.

On the price side of the market, the total supply of pork, quantity of substitute meats, and per capita disposable income are hypothesized to influence retail prices of pork. Since consumers have a strong vote as to the prices of pork they are willing to pay, retail price is representative of inverse primary demand in the industry. The farm price, represented by

the slaughter price of barrows and gilts, is considered as an inverse derived demand. A wholesale-to-retail margin is included to provide a link between retail and slaughter prices.

All market equations are estimated with 1969 through 1982 semiannual data, based on the production periods December to May and June to November. A larger sample was desirable but was not available due to data classification changes. All price and income variables are deflated by the Consumer Price Index (1967 = 100) and all production variables defined in pounds are given on a per capita basis.

Sow Inventory Equation

The breeding herd inventory equation, measured by the number of sows farrowing, is specified as:

$$SF_t = f_1 (D2, H/C_{t-i}, E(SF_{t-j}), u_{1t-j}) \quad i \leq j$$

where

SF_t = number of sows farrowing, thousands of head, 10 states (endogenous).

$D2$ = seasonal dummy variable for the June to November period.

H/C_{t-i} = hog-corn price ratio, the ratio of the slaughter price of barrow and gilts to the price of #2 yellow corn (endogenous).

$E(SF_{t-j})$ = lagged expectation of thousands of head (predetermined).

u_{1t-j} = autoregressive error term.

Feed costs comprise 60 to 70 percent of total pork production expenses. Therefore, the hog-corn price ratio was formed to measure the effect of output price relative to input costs on the number of sows farrowing. The hog-corn price ratio is typically used in econometric studies to indicate likely profits in future production, however, it does not provide information on the impact of the individual price components. It is expected that the ratio and sows farrowing would be positively correlated.

The USDA defines a hog-corn ratio as the number of bushels of corn equal in value to one hundred pounds of live hogs. Efficient producers can usually produce one pound of pork from three to four pounds of feed. Historically a break-even hog-corn ratio has been about 18.0.² This ratio has been considered a satisfactory conversion for efficient producers but not high enough to make a profitable enterprise for the less efficient producer (Bundy, Diggins, and Christenson, 1976). Because in this model a price ratio is used, and not the USDA variable, the possibility exists that sows farrowing and the hog-corn price ratio are jointly endogenous variables. Therefore, the latter variable is entered as an instrument variable to pursue any potential correlation from the error structure.

The inclusion of the lagged dependent variable is to account for lags in breeding herd adjustment due to biological and capacity production constraints. For example, introduction of a replacement sow (producer raised) requires at a minimum, three production periods. This interval is inclusive of birth, growth to breeding maturity, and gestation period. Seasonal influences upon sows farrowing (and other behavioral equations that follow in this model) are accounted for by inclusion of the seasonal dummy variable D2 (D1, the December to May binary is omitted).

Slaughter Supply Sector

Barrow and Gilt Slaughter

The quantity of slaughter hogs supplied to packing and processing firms is hypothesized to depend upon primary supply conditions and other economic variables. More specifically, barrow and gilt slaughter is given as:

$$BGSL_t = f_2 (D2, PC_{t-k}, BGP_{t-k}, PCN_{t-k}, E(BGSL_{t-j}), u_{2t-j}) \quad k \leq j$$

² Alternatively stated, 100 pounds of pork should bring the price of 18 bushels of corn. For example, if corn sells for \$2.00 per bushel, then 100 pounds of pork should sell for \$36.00.

where

$BGSL_t$ = barrow and gilt slaughter, thousands of head, 48 states (endogenous).

PC_{t-k} = pig crop numbers, thousands of head (endogenous).

BGP_{t-k} = barrow and gilt slaughter price, 7 market average, average cost per hundred weight, dollars (endogenous).

PCN_{t-k} = price of #2 yellow corn, Chicago, dollars per bushel (exogenous).

$E(BGSL_{t-j})$ = lagged expectation of barrow and gilt slaughter, thousands of head (predetermined).

u_{2t-j} = autoregressive error term.

Pig crop is included as a principal regressor since it represents the technical pool from which slaughter animals are drawn. Pig crop is expected to be significant and positively correlated with slaughter numbers. The variable itself is generated through an identity relation;

$$PC_t = (SF_t \times PSPL_t)$$

where

PC_t = contemporaneous pig crop numbers, thousands of head (endogenous).

SF_t = number of sows farrowing, thousands of head, 10 states (endogenous).

$PSPL_t$ = pigs saved per litter, number of head (exogenous).

Economic theory suggests that the quantity of a good supplied should be a positive function of its own price. Thus, the slaughter price of barrows and gilts, which represents the offer price to producers (by processors and packers), is hypothesized to be positively correlated with barrow and gilt slaughter. Due to the potential joint dependency between slaughter price and slaughter numbers, barrow and gilt slaughter is treated as an instrument variable.

The purpose in specifying the price of corn is twofold. First, changes in feed costs could cause the number of barrow and gilts slaughtered to vary in a specific time period

because of feeding to different weights; and second, feed costs can influence the number of gilts retained for breeding. Since slaughter weights may be more determined by packers, gilt retention may be the most important factor. Thus, if corn prices decline, barrow and gilt slaughter in the current period may decline since it may be profitable to add more gilts to the breeding herd.

The supply of slaughter hogs in any given period is also dependent upon allocation of production resources during previous production periods. This is partly reflected in capacity constraints. In order to account for these effects the lagged dependent variable is also specified as a regressor.

Cull Sow Slaughter

In any viable production process the replacement of physical production capital is mandatory. For pork producers, economic and biological factors (including the age of sows) are criteria upon which replacement decisions are made. Cull sows are usually sold to packers and processors because of lack of productivity and/or poor economic conditions in farrowing operations (i.e., high feed costs relative to barrow and gilt prices). Thus, sow slaughter is the direct result of replacement decisions to increase or decrease breeding herds based upon expected returns. The equation is specified as:

$$SSL_t = f_3 (D2, SOWP_{t-i}, H/C_{t-i}, E(SSL_{t-j}), u_{3t-j}) \quad i \leq j$$

where

SSL_t = sow slaughter numbers, thousands of head, 48 states (endogenous).

$SOWP_{t-i}$ = sow slaughter price, 7 market average, average cost per hundred weight, dollars (endogenous).

H/C_{t-i} = hog-corn price ratio, dollars (endogenous).

$E(SSL_{t-j})$ = lagged expectation of sow slaughter numbers, thousands of head (predetermined).

u_{3t-j} = autoregressive error term.

Economic theory suggests inclusion of own price as a principle regressor in a supply equation, thus, the specification of sow price above. However, since the major objective of pork producers is not to produce slaughter sows, sow slaughter price is merely specified as a measure of salvage value. It is not expected to be highly significant.

As mentioned earlier, potential profits from current and future pork production are measured by the hog-corn price ratio. This variable is expected to have a negative impact on sow slaughter. For example, an increase in the price ratio may encourage producers to carry marginal sows into future production periods.

Through an identity relationship total slaughter numbers can now be transformed into pounds of domestic processed pork;

$$QWP_t = [(BGSL_t + SSL_t) \times ADW_t]$$

where

QWP_t = quantity of wholesale pork produced, millions of pounds (endogenous).

$BGSL_t$ = barrow and gilt slaughter numbers, 48 states, thousands of head (endogenous).

SSL_t = commercial sow slaughter, 48 states, thousands of head (endogenous).

ADW_t = average dressed weight of hog carcasses, pounds (exogenous).

This multiplicative transformation from number of head to number of pounds of processed meat provides the link between producer and retail supplier. Since the slaughter variables are endogenous, they are entered as instrument variables.

Stocks of Pork

Cold storage holdings of pork are representative of the quantities of processed pork held from one production period to the next. The commodity has a limited storage life, usually not exceeding one year. The importance of cold storage holdings of pork is revealed by the fact that, on a monthly basis, its quantity is about 10-15 percent of domestic production.

The specification of pork cold storage holdings is given as:

$$STK_t = f_4(D2, QWP_{t-i}, PR_{t-i}, E(STK_{t-j}), u_{4t-j}) \quad i \leq j$$

where

STK_t = quantity of storage holdings of pork at the end of the production period, millions of pounds (endogenous).

QWP_{t-i} = quantity of wholesale pork produced, millions of pounds (endogenous).

PR_{t-i} = retail price of pork, dollars per hundred weight (endogenous),

$E(STK_{t-j})$ = lagged expectation of stocks of pork (predetermined).

u_{4t-j} = autoregressive error term.

Since stocks represent the difference between current consumption and current production at a given equilibrium price, it is hypothesized that increases in retail price (due to increased demand) would entail a decrease in pork stocks (Tomek and Robinson, 1981, p. 100). Quantity of wholesale pork production is also included as an explanatory variable. All other variables constant, it is expected that increases in production would lead to increased stocks.

Slaughter Price Sector

Barrow and Gilt Slaughter Price

The demand price of slaughter barrow and gilts by meat packers and processors is considered a derived price due to the fact it is based on consumer demand. The distributed lag equation is specified as:

$$BGP_t = f_s(D2, BGSL_{t-i}, BPV_{t-i}, M_{t-i}^{(W-R)}, E(BGP_{t-j}), u_{5t-j}) \quad i \leq j$$

variables are defined as

BGP_t = slaughter price of barrows and gilts, 7 market average, average cost per hundred weight (endogenous).

$BGSL_{t-i}$ = commercial slaughter of barrows and gilts, 48 states, thousands of head (endogenous).

BPV_{t-i} = farm by-product value, centers per pound (exogenous).

$M_{t-i}^{(W-R)}$ = wholesale-to-retail marketing margin, cents (exogenous).

$E(BGP_{t-j})$ = lagged expectation of barrow and gilt slaughter price (predetermined).

u_{5t-j} = autoregressive error term.

The adjustment of hog slaughter price to changes in farm level production is accounted for by lagged commercial slaughter. Since contemporaneous barrow and gilt slaughter is a jointly endogenous variable, it enters the regression equation as an instrument variable. Past slaughter numbers are assumed to explain slaughter price because of the adjustment lags in slaughter animal production.

Firms that process pork essentially produce two outputs: (1) by-products from live hogs and carcasses, and (2) retail pork cuts, with the value of by-products being considerably less. The meat processing industry, however, depends highly upon these by-product

values to cover slaughter costs and profit margins. A priori, an increase in the value of by-products would be expected to increase packer demand for slaughter hogs, hence, an increase in slaughter price.

Economic theory suggests that marketing margins are shifters of derived demand (Tomek and Robinson, 1981). In this model the wholesale-to-retail marketing margin is specified as a exogenous variable, consisting of the costs of processing hog carcasses and distributing the cuts to retail outlets. Other variables constant, an increase in the value of the marketing margin would decrease packer demand for slaughter hogs, hence a decrease in slaughter price.

Sow Slaughter Price

Slaughter prices for cull sows average lower than prices of market barrows and gilts. This is due to the fact that sow prices represent the salvage value of depreciating breeding herds; also, their meat quality is usually inferior. The behavioral equation is specified as:

$$\text{SOWP}_t = f_6 (\text{D2}, \text{SSL}_{t-i}, \text{PR}_{t-i}, \text{E}(\text{SOWP}_{t-j}), u_{6t-j}) \quad i \leq j$$

where

SOWP_t = slaughter price of cull sows, 7 market average, average cost per hundred pounds (endogenous).

SSL_{t-i} = commercial sow slaughter, thousands of head, 48 states (endogenous).

PR_{t-i} = retail price of pork, dollars per one hundred pounds of carcass (endogenous).

$\text{E}(\text{SOWP}_{t-j})$ = lagged expectation of sow slaughter price (endogenous).

u_{6t-j} = autoregressive error term.

Commercial sow slaughter enters the equation as an instrument variable because of its suspected correlation with the error term. This variable is expected to be significant and exhibit an inverse relationship with sow price.

Producer objectives are centered on market hog production, and sow slaughter is viewed as a residual function. Therefore, based on age, past production, and current physical condition producers view cull sows in two categories: (1) sows with total depletion of reproductive capability, and (2) sows with marginal reproductive capability. It was shown earlier that the hog-corn price ratio impacts the numbers of sows slaughtered, hence, indirectly it also affects sow price. In addition to slaughter numbers, retail price should be considered since it is a barometer of primary demand for pork. Thus, if there is an increase in primary demand for pork, part of this demand is met by cull sow slaughter. *Ceteris paribus*, it is expected that an increase in retail price would increase the cull price of sows. Since retail price is endogenous, correlation with the error structure (u_{6t}) is suspected, thus, it enters the equation as an instrument variable.

Retail Price of Pork

Primary demand for pork is established at the retail level. Inverse demands, or retail pork price, is expressed as:

$$PR_t = f_7 (D2, TSP_{t-i}, QB_{t-i}, QPLT_{t-i}, Y_{t-i}, E(PR_{t-j}), u_{7t-j}) \quad i \leq j$$

where

PR_t = retail price of pork, dollars per one hundred weight (endogenous).

TSP_{t-i} = total supply of pork, millions of pounds (endogenous).

QB_{t-i} = commercial production of beef, millions of pounds (exogenous).

$QPLT_{t-i}$ = poultry production, federally inspected, millions of pounds (exogenous).

Y_{t-i} = per capita disposable personal income, dollars (exogenous).

$E(PR_{t-j})$ = lagged expectation of retail price, dollars per hundred weight (predetermined).

u_{7t-j} = autoregressive error term.

The total supply of pork available at the retail level is the summation of wholesale pork production, cold storage holdings, and pork imports. The identity relationship is represented by:

$$TSP_t = (QWP_t + STK_t + IMP_t)$$

where

TSP_t = retail supply of processed pork, millions of pounds (endogenous).

QWP_t = quantity of wholesale pork produced, millions of pounds (endogenous).

STK_t = quantity of processed pork in storage, beginning of production period, millions of pounds (endogenous).

IMP_t = pork imports, millions of pounds (exogenous).

Another equation, the disappearance of pork at the retail level, is also given to demonstrate an equilibrium relationship. It is given as:

$$TDP_t = (CONS_t + EXP_t + ESTK_t)$$

where

TDP_t = disappearance of processed pork at the retail level, millions of pounds (endogenous).

$CONS_t$ = domestic consumption of pork, millions of pounds (endogenous).

EXP_t = pork exports, millions of pounds (exogenous).

$ESTK_t$ = quantity of processed pork in storage, end of production period, millions of pounds (endogenous).

Both supply and demand conditions must be considered in the determination of retail price. Equilibrium price in the retail market is representative of the condition that total supply equals total disappearance. That is, this model indicates that retail price depends upon more than just domestic consumption, but cold storage supplies and the export-import trade.

The endogenous nature of retail pork supply requires that it enter the regression equation as an instrument variable. Other factors constant, it is hypothesized that increases in the per capita supply of processed pork would reduce retail price since production, imports, and movements of pork out of cold storage would only be sold at lower prices to consumers.

Per capita beef and pork production are specified in the retail pork price equation to account for substitution effects. A priori, increases in either variable would be expected to decrease pork price due to the reduction in the demand for pork.

Per capita disposable income is included as a regressor to measure the impact of changes in consumer purchasing power on the retail price of pork. It is expected that increases in per capita income would increase retail price since the demand schedule for pork would increase (positive income effect).

CHAPTER 3

EMPIRICAL RESULTS

The maintained hypotheses presented in Chapter 2 represent the dynamic structure of the pork supply and price model. In all, there are seven structural and four identity equations. This chapter presents the statistical results and the economic implications of each behavioral equation. It should be noted that the final equations may not exactly match the maintained hypotheses since certain variables may be omitted due to lack of statistical significance. Table 2 presents the regression results of the supply sector and Table 4 presents the regression results of the price sector. Tables 3 and 5 present the short, intermediate, and long term price flexibilities and supply elasticities specific to the model equations.

Sow Farrowing Equation

The final sow farrowing equation is estimated as a function of two binary variables, lagged barrow and gilt slaughter price, lagged corn price, and a second order nonstochastic difference equation with negative first order serial correlation. The regression results are summarized in Table 2. All signs of the estimated coefficients meet a priori expectations and the asymptotic t ratios, overall, are good. The fit of the equation ($\bar{R}^2 = .90$) appears comparable to that of Harlow (1962).

The two binary variables, D2 and D (1982:1), are respectively included to measure seasonal production and to account for an extreme observation in the data sample. Seasonality in farrowings is evident since spring sow farrowings average larger than fall sow farrowings. The binary variable D (1982:1), represents the December to May period of 1982.

Table 2. Regression Results for Sows Farrowing, Sows Slaughtered, Barrows and Gilts Slaughtered, and Pork Cold Storage Holdings.^a

Equations	VARIABLES ^b															
	Intercept	Dpf	D(82:1)	D2	BGP	BGP-1	BGP-2	PCN	PCN-1	PCN-2	H/C	H/C-1	PC	PC-1	PC-2	QWP
SF	2073.5 (5.654)		-805.03 (-5.051)	-228.04 (-.903)	-54.284 (-4.889)	104.51 (5.269)	-33.495 (-1.666)	-234.82 (-.869)	-996.87 (2.164)	802.05 (2.950)						
SSL	-771.7 (-3.953)			1393.7 (5.592)							-15.908 (-1.676)	33.500 (3.652)				
BGSL	20605.0 (2.300)	-1866.9 (-1.161)		-951.95 (-2.483)							-325.13 (-3.128)		.176 (1.589)	.144 (1.642)	.243 (2.820)	
STK	-.0496 (-1.650)			-.0291 (-3.915)												.000041 (3.648)
																.426 (2.192)

^aThe asymptotic t-ratios are in parentheses under each coefficient. All variables are significant at the 95 percent probability level except seven; they are D2, BGP-2, PCN, H/C, Dpf, PC, and PC-1.

^bEquation test statistics are defined as: $\bar{R}^2$ = adjusted multiple R-squared, Sy = standard error of the estimate, DW = Durbin-Watson statistic, and p = autoregressive term. The test statistics for each equation are: SF, the $\bar{R}^2$ = .9020, Sy = 188.354, DW = 2.365, p = -.323; SSL, the $\bar{R}^2$ = .7267, Sy = 220.746, DW = 1.994, p not specified; BGSL, the $\bar{R}^2$ = .8561, Sy = 1473.033, DW = 1.996, p = .850; STK, the $\bar{R}^2$ = .7225, Sy = .0149, DW = 1.550, p = .455.

^cE(Dep-i) = the lagged expectation of the appropriate dependent variable.

During the 1981-1982 period there were market irregularities due to unusually low sow slaughter prices, increased corn prices, and financial strain from high interest rates (USDA). Overall, a national breeding herd reduction that began in the late 1970s overlapped into the early 1980s. However, an abrupt halt in this process yielded an inconsistency in sow farrowing numbers for 1982. The Economic Research Service of the USDA stated:

Producers are not reducing output as much as they indicated on June 1. Instead, they are responding to a \$8-per-cwt. increase in hog prices over the past 4 months, a 62-cent-a-bushel drop in corn prices since July, and prospects for even cheaper corn later on. Farrowings in the major producing States during June-August were down 4 percent from a year earlier, instead of the 7 percent decline stated in the June Hogs and Pigs report. In addition producers indicated on September 1 that they intend to have 6 percent fewer sows farrow during September-November much less than the 11 percent decline indicated earlier...¹

Table 3. Estimates of Supply Elasticities from the Pork Model.^a

Equations	BGP	PCN	H/C	PC	QWP
SF	-.212 (.115) [.210]	-.056 (-.421) [-.329]			
SSL			-.120 (.126) [1.289]		
BGSL ^b			-.149	.194 .158 .266	
STK					1.092 (1.756) [1.902]

^aThe top number in each row represents the short run effects, intermediate run effects are in parentheses, and long run effects are enclosed by brackets. These elasticities are evaluated at their respective means.

^bThe top number represents the six month elasticity, the second number indicates the twelve month effects, and the third number is the eighteen month effect.

¹ U.S. Department of Agriculture. Economic Research Service. Livestock and Meat Statistics. Bulletin Number 243. Washington, D.C.: Government Printing Office, October 1981 (p. 6).

As a result of the change in anticipated reductions, farrowing numbers in June-November 1982 were larger than the December-May 1982 farrowings, which is consistent with the negative sign of the dummy variable.

Inclusion of the hog-corn price ratio as a measure of profitability in farrowing operations yielded unsatisfactory statistical results. Consequently, compound parts of the ratio were specified as separate regressors. Because of the endogenous nature of contemporaneous slaughter price, it was specified in the regression as an instrument variable. The negative coefficient of contemporaneous price is valid given the biological production constraints which exist in the industry. The summation of the contemporaneous and lagged slaughter price (periods $t-1$ and $t-2$) coefficients is, however, positive which indicates that producers expand farrowings beyond one-time period following an increase in output price. The estimated short-run supply elasticity shows that a 10 percent increase in barrow and gilt slaughter price will decrease contemporaneous farrowings by 2.12 percent, primarily since gilts retained for breeding purposes require at least 12 months before farrowing. This biological constraint is less restrictive in the intermediate run where a 10 percent slaughter price increase yields a 1.2 percent increase in sow farrowing numbers.

The negative effect of corn price on sow farrowings (shown by the summation of the corn price coefficients) is consistent with the maintained hypothesis; that is, an increase in corn price implies decreased returns in farrowing operations due to increased feed costs. Concluded from the intermediate and long run elasticities of supply, the percentage effects of corn price on farrowing decisions exceeds the percentage effect of barrow and gilt slaughter price. This may be somewhat unusual in that output price in livestock production decisions generally have a greater weight than input prices. Both elasticities, however, are relatively small. Dixon and Martin (1982) attribute such low output price and input price supply elasticities to fixed investment in confinement technology.

The sizes of the estimated difference equation coefficients, .96 and $-.27$, indicate that the difference equation is stable and possesses imaginary roots. Thus, the behavior of sows farrowing subsequent to a change in either slaughter price or corn price is cyclical, dampening rather quickly due to the small absolute value of λ_2 (.27). Though these oscillatory patterns are not a direct measure of the hog cycle, they appear to be consistent with the average length of the cycle. For example, the distributed lag patterns of sows farrowing show that the effects of barrow and gilt price and corn price tend to dissipate within three to five years (the average length of the hog cycle is about four years). One reason for the three to five year dissipation period is the time lag required in adopting newer technology and/or adjustment to price changes. Also, some producers may be reluctant to make rapid production adjustments based only on a recent price change. That is, they are expecting continuous changes in input-output prices. This reasoning is also supported by Marsh (1984) in his econometric study of the slaughter sector of the livestock-meat economy.

Slaughter Supply Sector

The processing sector consists of three behavioral equations, barrow and gilt slaughter, sow slaughter, and cold storage holdings. The statistical results of these equations are summarized in Table 2, and the elasticities of supply are given in Table 3.

Barrow and Gilt Slaughter Supply

Barrow and gilt slaughter is estimated as a function of a seasonal dummy, a binary variable accounting for irregular market behavior in the 1973, contemporaneous and lagged values of the pig crop, the contemporaneous hog-corn price ratio, and first-order positive serial correlation. The difference equation coefficients were not significantly different from zero and, consequently, omitted. The signs of the contemporaneous and lagged parameter estimates appear to satisfy a priori expectations.

The positive coefficients of the pig crop variables indicate that barrow and gilt slaughter increases subsequent to larger pig crops. The summation of the coefficients is .56, indicating that the remainder (.44) is a combination of statistical error, death loss, and gilt and boar retention. Thus, for every 1000 head increase in pig crop in time period t , over three time periods 560 head are slaughtered. The contemporaneous pig crop variable is considered endogenous and enters the equation as an instrument variable (since pig crop is the product of sow farrowing numbers and pigs saved per litter). Lagged pig crops are assumed predetermined.

The hog-corn price ratio represents the relationship of market output price to feed cost in the finishing of slaughter hogs. The variable is assumed jointly endogenous and is therefore entered as an instrument variable. Note that the ratio is significant only in the contemporaneous time period and exhibits a negative relationship with barrow and gilt slaughter numbers. This occurs since an increase in the price ratio, all other factors unchanged, leads producers to retain more gilts for breeding purposes. Also, but probably a weaker argument, an increase in the price ratio could lead some producers to feed barrows and gilts to heavier slaughter weights (thus, carrying them into period $t+1$). This might be particularly so for lighter hogs near the end of the semiannual period.

A binary variable, D_{pf} , is included for the second period of 1973 to account for market irregularities. During this time institutional change, the Nixon price freeze on beef, poultry, and pork affected the market. This event, coupled with the 1973 consumer beef boycott and the commercial truckers' strike in early 1974 produced artificial restrictions on prices. After the lifting of the freeze subsequent commodity price adjustment problems occurred as a result of producer uncertainty. Coefficient of the binary variable is significant at the 90 percent level and negative correlation with barrow and gilt slaughter indicates that market hogs were withheld from slaughter. The equation fit and stability were improved by inclusion of this variable.

Sow Slaughter Supply

Sow slaughter is estimated as a function of the seasonal dummy variable, the hog-corn price ratio, and a second order nonstochastic difference equation. Initially, a first order serially correlated error term was included in the regression equation, but was deleted due to statistical insignificance.

Sow slaughter and sow farrowings are quite similar in terms of their seasonal production patterns. Sow slaughter is seasonally largest during the June-November production period, this result is confirmed by the positive coefficient of D2.

A negative correlation exists between the dependent variable and the contemporaneous hog-corn price ratio, while a positive correlation characterizes the relationship for the ratio lagged one period. This pattern reflects both an economic and biological slaughter response. Initially, an increase in the hog-corn ratio is a signal for better production returns, thus, more gilts will be retained to increase production capacity. Also, some marginally productive sows may be retained for farrowing purposes rather than marketed for slaughter. The short-term supply elasticity is $-.12$, indicating that given a change in the hog-corn ratio, producers do not greatly vary culling rates in the initial period. The positive intermediate and long term supply elasticity estimates ($.12$ and 1.2 , respectively) reflect the biological condition that more cull sows are slaughtered due to increased breeding herds.

The difference equation is stable and has imaginary roots. Thus, sow slaughter behaves cyclically given a change in the hog-corn price ratio. This result is consistent with the stable oscillating pattern that characterizes sows farrowing. The distributed lag patterns reveal that sow slaughter adjustment to a change in the hog-corn price ratio peaks in two and one-half years and dissipates around five years.

The adjusted R^2 ($.73$) is relatively low for this equation and the estimated standard error of (220.8) is relatively high. However, estimating cull slaughter is usually difficult because of the randomness in producer decisions, characteristics of different production

units, and varying financial positions of producers. The inability to quantify these factors gives rise to a rather large residual sum of squares.

Pork Storage Supply

The statistical results for the pork storage supply equation are summarized in Table 2. Cold storage holdings are estimated as a function of the seasonal dummy variable and contemporaneous quantity of slaughter production. A first-order nonstochastic difference equation with a positive first order serial correlation is employed.

Retail price was initially specified in the stock equation (see the maintained hypothesis, Chapter 2), however, it was omitted because of an insignificant asymptotic t ratio. Assuming no serious specification errors, the coefficient's insignificance implies that processors add to and subtract from cold storage primarily to provide a buffer between consumption and production.

Wholesale pork production (QWP) is statistically significant in terms of impacting cold storage holdings. Wholesale pork production is formulated by the use of an identity relationship, i.e., the summation of barrow and gilt slaughter and sow slaughter multiplied by their average dressed weight (Chapter 2). Since hog slaughter numbers are endogenous in the model, instrument variables estimated from reduced form equations enter the identity. The contemporaneous value of wholesale production is specified in the cold storage equation because of the limited storage life of fresh and processed pork, and the fact that lagged values are not needed due to the presence of the difference equation.

The responsiveness of cold storage holdings to changes in wholesale production is slightly higher than unity in the short run. That is, over a six month period, a 10 percent increase in wholesale production will increase storage holdings by 10.9 percent. Over the long run, the 10 percent increase in wholesale production increases pork storage holdings about 19 percent.

The first-order nonstochastic difference equation is stable with the value of the estimated difference equation term at .42. This implies a relatively small long run supply elasticity because of the short geometric adjustment period. This rapid adjustment process is consistent with the semi-perishable nature of pork. Stocks of pork also exhibited considerable seasonal fluctuation, primarily based on the need to store pork products for consumption at times different from their seasonal production. Indeed the negative coefficient sign on D2 indicates stocks are down in the June-November time period (compared to the December to May period) when seasonal consumption is usually higher.

Price Sector

The regression results for the farm and retail price equations are summarized in Table 4. The price flexibilities are given in Table 5.

Barrow and Gilt Slaughter Price

The price of slaughter barrow and gilts is estimated as a static equation with first order serial correlation. The independent variables include a seasonal dummy, contemporaneous farm by-product value, retail price, corn price, and contemporaneous slaughter supply. Attempts to estimate this equation within a rational distributed lag framework produced unsatisfactory results. Statistical results based on the six month observation period indicate that previous carcass prices do not affect current prices. This result could be due to the short-term nature of meat packer pricing decisions. Typically wholesale prices are determined by the yellow sheet and through bid-offer negotiations between packers and retailers, which may occur weekly or even on a daily basis. These negotiations highly impact hog prices. The static specification of this market sector is also supported by comparable findings in the beef industry by Brester and Marsh (1983).

Table 4. Regression Results for the Sow Slaughter, Barrow and Gilt Slaughter, and Retail Price Equations.^a

Equations	VARIABLES ^b													
	Intercept	Dpf	D2	SSL	BPV	PR	PCN	BGSL	QS	Y	Y-1	TSP	TSP-1	E(Dep-1) ^c
SOWP	10.189 (1.567)	1.468 (.741)	2.166 (2.629)	-.00496 (-3.062)		.278 (4.275)								
BGP	22.402 (3.554)		-.618 (-2.290)		2.998 (4.399)	.172 (4.775)	-3.268 (-2.693)	-.00043 (-3.098)						
PR	86.552 (3.029)		6.539 (2.269)						-8.259 (-3.991)	.023 (7.315)	-.022 (-7.366)	-22.692 (-9.340)	15.397 (5.382)	.942 (20.668)

^aThe asymptotic t-ratios are in parentheses under each coefficient. All variables are significant at the 95 percent probability level except one, Dpf.

^bEquation test statistics are defined as: $\bar{R}^2$ = adjusted multiple R-squared, Sy = standard error of the estimate, DW = Durbin-Watson statistic, and ρ = autoregressive term. The test statistics for each equation are: SOWP, the $\bar{R}^2$ = .8608, Sy = 1.858, DW = 1.653, ρ = .530; BGP, the $\bar{R}^2$ = .9720, Sy = .965, DW = 2.384, ρ = .662; PR, the $\bar{R}^2$ = .9199, Sy = 3.099, DW = 1.908, ρ not specified.

^cE(Dep-1) = the lagged expectation of the appropriate dependent variable.

Table 5. Estimates of Price Flexibilities from the Pork Model.^a

Equations	SSL	BPV	PR	PCN	BGSL	QS	Y	TSP
SOWP ^b	-.546		.981					
BGP ^b		.404	.530	-.199	.728			
PR						-.979 (-2.773) [-17.148]	1.119 (1.121) [1.132]	-1.173 (-1.776) [-6.618]

^aThe top number in each row represents the short run effects, intermediate run effects are in parentheses, and long run effects are enclosed by brackets.

^bThese numbers represent the six month effects.

The negative coefficient on the seasonal dummy variable is consistent with lower hog slaughter prices in the second half of the year due to seasonally larger slaughter supplies. Carcass by-product values exhibit a positive relationship with the dependent variable, which is plausible since by-product values cover processing costs and profit margins. The short run price flexibility shows that a 10 percent increase in the value of by-products leads to a four percent increase in slaughter hog prices. This percentage effect is very close to the impact of carcass and slaughter by-product values of fed slaughter steer prices (Brester and Marsh, 1983).

A wholesale-to-retail marketing margin was initially specified in the equation to provide a link between the processing and retail markets. However, its coefficient was not statistically different from zero. This was partly due to collinearity with other regressors. However, Foote (1958) shows that substitution of retail price in the right hand side of the equation can accomplish the same necessary market link between the processing and retail levels. The jointly dependent nature of retail price required it to enter the systematic part of the equation as an instrument variable. The coefficient estimate of retail price is positive and statistically significant, which implies an increase in retail demand increases the

derived demand, thus, the price of slaughter hogs. The price flexibility coefficient shows that a 10 percent increase in retail price increases slaughter price by about five percent.

The negative coefficient estimate for the price of corn is in agreement with most studies that show livestock prices are inversely correlated with feed costs. In this equation the price flexibility is quite small at $-.199$. Thus, it appears that the other regressors overshadow its importance. Marsh found similar results in the beef industry when feed costs impacted slaughter steer prices less than other price and production variables.

Contemporaneous barrow and gilt slaughter enters the equation as an instrument variable. Its negative coefficient is in agreement with economic theory, since barrow and gilt prices decline with additional slaughter supply on the market. Note from Table 5 that among the price flexibility coefficients that the percentage impact of barrow and gilt slaughter exceeds the percentage impact of the other independent variables.

Sow Slaughter Price

The sow slaughter price equation is estimated as a function of two binary variables, contemporaneous sow slaughter, retail price, and first-order serial correlation in the error term. The coefficient signs of each variable are as hypothesized and, with the exception of one, are statistically significant. The adjusted R^2 of $.86$ is lower than those of the other price equations, but is somewhat typical of estimating prices and quantities in cull livestock markets.

The binary variables specified are $D2$ and Dpf . The seasonal variable, $D2$, reveals a significant positive correlation with the dependent variable. This appears contrary to a priori reasoning. Although the majority of sows farrow during the first semiannual period with increased culling occurring in the second, the effect is offset by seasonally higher pork demand (i.e., retail pork price) in the second period. As discussed earlier, the Nixon price freeze and consumer beef boycott of 1973, and the commercial trucking strike in early

1974 were institutional changes in the market. The positive coefficient of D_{pf} reveals that these actions led to higher sow slaughter, however, the asymptotic t ratio indicates it was not significantly different from zero.

The quantity of sows slaughtered is negatively correlated with sow slaughter price. The empirical results show that a 10 percent increase in sows slaughtered reduces the cull sow price by about 5.5 percent. Significance is not surprising since the salvage value of a livestock unit would be highly influenced by the supply of depreciated livestock marketed.

Changes in consumer demand at the retail level usually impact variables in the marketing and production sectors. Retail price is included in the sow slaughter price equation to quantify the effects from the primary level of demand. For example, increased consumer demand for pork translates into higher slaughter prices for all hogs because of the increase in demand for all pork meat. Quantitatively, a 10 percent increase in retail price results in 9 percent increase in sow slaughter price.

Retail Pork Price

Retail pork price is estimated as a first-order nonstochastic difference equation. The independent variables specified are the seasonal dummy, per capita disposable income for periods t and $t-1$, total supply of processed pork in periods t and $t-1$, and the contemporaneous value of meat substitutes. All signs of the estimated coefficient are as anticipated. The statistical results are presented in Table 4 and the price flexibilities are given in Table 5.

Theoretically, meat substitutes for pork are shifters of retail demand and should have an inverse effect on price. That is, in the case of substitutes, an increase in their supply reduces the demand for pork, hence, pork price. The primary substitutes for processed pork are beef and poultry. Initially, these variables were specified as separate regressors in the maintained hypothesis. However, the asymptotic t -values indicated their individual effects were not significantly different from zero, partly due to a multicollinearity problem.

Consequently, the two were aggregated into one variable, QS, to account for the competitive effects on retail pork price. It can be seen that the negative impact of pork substitutes is large as given by the price flexibility coefficients for various lengths of run.

Per capita disposable income, a shifter of primary demand, is a measure of consumer purchasing power. The model shows that retail pork price adjustments, subsequent to increases in this variable, are positive. For example, a \$100 increase in per capital disposable income increases contemporaneous retail pork price by \$2.30 per hundred weight. The estimated short- and long-run price flexibilities with respect to income are about the same at 1.12 to 1.13. These estimates compare favorably with those of Arzac and Wilkinson (1979). It is interesting to note that the retail income price flexibility for beef is higher than that for pork (Brester and Marsh, 1983). Consumption of pork and its adjustments to changes in income is unique since consumers perceive pork as lower quality meat when compared to beef. Consumers allocate a larger proportion of temporary (short-run) and permanent (long-run) increases in disposable income to beef consumption than to pork consumption. However, as evidenced by the positive income flexibility estimates, consumers view pork as a normal good (i.e., early statistical studies showed pork to have a negative income elasticity of demand). This may be due, in part, to increased promotion activities of the National Pork Producers Council and pork producer support groups aimed at consumer education.

The total supply of processed pork is an aggregate measure of all processed pork, and is derived from an identity relationship of wholesale pork production, cold storage holdings, and pork imports. Since production and cold storage are jointly endogenous, they enter the identity equation as instrument variables. The collective impact on pork price of total supply of processed pork for periods t and $t-1$ is negative. However, based on the price flexibility coefficients, its importance is relatively less than the competitive supply effects of beef and poultry.

The size of the estimated difference equation coefficient (.942) is indicative of a long geometric adjustment process. Under normal conditions a 1 cent per pound increase in retail pork price in period t leads to a .9 cent per pound increase in $t+1$. Since the polynomial denominator of the rational lag function is imposed across all the independent variables, the distributed lag effects of income, substitutes, and pork supply are all geometric in nature. Because of the large value of the difference equation coefficient, the long run flexibility estimates for all these independent variables are large.

CHAPTER 4

CONCLUSIONS

Changes in producer expectations and technological advancements have resulted in the adoption of capital intensive production practices in the pork industry. Likewise, changes in pork consumption and marketing practices have taken place. All these changes together have produced a dynamic market in which analysis of prices and quantities is more complex. A dynamic econometric model employing rational distributed lags was used to estimate the pork price and supply sectors at the production, processing, and retail levels. Semiannual data from 1969 through 1982 was used in the model. The system of equations at these marketing levels were logically linked by appropriate price and quantity variables. The coefficient estimates specific to the model equations were utilized to calculate short, intermediate, and long run supply elasticities and price flexibilities. The various length of run effects were useful in analyzing the distributed lag patterns of the endogenous variables (given changes in the exogenous regressors).

The number of sows farrowing (the herd inventory equation) served as primary supply, and was estimated as a function of lagged barrow and gilt slaughter price and lagged corn price. The second-order nonstochastic difference equation possessed imaginary roots, showing a cyclical pattern, which reflected biological and economic constraints in production. The time period of dissipation for the cyclical pattern was reasonably close to previous studies that estimated the length of the hog cycle. The interdependent variables, slaughter price and corn price, were statistically significant and served as the decision base

for expanding or contracting farrowing enterprises. The elasticity of supply for each variable was relatively small, reflecting, over the sample period, high investment costs in confinement technology.

Commercial sow slaughter was estimated as a function of a lagged hog-corn price ratio with a second-order nonstochastic difference equation. The hog-corn ratio served as a proxy for producers' expectations of returns in farrowing sows, thus, directly affecting sow slaughter decisions. Since the breeding herd represents the pool upon which sow slaughter is based, increases in the hog-corn price ratio resulted in increased sow slaughter. The difference equation allowed the model to account for this biological age factor.

Barrow and gilt slaughter was estimated as a function of a binary variable, the contemporaneous hog-corn price ratio, and lagged pig crops. The binary variable was included to address peculiarities that existed in market behavior during the 1973-74 period; that is, the 1973 Nixon price freeze, consumer beef boycott, and a commercial trucking strike in early 1974. This variable proved to be significant and improved the equation test statistics. Barrow and gilt slaughter appeared to be quite sensitive to the hog-corn price ratio, primarily through changing the number of gilts held for breeding purposes and feeding slaughter hogs to different weights. Pig crop was calculated by an identity relationship, i.e., the number of sows farrowing multiplied by average pigs saved per litter. The pig crop, the contemporaneous sow slaughter and retail price variables were endogenous, and therefore entered as instrument variables. Sow slaughter was highly significant and had a negative impact on sow price, which was expected since producers would be marketing increased numbers of a depreciated capital asset. Retail price was positively correlated with sow price, indicating that when primary demand for pork increases, the derived demand (hence price) for all pork meat (including cull sows) increases. The static nature of the sow slaughter price equation was consistent with barrow and gilt pricing, that is, live hog prices

adjust quickly to changes in economic variables due to short-term yellow sheet pricing in the wholesale market.

The retail pork price equation is considered a primary inverse demand function. This equation was estimated as a function of per capita disposable income, per capita supply of processed pork, and per capita quantity of substitute meats. The income price flexibility coefficient was positive and significant, however, its impact on pork price is not as strong as on beef price. Thus, it may still be a less preferred meat. The effect of substitute meats (i.e., poultry and beef) figured prominently in the variation of retail pork price. Poultry and beef were chosen as the nearest substitutes for pork based on earlier studies and perceived consumer practices. The supply of processed pork was formulated via an identity relationship and was comprised of the wholesale pork production, cold storage holdings, and pork imports. Import quantities are assumed as predetermined while wholesale and storage quantities of pork are endogenous. Though pork supply was highly significant in affecting pork price, its impact, based on the flexibility coefficients, was not as important as the substitute meats. The equation was estimated as a first-order nonstochastic difference equation, reflecting consumer habits and market rigidities. The coefficient estimate of the difference equation was .948 denoting a long geometric adjustment process.

Some of the supply elasticities and price flexibility estimates of the model were compared with those of previous works to validate the results of the model. Such comparisons are mentioned in Chapter 3. However, comparative values for all variables do not exist and are difficult to interpret. That is, other models differ in research methods, data measurements and sample size, and specification of the maintained hypotheses.

The distributed lag patterns revealed in several of the farm-retail model equations the biological and economic constraints on the endogenous variables. Overall, this complex nature of interactions between the market levels as well as peculiarities specific to each market was adequately modeled in the rational distributed lag framework. The rational

generating function is flexible enough to measure both very short term and long term dynamic adjustments. In the model these ranged from short term adjustments in farm hog prices to long term adjustments in sow herd expansion and contraction. Such information would be valuable for ex post forecasting and economic evaluation of likely prospects in the hog and pork industry.

The model presented here is not without shortcomings. First, the assumption that variables such as corn price, average dressed weights, and substitute meat quantities are predetermined could be too restrictive. An expanded model where the possible joint dependency of these variables is addressed may be required, however, this infers a much more comprehensive approach. Second, an efficient price model should also include behavioral price equations at the wholesale level, something that is difficult due to the highly processed nature of pork. Third, quarterly or perhaps monthly data applied to the model specification would increase degrees of freedom for the statistical computations. Also, shorter units of observation may reveal important adjustment processes that are masked by semiannual observation periods. There would be, however, additional risk in terms of empirical evaluation. The additional seasonal influences may become confounded with the market's dynamics and lead to questionable coefficient estimates and distributed lag effects. In addition, shorter measurement units often entail more complicated disturbance terms.

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APPENDIX

Table 6. Original Data Used for the Price and Supply Equations.^a

OBS	Consumer Price Index	Retail Pork Price	Barrow and Gilt Slaughter Price	Price of Farm By-Product	Commercial Beef Production	Per Capita Disposable Income	Poultry Production	Pork Imports
1	.10765E+01	.68860E+02	.20530E+02	.29000E+01	.10147E+05	.30395E+04	.36015E+04	.23100E+03
2	.11093E+01	.77650E+02	.25890E+02	.39000E+01	.10656E+05	.31555E+04	.47551E+04	.21799E+03
3	.11425E+01	.80810E+02	.26010E+02	.44000E+01	.10599E+05	.33160E+04	.40324E+04	.24499E+03
4	.17333E+01	.77060E+02	.20870E+02	.34000E+01	.10826E+05	.34140E+04	.52476E+04	.24400E+03
5	.11975E+01	.68830E+02	.17020E+02	.27000E+01	.10683E+05	.35545E+04	.41423E+04	.25399E+03
6	.12210E+01	.71050E+02	.19230E+02	.30000E+01	.11099E+05	.36345E+04	.53291E+04	.22999E+03
7	.12385E+01	.77410E+02	.23870E+02	.31000E+01	.10791E+05	.37535E+04	.45129E+04	.30499E+03
8	.12598E+01	.85310E+02	.28200E+02	.36000E+01	.11382E+05	.39305E+04	.56969E+04	.30499E+03
9	.12926E+01	.97460E+02	.34930E+02	.47000E+01	.10516E+05	.41935E+04	.44813E+04	.26700E+03
10	.13498E+01	.11641E+03	.44790E+02	.74000E+01	.10608E+05	.43955E+04	.56403E+04	.26700E+03
11	.14203E+01	.91010E+02	.35270E+02	.61000E+01	.11010E+05	.45330E+04	.48548E+04	.27100E+03
12	.15063E+01	.10565E+03	.35740E+02	.65000E+01	.11693E+05	.47420E+04	.55429E+04	.21400E+03
13	.15740E+01	.11545E+03	.40850E+02	.60000E+01	.11504E+05	.49555E+04	.45098E+04	.23800E+03
14	.16325E+01	.14801E+03	.55990E+02	.75000E+01	.12031E+05	.51660E+04	.55576E+04	.20800E+03
15	.16750E+01	.14088E+03	.48180E+02	.53000E+01	.12531E+05	.54080E+04	.51266E+04	.24595E+03
16	.17213E+01	.13221E+03	.41190E+02	.46000E+01	.13078E+05	.55990E+04	.63500E+04	.22258E+03
17	.17751E+01	.11966E+03	.39010E+02	.45000E+01	.12376E+05	.58530E+04	.52693E+04	.23457E+03
18	.18360E+01	.12878E+03	.42590E+02	.47000E+01	.12678E+05	.61635E+04	.63855E+04	.19245E+03
19	.18933E+01	.13741E+03	.46920E+02	.55000E+01	.12127E+05	.65025E+04	.56341E+04	.26972E+03
20	.19855E+01	.14635E+03	.49080E+02	.61000E+01	.12026E+05	.68715E+04	.67930E+04	.23493E+03
21	.20835E+01	.15311E+03	.49060E+02	.64000E+01	.10798E+05	.75230E+04	.62331E+04	.25019E+03
22	.22245E+01	.13748E+03	.37770E+02	.50000E+01	.10670E+05	.76275E+04	.74507E+04	.24594E+03
23	.23790E+01	.13158E+03	.34290E+02	.43000E+01	.10470E+05	.78135E+04	.67939E+04	.26030E+03
24	.25130E+01	.14451E+03	.44730E+02	.55000E+01	.10837E+05	.82100E+04	.72764E+04	.28317E+03
25	.26400E+01	.14791E+03	.41670E+02	.50000E+01	.10993E+05	.86245E+04	.71015E+04	.27754E+03
26	.27695E+01	.15628E+03	.48020E+02	.57000E+01	.11176E+05	.90290E+04	.79067E+04	.27238E+03
27	.28515E+01	.16172E+03	.49130E+02	.57000E+01	.10818E+05	.92200E+04	.74143E+04	.26306E+03
28	.29310E+01	.18470E+03	.59260E+02	.65000E+01	.11548E+05	.95035E+04	.80137E+04	.33930E+03

^a Observations 1-28 represent years 1969-1982.

Table 6 (continued).

OBS	U.S. Population	Numbers of Barrows and Gilts Slaughtered	Numbers of Sows Slaughtered	Sow Slaughter Price	Pork Cold Storage Holdings	Average Dressed Weight	Expected Quantity Wholesale Production	Corn Price
1	.20196E+06	.36846E+05	.22410E+04	.17480E+02	.27713E+03	.18408E+03	.71951E+04	.12100E+01
2	.20299E+06	.33496E+05	.27690E+04	.22800E+02	.20105E+03	.18600E+03	.67453E+04	.12600E+01
3	.20409E+06	.34822E+05	.19160E+04	.22410E+02	.26780E+03	.18707E+03	.68726E+04	.12600E+01
4	.20519E+06	.36264E+05	.30210E+04	.16600E+02	.25603E+03	.18670E+03	.75985E+04	.14300E+01
5	.20631E+06	.42062E+05	.24540E+04	.14210E+02	.39523E+03	.18425E+03	.80657E+04	.15500E+01
6	.20734E+06	.38964E+05	.29000E+04	.16010E+02	.35870E+03	.18560E+03	.77659E+04	.12800E+01
7	.20826E+06	.39074E+05	.21190E+04	.20670E+02	.33760E+03	.18528E+03	.76106E+04	.12400E+01
8	.20908E+06	.35611E+05	.25850E+04	.24210E+02	.23702E+03	.18603E+03	.71268E+04	.13100E+01
9	.20987E+06	.35365E+05	.20990E+04	.30190E+02	.22763E+03	.18613E+03	.71193E+04	.16700E+01
10	.21063E+06	.32221E+05	.21730E+04	.39870E+02	.22148E+03	.18853E+03	.64400E+04	.25300E+01
11	.21136E+06	.36290E+05	.21220E+04	.30040E+02	.34233E+03	.19180E+03	.73480E+04	.28500E+01
12	.21214E+06	.34433E+05	.31340E+04	.29210E+02	.28778E+03	.19057E+03	.71315E+04	.34500E+01
13	.21290E+06	.33444E+05	.18640E+04	.36670E+02	.31144E+03	.18540E+03	.66164E+04	.30500E+01
14	.21381E+06	.27883E+05	.18440E+04	.49110E+02	.23013E+03	.18643E+03	.54249E+04	.28800E+01
15	.21460E+06	.31333E+05	.14300E+04	.41890E+02	.24909E+03	.18792E+03	.62318E+04	.26900E+01
16	.21540E+06	.34207E+05	.19290E+04	.34390E+02	.20666E+03	.18647E+03	.66784E+04	.27300E+01
17	.21625E+06	.35396E+05	.19300E+04	.33840E+02	.23081E+03	.17155E+03	.65038E+04	.24900E+01
18	.21715E+06	.34146E+05	.21260E+04	.43030E+02	.18088E+03	.17083E+03	.62626E+04	.19800E+01
19	.21806E+06	.35010E+05	.19220E+04	.41930E+02	.21838E+03	.16933E+03	.60744E+04	.23400E+01
20	.21898E+06	.34571E+05	.19890E+04	.43670E+02	.21482E+03	.17283E+03	.64476E+04	.22700E+01
21	.21990E+06	.37287E+05	.18820E+04	.44040E+02	.24995E+03	.17217E+03	.66597E+04	.24200E+01
22	.22088E+06	.41489E+05	.27660E+04	.31150E+02	.22166E+03	.17267E+03	.76650E+04	.27900E+01
23	.22194E+06	.44052E+05	.24650E+04	.30730E+02	.30498E+03	.17217E+03	.78966E+04	.26300E+01
24	.22547E+06	.41002E+05	.27490E+04	.39810E+02	.26782E+03	.17167E+03	.76191E+04	.32400E+01
25	.22941E+06	.42658E+05	.22380E+04	.38020E+02	.36898E+03	.17317E+03	.77293E+04	.35100E+01
26	.23014E+06	.39414E+05	.23700E+04	.43330E+02	.25927E+03	.17183E+03	.72646E+04	.29700E+01
27	.23124E+06	.38460E+05	.19770E+04	.40700E+02	.26900E+03	.17150E+03	.68977E+04	.27400E+01
28	.23232E+06	.35952E+05	.19820E+04	.53150E+02	.20400E+03	.17400E+03	.65495E+04	.24900E+01

Table 6 (continued).

OBS	Expected Barrow and Gilt Slaughter Price	Expected Hog-Corn Price Ratio	Numbers of Barrows and Gilts Slaughtered	Numbers of Sows Farrowing	Pig Crop	Pigs Saved Per Litter	Expected Numbers of Sows Farrowing	Expected Pork Storage Holdings
1	.20530E+02	.16960E+02	.36846E+05	.47970E+04	.35140E+05	.73100E+01	.47970E+04	.27713E+03
2	.25890E+02	.20540E+02	.33496E+05	.43150E+04	.31505E+05	.73000E+01	.43150E+04	.20105E+03
3	.26010E+02	.20640E+02	.34822E+05	.61610E+04	.45222E+05	.73300E+01	.61610E+04	.26780E+03
4	.14600E+02	.13390E+02	.37781E+05	.58910E+04	.42405E+05	.72000E+01	.62570E+04	.23387E+03
5	.19640E+02	.11670E+02	.41216E+05	.61920E+04	.44381E+05	.71500E+01	.59830E+04	.37536E+03
6	.18250E+02	.15220E+02	.39005E+05	.54010E+04	.39199E+05	.72600E+01	.55290E+04	.33854E+03
7	.23940E+02	.19340E+02	.38908E+05	.55890E+04	.40838E+05	.73100E+01	.54400E+04	.33942E+03
8	.28550E+02	.21370E+02	.35865E+05	.51420E+04	.37029E+05	.72100E+01	.52050E+04	.25211E+03
9	.34600E+02	.19900E+02	.36019E+05	.55910E+04	.40025E+05	.71500E+01	.56030E+04	.25349E+03
10	.45260E+02	.18160E+02	.31938E+05	.50910E+04	.36358E+05	.71400E+01	.51640E+04	.24989E+03
11	.34330E+02	.12280E+02	.36301E+05	.55030E+04	.39010E+05	.70700E+01	.53720E+04	.34099E+03
12	.37120E+02	.10430E+02	.34406E+05	.47040E+04	.33380E+05	.71000E+01	.49440E+04	.27956E+03
13	.39900E+02	.12870E+02	.33631E+05	.42250E+04	.30240E+05	.71500E+01	.39840E+04	.31489E+03
14	.56100E+02	.20610E+02	.27332E+05	.41920E+04	.30236E+05	.72200E+01	.43670E+04	.21086E+03
15	.48680E+02	.16960E+02	.31805E+05	.57770E+04	.36221E+05	.72800E+01	.56490E+04	.26020E+03
16	.40020E+02	.15760E+02	.33654E+05	.58500E+04	.36359E+05	.72200E+01	.58550E+04	.22375E+03
17	.40230E+02	.15510E+02	.36082E+05	.60500E+04	.36972E+05	.70800E+01	.60530E+04	.25703E+03
18	.41730E+02	.19880E+02	.34573E+05	.60090E+04	.37189E+05	.72000E+01	.60810E+04	.20764E+03
19	.47950E+02	.21500E+02	.34158E+05	.60340E+04	.36377E+05	.70300E+01	.61290E+04	.21250E+03
20	.47870E+02	.21300E+02	.35105E+05	.63980E+04	.39218E+05	.72000E+01	.61710E+04	.19653E+03
21	.49460E+02	.20410E+02	.36738E+05	.61400E+04	.43207E+05	.70200E+01	.62640E+04	.21823E+03
22	.38060E+02	.13850E+02	.41711E+05	.61770E+04	.44186E+05	.71600E+01	.61380E+04	.20192E+03
23	.34360E+02	.13420E+02	.43440E+05	.60960E+04	.44250E+05	.72500E+01	.60640E+04	.29734E+03
24	.44040E+02	.12990E+02	.41656E+05	.57550E+04	.41593E+05	.72300E+01	.56420E+04	.27837E+03
25	.41380E+02	.12060E+02	.42295E+05	.55090E+04	.40811E+05	.73900E+01	.56830E+04	.36474E+03
26	.48690E+02	.15920E+02	.39855E+05	.54110E+04	.39910E+05	.73800E+01	.53460E+04	.26868E+03
27	.49200E+02	.18470E+02	.38347E+05	.48300E+04	.35430E+05	.73100E+01	.48600E+04	.27139E+03
28	.59140E+02	.23630E+02	.35630E+05	.50330E+04	.37324E+05	.74100E+01	.50250E+04	.18913E+03

Table 6 (continued).

OBS	Expected Numbers of Sows Slaughtered	Expected Retail Pork Price
1	.22410E+04	.68860E+02
2	.27690E+04	.77650E+02
3	.19160E+04	.80810E+02
4	.29180E+04	.69420E+02
5	.25600E+04	.72440E+02
6	.28370E+04	.69600E+02
7	.21680E+04	.76600E+02
8	.24450E+04	.85920E+02
9	.22300E+04	.97330E+02
10	.22210E+04	.11668E+03
11	.20100E+04	.90670E+02
12	.30160E+04	.10695E+03
13	.20560E+04	.11508E+03
14	.17670E+04	.14818E+03
15	.13570E+04	.14060E+03
16	.21610E+04	.13008E+03
17	.18300E+04	.12148E+03
18	.20870E+04	.12858E+03
19	.17150E+04	.14008E+03
20	.22010E+04	.14400E+03
21	.19430E+04	.15097E+03
22	.26800E+04	.14177E+03
23	.24250E+04	.12993E+03
24	.27260E+04	.14454E+03
25	.23390E+04	.14447E+03
26	.24230E+04	.15674E+03
27	.18730E+04	.16578E+03
28	.20110E+04	.18203E+03



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