1957

# Supply functions for hogs

Gerald Wallace Dean
*Iowa State College*

# SUPPLY FUNCTIONS FOR HOGS

by

Gerald Wallace Dean

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Agricultural Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

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Head of Major Department

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# INTRODUCTION

A knowledge of supply responses and relationships for individual and aggregate agricultural commodities is of importance for farmers, economists, marketing organizations, national farm program administrators and consumers. Supply relationships are of immediate concern to outlook workers and other agricultural specialists who furnish information on which farmers base decisions. With more perfect knowledge, farmers might organize their resources for greater individual profits and efficiency. A knowledge of supply functions would allow marketing firms to anticipate more accurately the timing and magnitude of future commodity supplies, leading to marketing efficiencies and lower consumer prices. Agricultural supply relations and elasticities also are vital for policy decisions, particularly those dealing with price support levels for various farm products.

Despite the importance of information concerning supply, relatively little research effort has been directed toward empirical verification or rejection of hypotheses in this area. Agricultural price analysts have concentrated heavily on the demand function for farm products, conveniently making the assumption, sometimes only implied, that the quantity supplied may be regarded as predetermined. For many farm commodities, such a procedure has resulted in useful short-run predictions of price. Yet, more knowledge on the supply side is required if reasonably accurate representations of the demand-supply interrelationships are to be obtained.

Recent wide price fluctuations for several farm products have led to a resurgence of interest in supply phenomena. For example, Breimyer (4, p. 683-684) states:

> Demand has been analyzed, cross-analyzed, re-analyzed without respite. Ingenious demand shifters have been worked up. Yet the supply curve and its shifts remain an area of ignorance. . . . . If price making is a scissors action, how can we understand it without understanding supply?

The hog market, in particular, has shown wide price swings in the past several years. One measure of the variability of prices is the coefficient of variation (C).[1] Table 1 indicates that in the months of heaviest hog marketings (October through April), year-to-year variations in deflated hog prices increased in the post-war period compared with the pre-war period. (In the pre-war period, data for 1931-1934 were omitted because of the abnormally depressed hog prices throughout these years.) From the pre-war to the post-war period the coefficient of variation increased from 16 percent

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[1]The coefficient of variation (C) is defined as follows:

$$C = \frac{s}{\bar{x}} \times 100$$

Quantity s is the standard deviation of a series $X_i$ while $\bar{x}$ is the mean of the series. The coefficient of variation expresses the standard deviation as a percentage of the mean and hence measures the relative variation between series which are unlike in magnitude or in units of measure.

Table 1. Measures of year-to-year variation in deflated United States hog prices for selected marketing months and groups of years[a]

| Years | Marketing months | Standard deviation (s) (dollars/ cwt.) | Mean ($\bar{x}$) (dollars/ cwt.) | Coefficient of variation ($C = \frac{s}{\bar{x}}$) (percent) |
|---|---|---|---|---|
| 1923-1942[b] | October-April | 2.34 | 14.64 | 16 |
| 1946-1957 | October-April | 4.56 | 18.10 | 25 |
| 1953-1957 | October-April | 4.36 | 15.53 | 28 |
| 1923-1941[c] | May-September | 2.73 | 15.16 | 18 |
| 1946-1956 | May-September | 3.43 | 19.49 | 18 |
| 1953-1956 | May-September | 3.60 | 17.32 | 21 |

[a]Hog prices deflated by the index of wholesale prices.

[b]Omitting three depression years from October, 1931 to April, 1934.

[c]Omitting three depression years 1932-1934.

to 25 percent, while in the last four years (1953-1957) the coefficient reached a high of 28 percent. The coefficient of variation for May through September (the remaining marketing months) showed no change from the pre-war to post-war period. Again, however, greater variability has occurred in the past four years as is evidenced by an increase in the C value to 21 percent. Many farmers, economists and legislators were especially puzzled by the weak hog prices in the fall and winter of 1955-1956. The present study is an attempt to test hypotheses explaining the recent increased price fluctuations in the hog market.

# ECONOMIC THEORY AND RELATED HYPOTHESES AND OBJECTIVES

## Cobweb Theorem

In 1938, Mordecai Ezekiel (13) summarized and expanded the previous theoretical statements of the "cobweb theorem". Briefly, the cobweb theorem is an attempt to explain recurring cycles in the production and price series for particular commodities. Traditional economic theory assumes that, under static conditions of pure competition, market price tends to be established at the intersection of the demand and supply curves. However, where a considerable time lag occurs between the price change for a commodity and the resulting supply response, the cobweb relationship may lead to widely fluctuating prices and quantities.

Ezekiel distinguishes three possible cases of the cobweb theorem:

Case 1. Continuous fluctuation. This case is represented geometrically by the left diagram in Figure 1. Assume quantity $Q_1$ is produced in time period 1 and placed upon the market. The resulting price is established at $P_1$. However, the low price $P_1$ results in supply of only $Q_2$ in time period 2. With only $Q_2$ supplied, price is established at the relatively high price $P_2$. Producers respond to the price $P_2$ by producing $Q_3$. But with the quantity $Q_3$ supplied, price once more falls to $P_3$. Price $P_3$ is the same as the original price $P_1$ and the

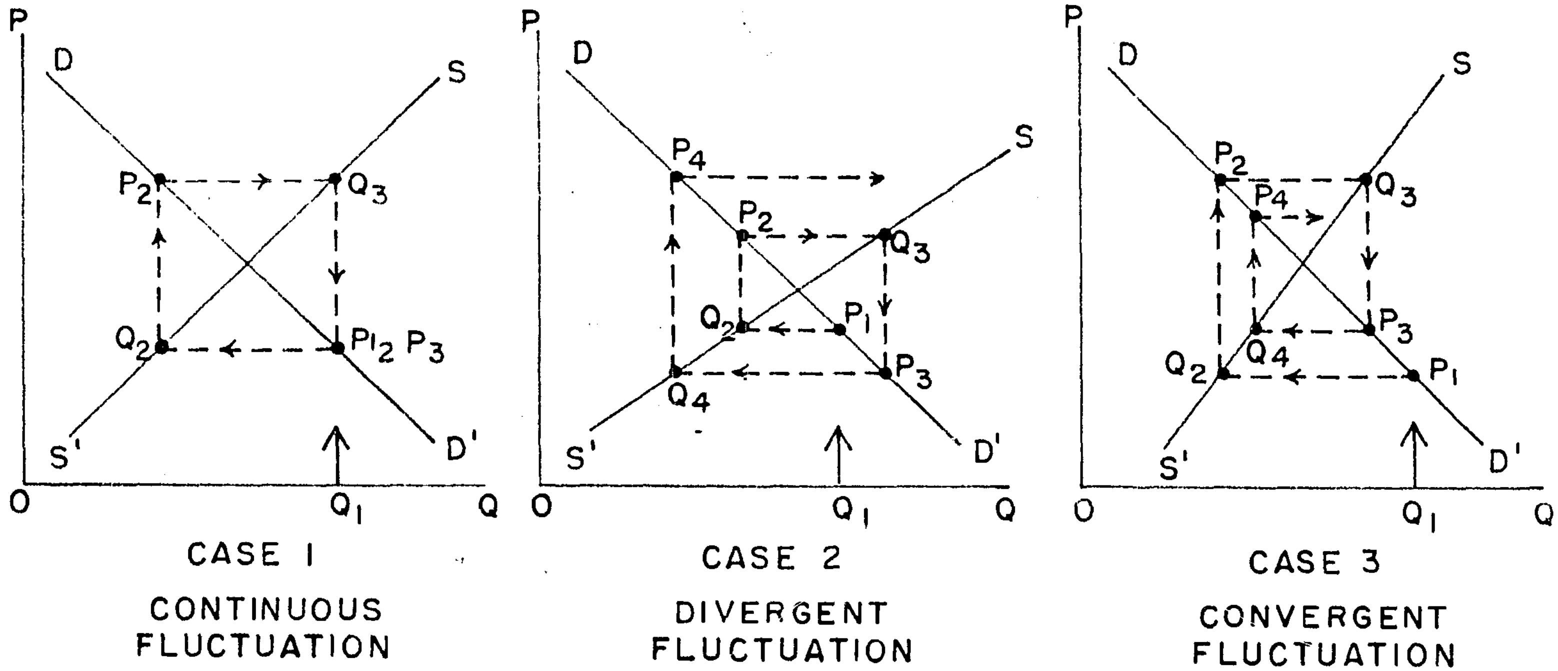


Figure 1. Three cases illustrating the cobweb theorem

pattern is then repeated in following time periods. When the demand curve is the exact reverse of the supply curve this same pattern will theoretically repeat indefinitely. Thus, in the simple case of linear demand and supply functions, the continuous case occurs when both functions have the same slope (with opposite signs).

Case 2. Divergent fluctuation. This case, represented by the center diagram in Figure 1, occurs when the absolute slope of the demand function is greater than that of the supply function. Beginning with a quantity $Q_1$ and corresponding price $P_1$ the series of reactions trace out a pattern of successively larger fluctuations in price and quantity.

Case 3. Convergent fluctuation. The right diagram in Figure 1 represents the case of successively converging prices and quantities. Starting from quantity $Q_1$ and price $P_1$ the quantities and prices show successively smaller fluctuations as they approach the equilibrium point at the intersection of the demand and supply functions. In this situation the absolute slope of the supply function is greater than that of the demand function.

Three conditions are required for the cobweb theory to exactly explain the functioning of a commodity market: (a) producers must base output in period $t + 1$ entirely on prices in period $t$; (b) once production plans are made, they cannot be changed until the following time period; (c) price must be determined by the quantity supplied. It appears that the demand and supply structure for hogs in the United States approximately meets the conditions outlined. It is necessary, however, to investigate each of the conditions in detail as it pertains to hog production and marketing.

In regard to condition (a), few empirical results are available which indicate the nature of price expectation models used by farmers. However, there is evidence that many farmers use current prices as the basis for projection or forecasting. Heady (22) cited the presence of commodity cycles in themselves as evidence that the majority of farmers employ the "extension of current prices" method. From a 1940 survey, Schultz and Brownlee (36) concluded that Iowa farmers formulated price expectations for hogs largely on the basis of current prices, at least for the time period investigated. However, Nerlove (32) hypothesized that farmers' price expectations are based not only on the current price but on prices observed in previous years. He proposed a scheme of deriving expected prices from previous prices, where the weight attached to each previous price declines as the time lag increases. Even with this method the most recent price carries the greatest influence in formulating price expectations. Based on the rather limited evidence available, the first condition for a cobweb relationship in hog production (i.e., that farmers base price expectations on current prices) seems approximately satisfied.

The nature of the hog production process indicates that conditions (b) and (c) also are reasonably fulfilled. Once sows are bred for farrowing, relatively little can be done to increase future production. Greater effort might be directed toward saving more pigs per litter and hogs can be carried to slightly heavier marketing weights, but these adjustments affect total supplies to only a limited extent. Somewhat greater flexibility is available in reducing supplies, however, since bred gilts may be sold before farrowing. Heavy price discounts on "piggy" sows tend to minimize this possibility, at least after the second month of pregnancy. A more serious limitation in applying the cobweb theory to hog production may be that hog supplies depend heavily on corn prices as well as on hog prices. However, hog prices in the heaviest marketing period of late fall and winter reflect, in part, the new corn supply and hence the expected price of corn during the next year. Condition (c) implies no interdependence or simultaneity between the price received and the quantity supplied, i.e., quantity is assumed to be predetermined. While farmers do vary marketing weights in response to very short-run price changes, the resulting influence in the total hog supply picture is probably relatively minor.

The above discussion suggests the possibility of a cobweb pattern of price and production in the United States hog market. Further evidence of this relationship is provided in Figure 2, where the hog-corn price ratio in October,

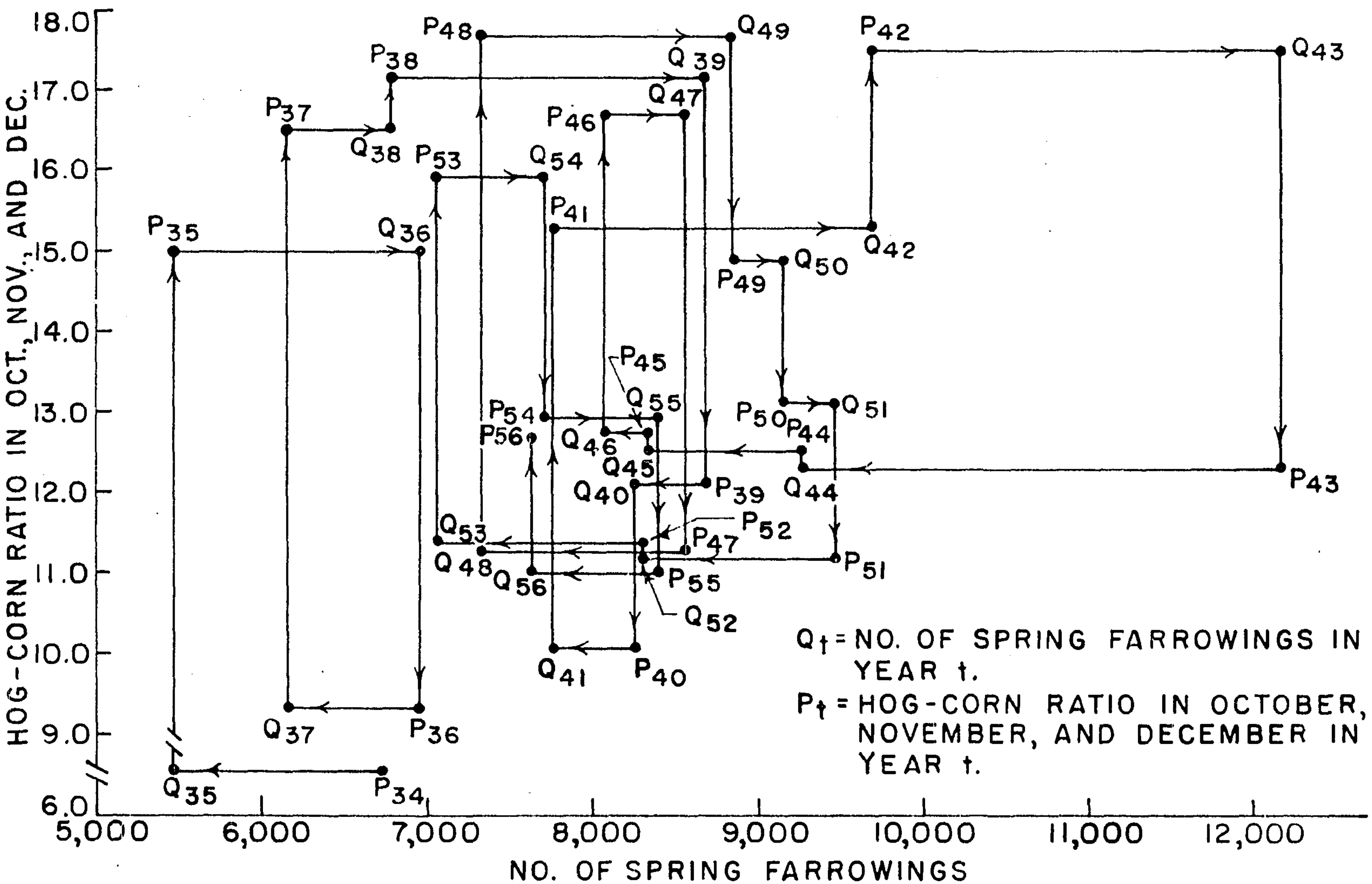


Figure 2. Cobweb relationship indicated by plotting the hog-corn price ratio and the spring farrowings in the United States, 1934-1956

November and December is measured along the vertical axis, and the number of sows farrowing in the spring months (December through May) is measured along the horizontal axis. Since the corn supply is a major factor in hog production, hog-corn price ratios rather than hog prices alone are used in Figure 2. October, November and December are the main months in which sows are bred for spring farrowings. The gestation period for hogs is approximately four months while the feeding period required to raise hogs to market weight is another six to eight months. Hence, the pigs raised from sows bred one fall usually are sold the next fall, some 10 to 12 months later. The prices at which these hogs are marketed then are available just prior to breeding time for the next spring pig crop. If the cobweb theorem is an accurate description of the hog market, relatively high hog prices one fall would lead to a large number of farrowings the next spring. Pigs from this large spring crop would be marketed the following fall, driving hog prices downward. Low hog prices would induce a smaller number of spring farrowings, which in turn would lead to high hog prices the following fall, etc.

Figure 2 provides strong indications that, with some modification, such a process has in fact taken place in the United States. The low hog-corn price ratio in the fall of 1934 ($P_{34}$) induced only 5,467 spring farrowings in the spring of 1935 ($Q_{35}$). This low number of spring farrowings resulted in a short supply in the fall of 1935 and a relatively high hog-corn price ratio ($P_{35}$). The higher hog-corn ratio ($P_{35}$) encouraged a larger number of spring farrowings in 1936 ($Q_{36}$), which in turn, resulted in a lower hog-corn ratio ($P_{36}$) in the fall, etc. While the data do not reveal a perfect cobweb, there is sufficient regularity in the clockwise rotation to indicate an underlying cobweb relationship. At times the pattern appears to be shifted out of its regular course by some outside force. For example, the effect of World War II and the Korean War seem to disrupt the regularity of the cobweb pattern. Of course, other factors such as the quantity of small grain production and the prices of competing farm products undoubtedly play a role not accounted for by this simple model. Nevertheless, it is argued that the cobweb relationship is the appropriate theoretical framework for explaining price and quantity fluctuations in the hog market of the United States.

## Hypotheses

The major hypothesis advanced in this investigation is that part of the recent fluctuations in hog prices can be traced to shifts in the supply elasticity for hogs. Specifically, it is hypothesized that the elasticity of supply for hogs has increased in recent years. As illustrated by the cobweb theory, an increase in supply elasticity (a flattening of the supply curve) leads to wider price fluctuations, other things remaining equal. Of course, an increase in supply elasticity does not necessarily mean that the hog market will be characterized by increasingly wider fluctuations. Starting from the convergent case, an increase in supply elasticity might not cause a shift to the continuous or divergent fluctuation cases; the relationship of the demand and supply curves still could fall well within the convergent case, with only the convergence delayed. A secondary hypothesis advanced in this study is that the demand for hogs has become more inelastic in the past few years. Under the cobweb hypothesis, a demand curve with greater absolute slope than formerly also could lead to wider fluctuations in hog prices. It is hypothesized that the combination of these two forces -- increased supply elasticity and decreased demand elasticity -- explains the recent behavior of the hog market.

Changes in supply and demand elasticities result from the interaction of a number of complex forces at work in the economy. An investigation of the way in which supply and demand functions are formed reveals the basis for the hypothesized changes in elasticities.

According to static economic theory, the supply curve of an individual firm is identical with its marginal cost curve. For maximum profits, output is expanded to the point where marginal cost equals marginal revenue; marginal revenue, in turn, is equal to price under perfect competition. Thus, for any product price there is a corresponding point on the marginal cost curve denoting optimum output. The marginal cost curve, therefore, traces out the quantities which should be supplied at each price in order to achieve maximum profits for the firm. Of course, in practice, the firm supply curve is not represented exactly by the marginal cost curve because of uncertainty and other considerations. The aggregate supply function for a commodity is derived merely as the summation of all individual firm supply functions in the industry.

The shape of the farm firm marginal cost curve depends directly on the shape of the production function. It is fairly obvious that the production function for hogs has shifted upward in recent years, causing a corresponding downward shift in the marginal cost curve (assuming prices of inputs constant). Use of antibiotics, improved rations and sanitation practices now allow greater output per unit of resource input than was possible a few years ago. However, there is no _a priori_ reason why this shift in the production function should cause a shift toward greater elasticity in the marginal cost curve, and hence in the supply function. While the marginal cost curve is shifted down and to the right, making it appear flatter, elasticity (being a percentage change concept) may remain constant or even decrease. Yet a common sense appraisal of changes in the farm economy suggests the plausibility of an increase in the supply elasticity for hogs in recent years. The hypothesis of increased supply elasticity for hogs implies that farmers are in a position of increased flexibility with respect to hog production. That is, producers now can shift more readily between enterprises with the occurrence of relative price changes. Improvements in building facilities and equipment, as well as in technical managerial skills, have made possible this type of between-enterprise flexibility. Changes in pork production methods also might contribute toward increases in supply elasticity. The time required to raise hogs to market weight has shortened in recent years, due to widespread adoption of new advances in swine nutrition, sanitation and breeding. Thus, the impacts of price changes are felt more rapidly in increases or decreases in output. Also, some producers now use a multiple farrowing system where pigs may be farrowed several times each year, or in some cases, during every month of the year. Such a farrowing scheme allows much greater intra-year output adjustment to price changes than is possible under a rigid one- or two-litter per year system.

The reasoning behind the hypothesis of a lower demand elasticity for hogs lies in changes in consumer preferences for meat. Shepherd (37) has shown an upward shift in the demand curve for beef and a downward shift in the demand curve for pork over time. Apparently, pork has become a less acceptable substitute for beef, poultry and other products than formerly. It is hypothesized here that, because pork is not as readily substituted for other meat products as formerly, consumers have become less responsive to price changes in making purchases of pork. This argument implies that pork has become more of a staple in the diet; consumers purchase more nearly a constant quantity regardless of price.

## Objectives

The objectives of the study flow directly from the hypotheses outlined above. A main objective is to empirically test the hypotheses of changes in supply and demand elasticities. As well as obtaining evidence on the directional shifts in elasticity, point estimates of the magnitudes of these elasticities will be obtained. It is anticipated that, in addition to obtaining estimates of structural relationships in hog supply and demand, forecasting equations can be developed for hog supplies in future time periods. Since the demand-supply relationships for hogs are not independent of other livestock products, auxiliary information should be obtained regarding these other products.

# REVIEW OF LITERATURE

A number of alternative procedures are available for deriving supply relationships in agricultural production. One general classification of procedures deals with the supply response of individual "typical" farm firms. Survey data from a sample of farms may provide information on the factors influencing supply response; other types of data may reveal past and anticipated changes in production in response to price changes and other phenomena. Another method of obtaining supply response is through budgeting, whereby the optimum pattern of farm production is estimated for various price relationships. The technique of linear programming for developing maximum-profit plans has made this approach more feasible in recent years. Still another approach from the firm level can be made through a study of the production function and related cost curves. A major difficulty in all firm approaches, however, is the problem of aggregating firm supply functions into an industry supply function.

Another group of procedures attempts to estimate the aggregate supply function directly, usually from annual, quarterly, monthly or daily time series data. The question of appropriate statistical technique arises in analyzing time series data. Both single-equation least squares and simultaneous equations methods have been used, with the emphasis on the former largely because of its relative simplicity. In addition to statistical problems, the aggregate method tends, in some instances, to obscure individual firm adjustments which offset or cancel one another. The following paragraphs review several of the main contributions to supply analysis, indicating the techniques used and results obtained. Following this discussion is a brief review of demand studies. The final paragraphs are devoted to a summary of a few of the more "complete" econometric studies which have been made. Models for these studies ordinarily include both demand and supply relationships.

Pioneering work in the field of supply analysis began in the 1920's under the direction of H. L. Moore, Ezekiel, Bean, Elliott, Henry Schultz and others. The general statistical technique used by this group was multiple regression, much of it by the short-cut graphic method. These analyses were hampered by the inadequacy of data, both as to accuracy and because of the short number of years for which data were available. As a result the forecasts and relationships derived frequently were found misleading, and supply analysis generally fell into disrepute through the 1930's. Only since World War II has interest again revived in empirical supply studies.

One of the first comprehensive studies dealing with supply response was conducted by Elliott (12) in 1927, in which he investigated fluctuations in supplies and prices of hogs for the period 1889 to 1916. Using first-difference regression analysis Elliott isolated nine independent variables to explain hog receipts at Chicago. He found that various lagged hog-corn ratios were the most significant factors in explaining supply response. Elasticities computed with respect to the hog-corn ratio ranged from 0.05 to 1.06 for various levels and lags of the ratio. Elliott also found that supply elasticities varied by type-of-farming regions within the state of Illinois.

Another early contribution to supply analysis was a study by Bean (1) on farmers' response to price for several agricultural commodities. Graphic correlation analysis was used for analyzing data for the rather short time period, 1921 to 1929. Again, the hog-corn ratio provided better explanations of hog production than hog prices alone. Bean found the elasticities of supply for several other agricultural products were all less than 1.0, although at the means of his curves the elasticities of rye, flax and watermelons were greater than unity.

In 1933 Wells (64) published a study on farmers' response to price in the production and marketing of hogs. Wells indicated his opposition to the budgeting method of obtaining supply response by quoting an extreme example where, in a given year, 80 percent of the increase in hog farrowings came from farms with no sows in the previous year. Thus, he argued, a budgeting procedure for hog farms would not have revealed this potential source of supply. Wells studied short-time, day-to-day changes as well as annual fluctuations in prices and receipts of hogs. He found that the elasticities of supply based on daily data were considerably greater than unity (from 4.4 on Tuesday and Saturday to 12.0 on Thursday) while the elasticity for annual data was only about 0.56. For individual states the elasticities ranged from 0.5 to 1.0.

During this period supply studies also were undertaken for a number of other farm commodities. In a 1928 study, Smith (39) studied forces affecting the price and acreage of cotton. Although elasticities were not computed, a regression analysis showed that the December cotton prices in each of the previous two years had some effect on cotton acreage. In a later study, Walsh (63) estimated that the elasticity of cotton acreage to adjusted price in the previous year ranged from 0.1 to 0.3. Pubols and Klaman (34) estimated that a change of 10 percent in the deflated price of potatoes in the United States was associated with a 2.3 percent change in acreage in each of the following two years.

In 1938 Cassels and Malenbaum (6) raised doubts about the validity of many previous statistical studies on supply. They reworked an earlier study by Ezekiel on milk production responses in Vermont and obtained widely divergent results. Whereas Ezekiel, using 1919 to 1925 data, had obtained a coefficient of determination of 0.79, Cassels and Malenbaum obtained a coefficient of determination of only 0.03 for the years 1922-1931. Cassels and Malenbaum pointed out several pitfalls in the indiscriminate use of regression techniques and suggested a combination of methods where possible.

In later years, a wider variety of techniques were used in supply analysis. In 1940 Mighell and Allen (31) compared supply elasticities for milk production when derived from regression analysis and from farm budget data. The budget analysis was used to project the elasticity of supply for 10 years ahead and revealed, as is logical, a greater elasticity than the year-to-year elasticity obtained by regression analysis. More recently Easley (11) derived a discontinuous or "stepped" supply function for milk using linear programming analysis. Schuh (35) estimated cost curves for typical Michigan dairy farms and aggregated these to derive an industry cost curve. He found low supply elasticities in the short-run, but estimated higher elasticities for a longer run period. Tolley (40) emphasized the possibility of deriving supply and demand curves from data arising out of unusual circumstances which occur in the economy. He used data resulting from a 1948 nationwide strike of packing house workers to obtain demand and supply relationships for hogs.

In most supply studies, the researcher continued to rely on some form of time series data which were analyzed by regression methods. For example, several recent studies used regression analysis in predicting supplies of spring and fall hog farrowings. Kohls and Paarlberg (28) found that September to November corn and hog prices, included as separate variables, explained 75 percent of the total variability in spring farrowings from 1925 to 1942. Fall farrowings were most closely associated with the preceding spring farrowings. In 1956, Brandow (3) published another study on estimation of spring and fall farrowings for 1926 to 1956, omitting war years 1942 to 1946. Using a combination of variables expressed as percentage of trend, first differences and actual numbers, he obtained a coefficient of determination for spring farrowings of 0.83 and for fall farrowings of 0.81. Brandow found that a large production of minor feed grains (oats, barley and sorghum grain) relative to corn production during the previous year led, other things equal, to more sow farrowing in the spring. Hiemstra (24) predicted quarterly sow farrowings based on time series data for the period 1930 to 1956, and obtained forecasting equations which might be used a month prior to the quarter to be estimated. Two other recent regression studies on supply might be mentioned. In one study Bowlen (2) obtained a wheat supply function for Kansas. He found a relatively inelastic short-run response, obtaining an elasticity of 0.32 for the eastern Kansas area. In the other study, Halvorson (21) derived short-run supply elasticities for milk by regions of the United States. The elasticities obtained were roughly in the neighborhood of 0 to 0.25, with response in the summer season toward the lower end of the range and response in the winter months falling in upper end of the range.

In addition to empirical investigations, several important conceptual contributions to supply analysis might be cited. Cassels (5) emphasized that there is no single curve which can be regarded as the supply curve for any particular commodity. He visualized a whole series of supply curves for each commodity representing all possible conditions between flexible long-run adjustments and rigid short-run fixity of supply. Hence, elasticities of supply must be carefully defined, not only regarding the specific point on the function at which the elasticity is computed, but with respect to length of run. Johnson (27) rejected former theories explaining the inelastic supply of aggregate agricultural production. His theory rested on the assumption that the supply functions of factors of production in agriculture are relatively inelastic. Heady (23) hypothesized that, even though aggregate farm output is unresponsive to price change, the supply functions for individual farm products are relatively elastic. The ease with which resources are transferred between agricultural enterprises is quoted as the main reason for this argument. Heady concluded, however, that empirical studies are urgently needed to provide meaningful estimates of structural supply relationships. Cochrane (8) advanced hypotheses as to the relative magnitudes of supply elasticities for a number of agricultural products. His estimate for hogs was relatively high, exceeded only by eggs and certain vegetable crops. Wheat, cotton and corn were estimated to be the most inelastic of major farm products.

Demand analysis has occupied a much more prominent place in the literature of agricultural economics than has investigation of supply relationships. Therefore, only a few major studies will be cited. The 1953 publication by Fox (19) is probably the most comprehensive demand study available for the United States. Using single-equation methods, Fox obtained price and income elasticities for the major farm products based on the inter-war period 1922 to 1941. Nordin et al. (33) estimated retail demand relationships for pork, beef, poultry products and eggs using both simultaneous equations and single equation methods. Simultaneous equations appeared to provide more reasonable results for pork, beef and poultry products; the single equation method provided more reasonable results for eggs. Learn (30) also used simultaneous equations and least squares methods in deriving demand relationships for livestock products at the farm level. Foote et al. (18) investigated the demand and price structure for corn and total feed concentrates.

Several studies employing rather complete econometric models have attempted to describe the working of the general feed-livestock economy. Hildreth and Jarrett (26) obtained quantitative estimates of the underlying relations determining the quantity and price of livestock products produced and sold in the United States. This highly aggregative study is perhaps most valuable from the standpoint of methodological contributions. A more recent study by Cromarty (9) provided estimates of structural relations which exist within and between twelve agricultural product categories. Single supply curves and multiple demand curves covering commercial, government and inventory demand were developed for each product category. Foote (16) developed a four-equation model of the feed-livestock economy based on data from 1922 to 1942. From these four equations it was possible to generate observations on price and production for successive years, revealing evidence of a stabilizing or explosive tendency in the system. In a later article, Foote (15) concluded that the system would probably involve cyclical fluctuations which would tend to increase in amplitude and ultimately explode. However, he stated that the divergent tendencies would manifest themselves slowly and the system probably would become inapplicable to the facts well before this tendency could be observed.

## CHOICE OF ESTIMATIONAL PROCEDURES

The present study employs statistical analysis of time series data in deriving estimates of supply and demand relationships. Thus, the question arises: Should single-equation least squares methods be used or are simultaneous equations appropriate? This question is answerable only after a consideration of (a) the conditions under which each method is applicable, and (b) the particular relationships which are to be estimated in this study. Discussion in following paragraphs draws heavily on the presentations by Foote (14), Foote and Fox (17) and Nordin *et al*. (33).

Explicitly or implicitly, econometric studies consist of three major steps: (a) specifying the model or system of economic relationships involved; (b) establishing the identifiability (uniqueness) of the individual equations; and (c) estimating the coefficients of the identifiable equations.

### Model Construction

In model construction, variables are classified into "predetermined" and "endogenous" groups. Predetermined variables are those which are taken as given, or determined outside of the economic model. The predetermined variables may be divided, in turn, into "exogenous" variables (*e.g.*, weather) and lagged values of endogenous variables (e.g., price in the previous year); these variables are classed as predetermined because they influence current values of endogenous variables but are not themselves affected by the current values of the endogenous variables. The number of structural equations in a complete model must be equal to the number of endogenous variables in the system. Thus, the single-equation least squares method assumes that one variable can be selected as the endogenous or dependent variable in an equation. It is possible that a system of equations can be constructed such that, in each equation, one variable can logically be selected as endogenous and the other variables as predetermined. In such a system it is appropriate to fit the individual equations by least-squares.[1] However, two or more current endogenous variables frequently enter the same structural equation. Since these variables are jointly determined, there is no reason for selecting a particular endogenous variable as dependent and the others as independent. Regression coefficients obtained from a different

[1]Foote (15) has shown how a potentially simultaneous model can be broken down into individual least-squares equations if the relationships operate in sequence. This sequential idea also forms the basis of the "recursive" or "causal chain" models emphasized by Wold and Jureen (65).

choice of dependent variable are, in general, inconsistent.[1] In this situation, one or more additional relationships between the variables are required to provide appropriate estimates of coefficients in the equation of interest.

## Identification of Equations

After a theoretical model has been specified, the next problem is one of deciding whether the equations or coefficients of interest are identifiable. In other words, it is necessary to know whether a unique value can be estimated for a given coefficient. Three possible cases of identification arise: An equation may be just-identified, underidentified or overidentified. The following illustrations of the three identification cases follow those presented by Nordin *et al.* (33).

### Just-identified case

Assume the following 2-equation model:

(1) Demand: $p + aq = u_1$

(2) Supply: $bp + q + cZ_1 = u_2$ .

---

[1] The problem of whether price or quantity should be the dependent variable has been debated throughout the history of demand analysis. Analysts recognized that one set of regression coefficients are obtained using price as dependent, while different coefficients are obtained if quantity is chosen as dependent.

Variables p and q are endogenous variables of price and quantity, respectively. Variable $Z_1$ is a predetermined variable representing weather while $u_1$ and $u_2$ are random disturbances. Since both equations include two endogenous variables neither equation can be logically fitted by least squares. Suppose it is desired to estimate the coefficients for Equation 1. First, Equations 1 and 2 are solved for p and q (the endogenous variables) in terms of the predetermined variable ($Z_1$). The resulting Equations 3 and 4 are

$$(3) \qquad p = \frac{ac}{1 - ab} Z_1 + \frac{u_1 - au_2}{1 - ab}$$

$$(4) \qquad q = \frac{c}{1 - ab} Z_1 + \frac{u_1 - bu_2}{1 - ab}$$

called reduced form equations. Since only one current endogenous variable occurs in each reduced form equation, least squares estimation is appropriate. The resulting estimates of the coefficients of $Z_1$ are given in Equations 5 and 6. Dividing Equation 5 by 6 gives the estimate of a in Equation 7.

In this case, $\hat{a}$ is uniquely determined. Hence, Equation 1 also is uniquely determined (just identified) because its coefficients are uniquely determined. If each equation in a system is just identified, there is always a unique algebraic transformation by which it is possible to go

(5) $$\frac{\widehat{ac}}{1 - ab} = \frac{\Sigma pZ_1}{\Sigma Z_1^2}$$

(6) $$- \frac{\hat{c}}{1 - ab} = \frac{\Sigma qZ_1}{\Sigma Z_1^2}$$

(7) $$\hat{a} = \frac{\Sigma pZ_1}{\Sigma qZ_1}$$

from the coefficients in the reduced form equations to the coefficients in the structural equations.

Underidentified case

An equation is underidentified if its coefficients are not uniquely determined. Substituting $\hat{a}$ from Equation 7 into Equation 6 results in Equation 8. An infinite number of combinations of values for $\hat{c}$ and $\hat{b}$ satisfy Equation 8.

(8) $$- \hat{c} \frac{\Sigma Z_1^2}{\Sigma qZ_1} = 1 + \hat{b} \frac{\Sigma pZ_1}{\Sigma qZ_1}$$

Thus, the coefficients $\hat{c}$ and $\hat{b}$ are not uniquely determined and Equation 2 is underidentified.

Overidentified case

In the overidentified case, two or more alternative estimates are derived for a structural coefficient. While the number of alternative values is not infinite (as in the underidentified case) the coefficients are not uniquely determined. Assume the following model:

(9) Demand: $p + aq = u_1$

(10) Supply: $bp + q + cZ_1 + dZ_2 = u_2$ .

Variable $Z_2$ is price lagged one year ($p_{t-1}$) and hence is classed as predetermined. Other variables are defined as previously. The reduced form equations are as follows:

$$(11) \qquad p = \frac{ac}{1 - ab} Z_1 + \frac{ad}{1 - ab} Z_2 + \frac{u_1 - au_2}{1 - ab}$$

$$(12) \qquad q = - \frac{c}{1 - ab} Z_1 + - \frac{d}{1 - ab} Z_2 + \frac{u_2 - bu_1}{1 - ab}$$

The least squares estimates of $Z_1$ and $Z_2$ in Equation 11 are

$$(13) \qquad \frac{\widehat{ac}}{1 - ab} = \frac{\Sigma pZ_1 \Sigma Z_2^2 - \Sigma pZ_2 \Sigma Z_1Z_2}{\Sigma Z_1^2 \Sigma Z_2^2 - (\Sigma Z_1Z_2)^2} \quad \text{and}$$

$$(14) \qquad \frac{\widehat{ad}}{1 - ab} = \frac{\Sigma Z_1^2 \Sigma pZ_2 - \Sigma Z_1Z_2 \Sigma pZ_1}{\Sigma Z_1^2 \Sigma Z_2^2 - (\Sigma Z_1Z_2)^2} \quad .$$

The least squares estimates of $Z_1$ and $Z_2$ in Equation 12 are

$$(15) \qquad - \frac{\hat{c}}{1 - ab} = \frac{\Sigma qZ_1 \Sigma Z_2^2 - \Sigma qZ_2 \Sigma Z_1Z_2}{\Sigma Z_1^2 \Sigma Z_2^2 - (\Sigma Z_1Z_2)^2} \quad \text{and}$$

$$(16) \qquad - \frac{\hat{d}}{1 - ab} = \frac{\Sigma Z_1^2 \Sigma qZ_2 - \Sigma qZ_1 \Sigma Z_1Z_2}{\Sigma Z_1^2 \Sigma Z_2^2 - (\Sigma Z_1Z_2)^2} \quad .$$

From the last four equations it is possible to derive two alternative estimates of a. Dividing Equation 13 by 15 gives Equation 17, while dividing Equation 14 by 16 gives Equation 18.

$$(17) \qquad \hat{a}_1 = - \frac{\Sigma pZ_1 \Sigma Z_2^2 - \Sigma pZ_2 \Sigma Z_1 Z_2}{\Sigma qZ_1 \Sigma Z_2^2 - \Sigma qZ_2 \Sigma Z_1 Z_2}$$

$$(18) \qquad \hat{a}_2 = - \frac{\Sigma Z_1^2 \Sigma pZ_2 - \Sigma Z_1 Z_2 \Sigma pZ_1}{\Sigma Z_1^2 \Sigma qZ_2 - \Sigma qZ_1 \Sigma Z_1 Z_2} .$$

Since the two estimates of a are not equivalent, a is overdetermined and hence demand Equation 9 is overidentified.

## Identification rules

Rules of thumb have been established which are useful in arriving at the degree of identification of a structural equation. The following quantities are defined:

$G$ = Total number of endogenous variables in the complete model.

$G^{\Delta}$ = Number of endogenous variables in the equation under consideration.

$G^{\Delta\Delta}$ = Number of endogenous variables in the complete model, but not in the equation under consideration.

$K$ = Total number of predetermined variables in the complete model.

$K^{*}$ = Number of predetermined variables in the equation under consideration.

$K^{**}$ = Number of predetermined variables in the complete model, but not in the equation under consideration.

For the equation under consideration to be just-identified,

$$K^{**} = G^{\Delta} - 1 \quad (19)$$

For the equation under consideration to be underidentified,

$$K^{**} < G^{\Delta} - 1 \quad (20)$$

For the equation under consideration to be overidentified,

$$K^{**} > G^{\Delta} - 1 \quad (21)$$

Unfortunately, these rules specify only the necessary conditions for determining the degree of identification in a particular equation. These rules imply only the order of the matrix of coefficients of the $K^{**}$ variables in the reduced-form equations. The necessary and sufficient condition for the identifiability of a structural equation involves the rank of the matrix of coefficients of the $K^{**}$ variables in the reduced-form equations.[1]

## Statistical Estimation

The appropriate method of statistical estimation is determined by the degree of identification of the equations

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[1]A detailed discussion and proof of the rank condition in matrix algebra notation may be found in Koopmans and Hood (29) or in Nordin <u>et al</u>. (33).

in the model. It is impossible to derive unique estimates of the coefficients of an equation which is underidentified. When an equation is just-identified, the coefficients can be estimated by the method of reduced-forms, as illustrated earlier. In this case, it is possible to make two simple unique transformations. One transforms structural equations into reduced-form equations, each containing one endogenous variable, which can be estimated by least squares; the other transforms the least-squares estimates of the coefficients back to estimates of the structural coefficients. Because of its simplicity, this method has been used in most applications of simultaneous equations. When an equation is overidentified, more difficult problems of statistical estimation arise. Theoretically, the ideal method for obtaining structural coefficients in this case is the maximum likelihood method. The maximum likelihood procedure provides a means of arriving at an average or reconciliation of the finite number of alternative estimates obtained in the overidentified situation. Logically, the "full-information" maximum-likelihood method, which utilizes all of the information in the model, is considered superior for the estimation of overidentified equations. However, this procedure is formidable from a computational standpoint. Hence, the "limited-information" maximum-likelihood method, which utilizes only part of the available information, is employed in this study for the estimation of overidentified equations.

Details of the computational procedure followed are set forth by Friedman and Foote (20) and are summarized in matrix notation by Chernoff and Divinsky (7).

The above discussion points up some of the assumptions and problems inherent in the single-equation least-squares and simultaneous-equations approaches. Foote (14, p. 989) states that, "there should be no question in the minds of research analysts as to whether they should use single-equation or simultaneous-equation methods for particular equations or groups of equations". That is, given the theoretical model or hypothesized relationships, the choice of statistical method should be clear. Thus, in the analysis which follows, the statistical techniques are dictated by the logic of the relationships investigated.

## ANALYSIS OF SPRING AND FALL HOG FARROWINGS IN THE UNITED STATES AND NORTH CENTRAL REGION

The total liveweight production of hogs in the United States depends directly upon the number of hogs marketed and their average marketing weight. For reasons mentioned earlier, average marketing weights are varied relatively little from year to year; the major changes in hog supplies result from changes in the number of hogs marketed. The number of hogs marketed is, in turn, determined largely by the number of sows farrowed in preceding time periods. Thus, the first and perhaps most important step in studying hog supply is an analysis of spring and fall farrowings. The analysis is carried out at two levels of aggregation: One analysis pertains to the United States as a whole; the other relates to the North Central Region. Since approximately 70 to 80 percent of spring pig crop (December through May) and 60 to 70 percent of the fall pig crop (June through September) are produced in the 12-state North Central Region, this area is singled out for special study.

To investigate the hypothesis of an increased supply elasticity for hogs, the analysis is further divided into two time periods. Comparisons between these time periods provide estimates of changes in structural relations. A logical division with respect to time might be into pre-war and post-war periods. Most available agricultural demand analyses are based on the inter-war period from about 1920 to 1941. A few analyses include several post-war years along with the pre-war period, omitting the war years because of disturbances due to government interference in pricing, rationing, etc.[1] In the latter procedure, however, changes in structural relationships over time may be obscured. On the other hand, a separate post-war analysis must be based on rather scanty data. As a compromise, the time periods selected in this study are 1924 to 1937 and 1938 to 1956 (omitting the war years, 1942, 1943 and 1944). In terms of relatively homogeneous periods, this appears to be a reasonable division. By 1938 the United States had recovered from the depths of the depression. Also, the agricultural sector no longer felt the major effects of the drouth years 1934 and 1936.

The nature of the production process for hogs indicates that a single-equation least-squares model is appropriate in estimating spring and fall farrowings. Because of the four-month gestation period for hogs, the number of sows farrowing cannot be changed quickly in response to price changes during the farrowing period. Most producer decisions regarding the

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[1]The reasons for omitting the war years in supply analysis are less apparent, since producers supposedly react to market prices whether they are administered or not. However, in this part of the study, the earlier war years are omitted because producers may have reacted to demands for more farm products through patriotism, etc., rather than in response to measurable phenomena.

number of sows to farrow are made at or before breeding time, preceding the farrowing period. Therefore, numbers of sows farrowing may be regarded as a function of predetermined variables, known in advance of the farrowing months. Two qualifications should be noted: First, since the farrowing periods are defined as six months in length and the gestation period is only four months, prices at the beginning of the period might influence the number of farrowings at the end of the period. Second, "piggy" sows may be sold during the gestation period if the outlook is for lower prices. These factors, while recognized, are felt to be of insufficient importance to destroy the assumption that farrowings are essentially predetermined.

## Spring Farrowings in the United States

Regression Equations 22 and 23 estimate spring farrowings in the United States for the period 1938 to 1956 (omitting war years 1942, 1943 and 1944). Standard errors of the regression coefficients are given in parentheses below the coefficients.

$$(22)\quad \hat{Y} = -5{,}969.6423 + \underset{(34.1780)}{392.3640X_1} + \underset{(11.3829)}{59.8738X_2} - \underset{(53.6229)}{104.5646X_3}$$

Throughout the thesis the coefficients and standard errors of the equations are carried out to four decimal places. Of course, for purposes of prediction, not all of the digits presented should be considered significant. However, the additional digits should aid other research workers who might wish to duplicate or compare results.

Data used in computing the equations presented throughout the thesis are compiled in the Appendix, beginning on page 125. In all cases an attempt is made to provide the basic data required to obtain each variable. The exact form of each variable (such as a first difference or a ratio of two other variables) may be obtained readily from the data provided. Column headings for each variable in the Appendix tables indicate the units in which the variables are computed. Reference numbers indicating the source for the particular variables also are presented in the column headings. Some difficulty may be encountered in determining the timing of the variables. The principle followed in the text is to consider as year t the period in which the dependent variable (Y) is measured. Thus, the term "current year" refers to year t; the term "preceding year" refers to year t-1.

$$(23)\quad \hat{Y} = -7{,}430.1469 + \underset{(35.7649)}{418.0920X_1} + \underset{(10.7840)}{66.4292X_2} + \underset{(229.3645)}{577.9985X_4}$$

The variables are defined as follows:

$\hat{Y}$ = Estimated change from the previous spring (Dec.-May) in the number of sows farrowing, United States.

$X_1$ = United States hog-corn price ratio as an average of October, November and December in the preceding year.

$X_2$ = Change in oats, barley and grain sorghum production as a percentage of corn production over the preceding two years, United States. That is, $S_{t-1} - S_{t-2}$, where S is oats, barley and grain production as a percentage of corn production, and t denotes years.

$X_3$ = Margin between 500-800 pound good-choice stocker and feeder cattle at Omaha and choice-prime slaughter steers of all weights at Chicago during October, November and December of preceding year, deflated by the Index of Wholesale Prices.

$X_4$ = Ratio between 500-800 pound good-choice stocker and feeder cattle at Omaha and the average United States hog price during, October, November and December of the preceding year.

In both equations, the hog-corn ratio ($X_1$) is the most important variable in predicting changes in spring farrowings, as judged by the standard partial regression coefficients. It appears that the absolute level of this ratio strongly influences the direction and magnitude of changes in farrowings. When hog prices are favorable relative to corn (a high hog-corn price ratio), farrowings tend to increase from the previous level and vice versa.

The hog-corn ratio reflects to a considerable extent the supply of corn available for feeding. However, Brandow (3) notes a separate influence exerted by production of oats, barley and grain sorghum. When these grains comprise a relatively large proportion of the total feed grain supply, hog production tends to increase and vice versa. The variable expressing this relationship ($X_2$) is next in importance in explaining changes in spring farrowings.

Table 2. Summary of statistics for regression Equations 22 and 23 for United States spring farrowings for the period 1938-1956 (omitting years 1942, 1943 and 1944)

| Equation | Value of $R^2$ | Value of d statistic | Ratios of regression coefficients to their standard errors | | |
|---|---|---|---|---|---|
| 22 | 0.92 | 1.55 | 11.48 | 5.26 | 1.95 |
| 23 | 0.93 | 1.02 | 11.69 | 6.16 | 2.52 |

Beef cattle feeding probably is the chief competitive farm enterprise with hogs in the major hog-raising areas. According to theory, the relative profitability of cattle and hogs should influence the number of sows farrowing. The variables in Equations 22 and 23 represent two possible methods of expressing this influence. The regression coefficient for the deflated price margin on beef cattle ($X_3$) is negative, indicating that as margins increase, the number of sows farrowing the following spring decreases. Thus, when cattle margins are relatively high, resources apparently are shifted from hog production to beef cattle production. In Equation 23, a price ratio between feeder cattle and hogs ($X_4$) indicates the relative attractiveness of beef cattle versus hog production. When feeder cattle prices are relatively high, farmers tend to reduce cattle production and increase hogs.[1]

Figures 3 and 4 show the actual spring farrowings compared with those predicted from Equations 22 and 23. Admittedly, comparing the predicted and actual farrowings over the time period used in developing the regression

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[1]While not shown here, a slaughter cattle-hog price ratio is nearly as effective as the feeder cattle-hog price ratio in predicting changes in sows farrowing. Because of the high correlation between feeder cattle and slaughter cattle prices, the regression coefficient for the slaughter cattle hog price ratio also has a negative sign. This result appears to be inconsistent with logic. In almost all the analyses undertaken, some form of beef cattle-hog price ratio is significant; however, the signs are sometimes positive, sometimes negative. Since feeder and slaughter cattle prices are highly correlated, either a feeder cattle-hog ratio or slaughter cattle-hog ratio produces a significant regression coefficient. Thus, it is possible to argue that producers are influenced in some instances by feeder cattle prices and in others by slaughter cattle prices. While it is always possible to obtain a "consistent" sign in this way, the method appears highly arbitrary. More investigation is needed on this relationship.

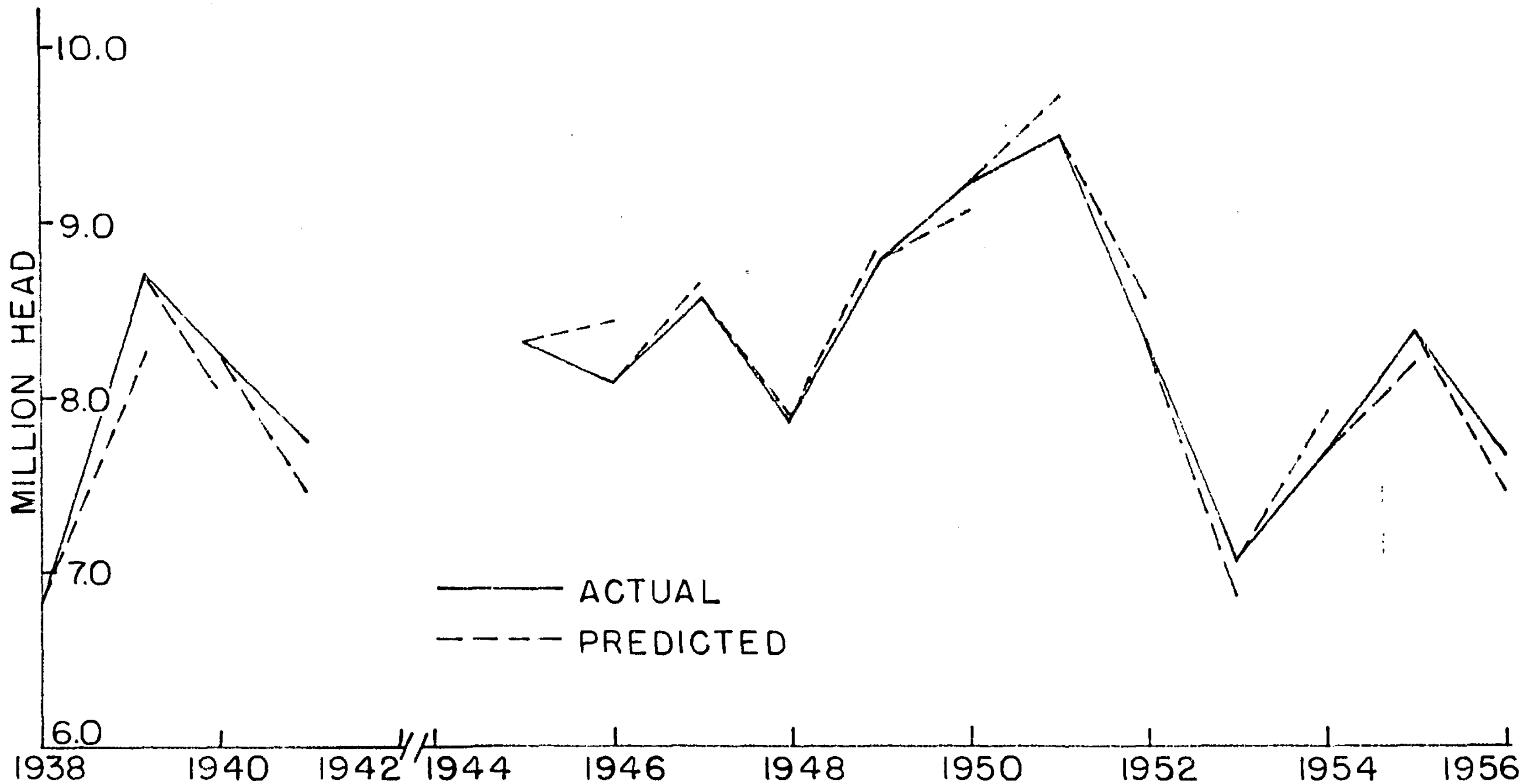


Figure 3. Actual spring farrowings in the United States compared with predictions from Equation 22

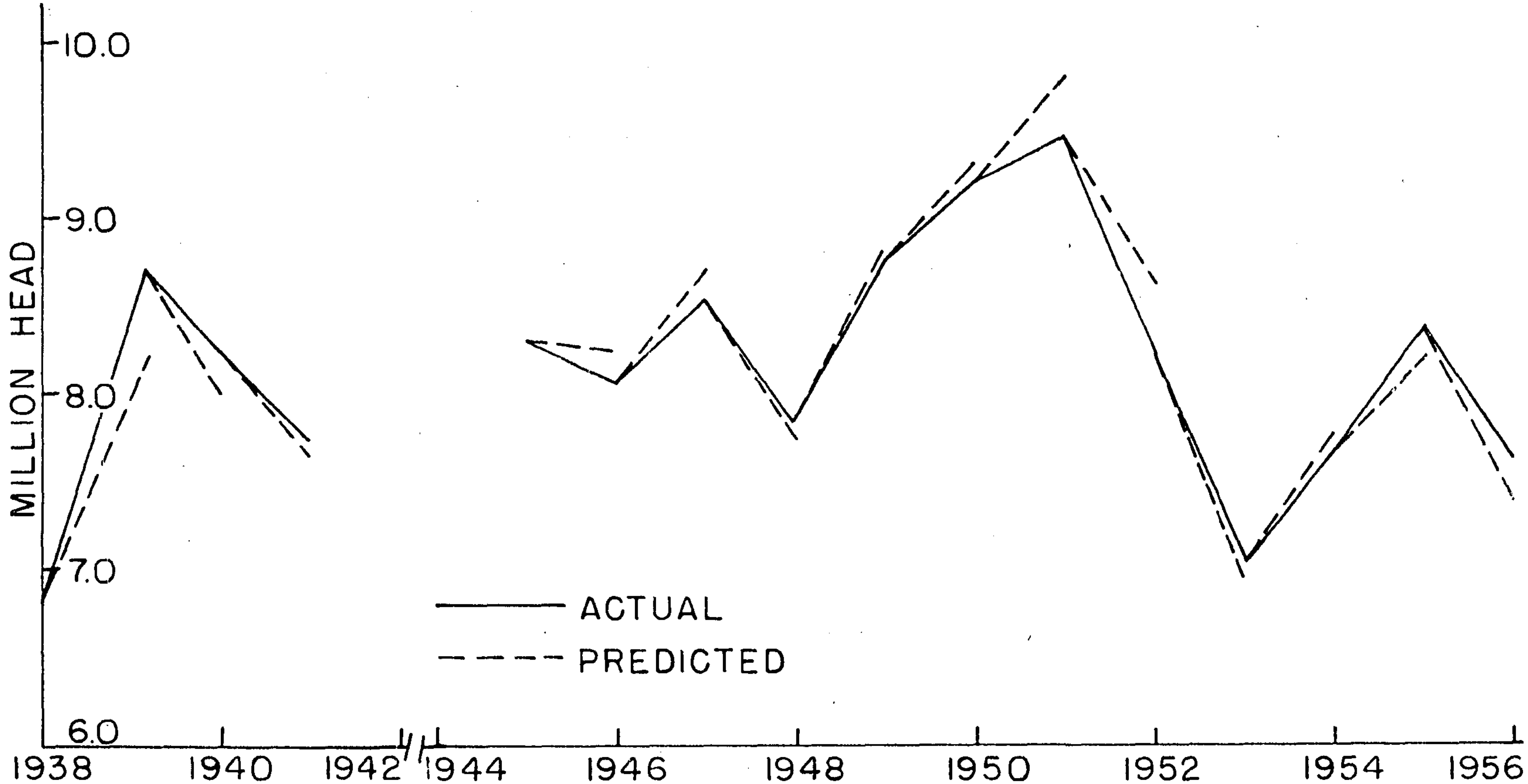


Figure 4. Actual spring farrowings in the United States compared with predictions based on Equation 23

equation is not a completely satisfactory test of the value of the equation for predictional purposes.[1] Recognizing the limitations of this test, the regression equations correctly indicate the direction of change in spring hog farrowings, with the single exception of the 1945 prediction for 1946 in Figure 3.

Some idea of the accuracy of the estimates is given by computing the standard error of the estimate. This figure provides a measure of the amount by which the estimates of farrowings deviate from the observed farrowings in the years studied. For Equation 22, the standard error of the estimate is 275,000 litters or approximately 3.36 percent of the mean number of sows farrowed each spring. Of course, the standard error of a forecast is somewhat larger. The standard error of the estimate for Equation 23 is 256,000 litters or 3.13 percent of the mean number of sow farrowings.

The Durbin-Watson (10) test for serial independence of the residuals also is computed, although the relatively low number of observations increases the probability of obtaining an inconclusive test result. The d statistic for Equation 22 is 1.55, which falls in the inconclusive range. However,

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[1]A somewhat better test might be to test one year at a time. For example, the data for 1938-1955 could be used to develop a regression equation containing the same variables used in Equations 22 and 23. Then, an estimate for 1956 could be made and compared with the actual 1956 value. This could be done, however, for only a few recent years in the time series.

the d statistic for Equation 23 is 1.02, indicating that the hypothesis of serial independence in the residuals is rejected. When plotted, the residuals for Equation 23 show a slight cyclical effect, which probably accounts for the significant test result.

Regression Equation 24 is computed for spring farrowings in the United States during the earlier period 1924 to 1937. Variables $\hat{Y}$, $X_1$ and $X_2$ are the same as those defined earlier. Variable $X_5$ is similar to $X_3$:

$$(24)\quad \hat{Y} = -7{,}400.8817 + \underset{(35.4355)}{366.0492X_1} + \underset{(10.3938)}{27.5435X_2} + \underset{(249.1799)}{961.8344X_5}$$

It is the average margin between feeder cattle and slaughter cattle prices at Chicago from August to December, deflated by the Index of Wholesale Prices. Chicago feeder cattle prices are used because the Omaha series does not extend back to 1924. However, the sign of the regression coefficient is positive for $X_5$, the opposite of $X_3$ in Equation 22. Economic logic indicates that as cattle margins increase, making cattle production more favorable, hog production should decrease. Perhaps in the earlier time period cattle margins were viewed more as an indicator of profitability of livestock production in general, rather than in a strictly competitive role with hogs. The extended depression period might have contributed to such psychology on the part of producers. A more likely explanation is that when margins are high, feeder cattle prices also are usually high, discouraging beef cattle production. Again, more study is needed of the supply relationships between beef cattle and hogs.

As shown in Figure 5, regression Equation 24 indicates the correct direction of change in hog farrowings in every year. The standard error of the estimate for Equation 24 is slightly larger than those for the later time period -- 335,000 litters per year or about 4.11 percent of the mean number of farrowings. The Durbin-Watson d statistic is 1.42, again an inconclusive test result.

Table 3. Summary of statistics for regression Equation 24 for United States spring farrowings for the period 1924-1937

| Equation | Value of $R^2$ | Value of d statistic | Ratios of regression coefficients to their standard errors | | |
|---|---|---|---|---|---|
| 24 | 0.92 | 1.42 | 10.33 | 2.65 | 3.86 |

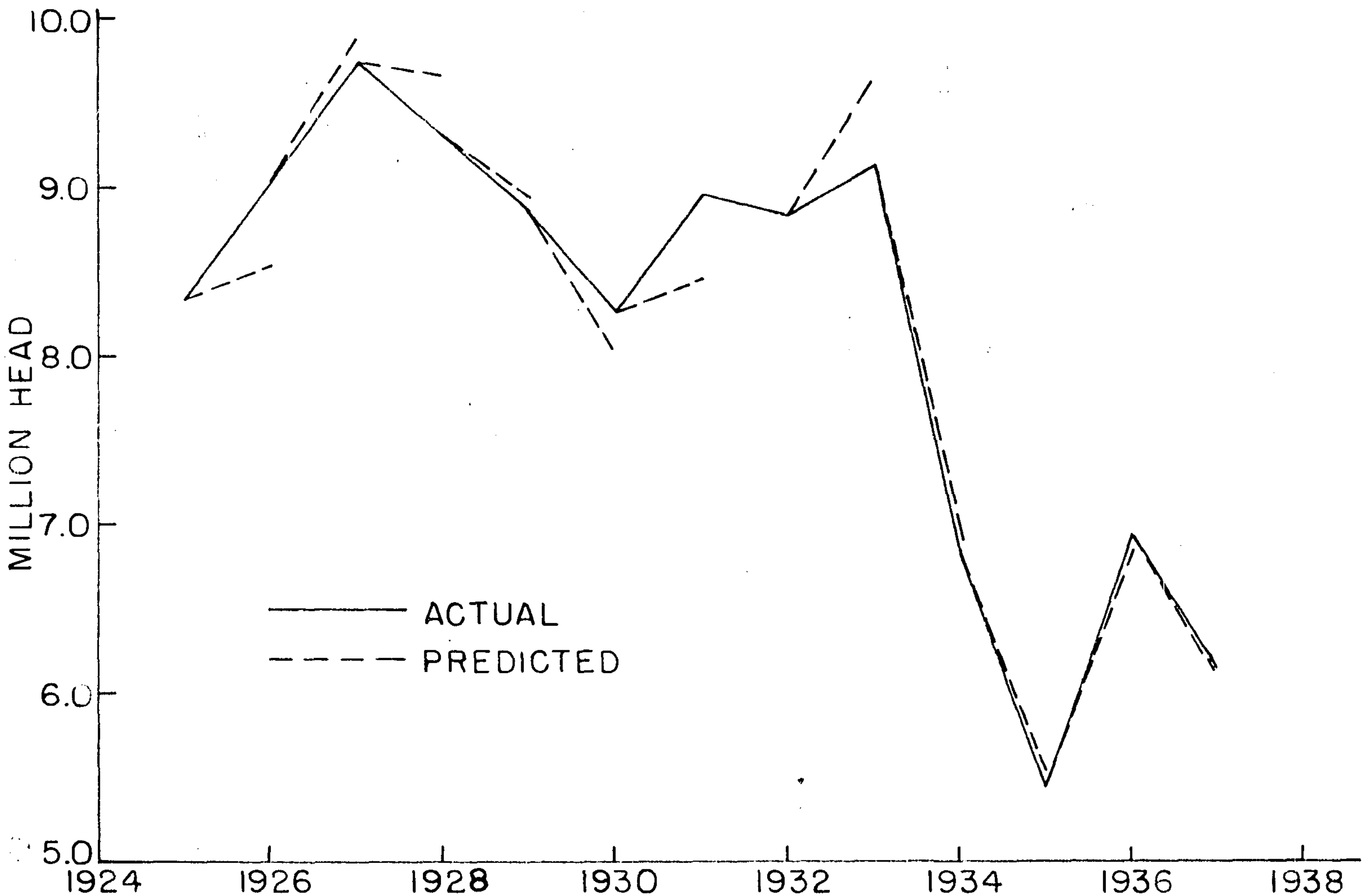


Figure 5. Actual spring farrowings in the United States compared with predictions based on Equation 24

Spring Farrowings in the North Central Region

As mentioned previously, 70 to 80 percent of the spring farrowings in the United States normally occur in the 12-state North Central Region.[1] Because of the importance of the North Central Region in the total hog supply picture, regression Equations 25 and 26 are computed for this region alone, for the two periods 1938 to 1956 (omitting years 1942, 1943 and 1944) and 1924 to 1937, respectively.

$$(25)\quad \hat{Y} = -6,770.0199 + \underset{(33.3043)}{400.3180X_1} + \underset{(8.6083)}{50.1002X_2} + \underset{(194.6409)}{726.0107X_6}$$

$$(26)\quad \hat{Y} = -6,621.4392 + \underset{(35.3437)}{315.6193X_1} + \underset{(10.3669)}{22.4962X_2} + \underset{(247.5443)}{893.6350X_7}$$

The variables are defined as follows:

$\hat{Y}$ = Estimated change from the previous spring (Dec.-May) in number of sows farrowing, North Central Region.

$X_1$ = Chicago hog-corn price ratio as an average of October, November and December in the preceding year.

$X_2$ = As defined previously, page 39.

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[1]The states included in this region are Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska and Kansas.

$X_6$ = Ratio between 500-800 pound good-choice stocker and feeder cattle at Omaha and average Chicago hog prices during October, November and December of the preceding year.

$X_7$ = Margin between feeder cattle and slaughter cattle at Chicago as an average for the months August through December of the preceding year, deflated by the Index of Wholesale Prices.

Table 4. Summary of statistics for regression Equations 25 and 26 for North Central Region spring farrowings for the periods 1938-1956 (omitting years 1942, 1943 and 1944) and 1924-1936, respectively

| Equation | Value of $R^2$ | Value of d statistic | Ratios of regression coefficients to their standard errors | | |
|---|---|---|---|---|---|
| 25 | 0.93 | 2.01 | 12.02 | 5.82 | 3.73 |
| 26 | 0.90 | 1.75 | 8.93 | 2.17 | 3.61 |

In Equation 25 for the later time period, the hog-corn ratio ($X_1$) remains the most important explanatory variable, followed by $X_2$ and $X_6$, respectively. Once again variable $X_3$, the feeder cattle-hog price ratio, has a positive and highly significant regression coefficient.[1] Figure 6 shows

[1]As pointed out previously, the slaughter cattle-hog price ratio is nearly as effective as the feeder cattle-hog price ratio in these equations. If interest is primarily in prediction rather than in estimation of structural relationships, some criterion such as the highest $R^2$ value might be used in selecting between these two variables.

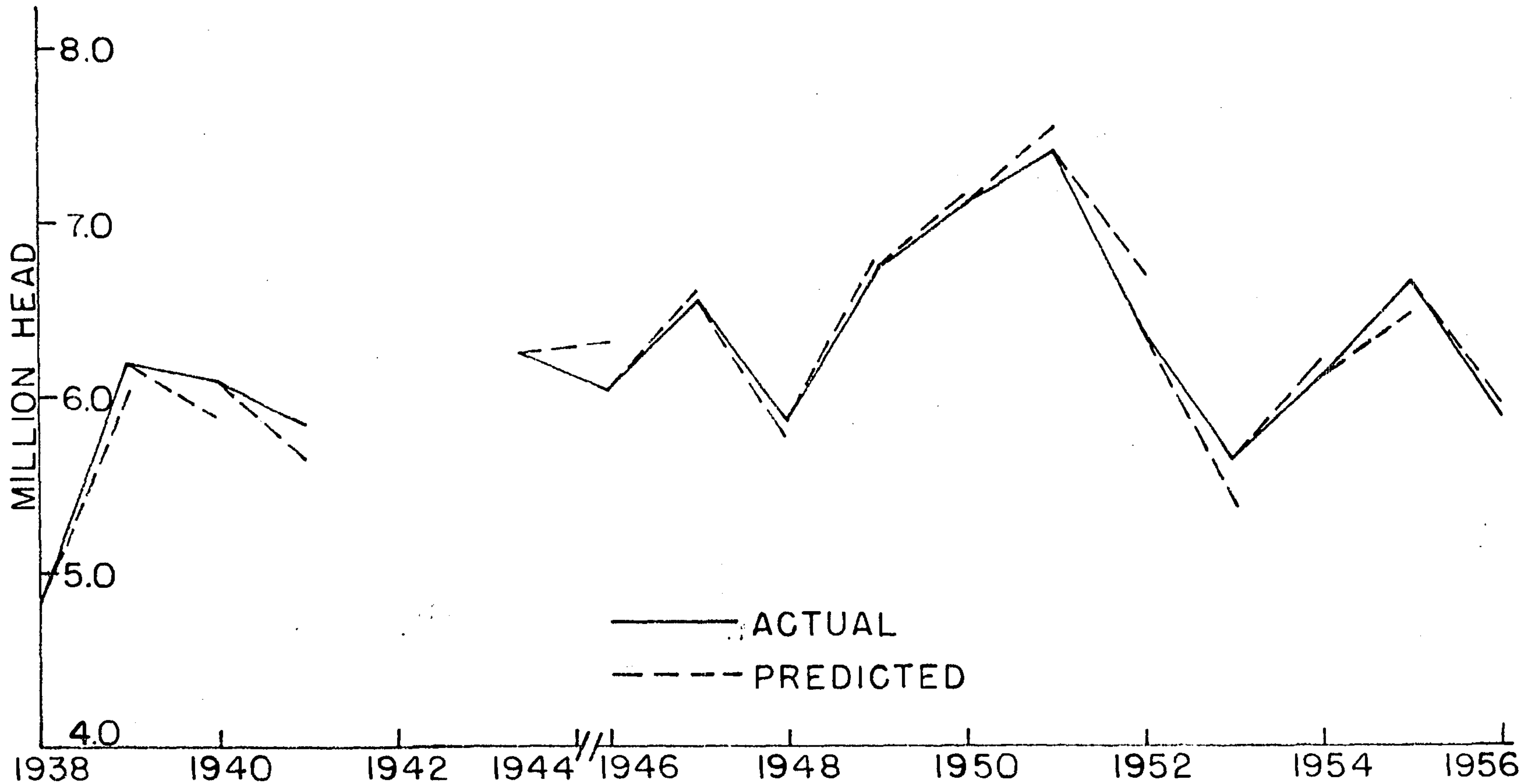


Figure 6. Actual spring farrowings in the North Central Region compared with predictions based on Equation 25

the actual farrowings for the North Central Region compared with those predicted by Equation 25. The direction of yearly changes was predicted correctly for every year except 1946. Regression Equation 22 for United States spring farrowings also failed for this year. The standard error of the estimate for regression Equation 25 is 199,000 litters per year or approximately 3.20 percent of the mean number of spring farrowings in the North Central Region. The calculated value of the Durbin-Watson d statistic is 2.01, indicating support for the assumption of serial independence of the residuals.

The coefficients of Equation 26 for the North Central Region (1924-1937) are similar to those obtained in Equation 24 for the United States. Again, the sign of $X_7$ (deflated cattle margins), while statistically significant, appears inconsistent with economic logic. Figure 7 shows that regression Equation 26 correctly indicates the direction of change in farrowings for every year. The regression equation for 1924-1937 again has a larger standard error of the estimate than the equations for 1938-1956. The standard error of the estimate for Equation 26 is 332,000 litters per year or 5.20 percent of the mean number of spring farrowings in the North Central Region from 1924-1937. The Durbin-Watson d statistic for Equation 26 is 1.75, indicating that the assumption of serial independence in the residuals is not rejected.

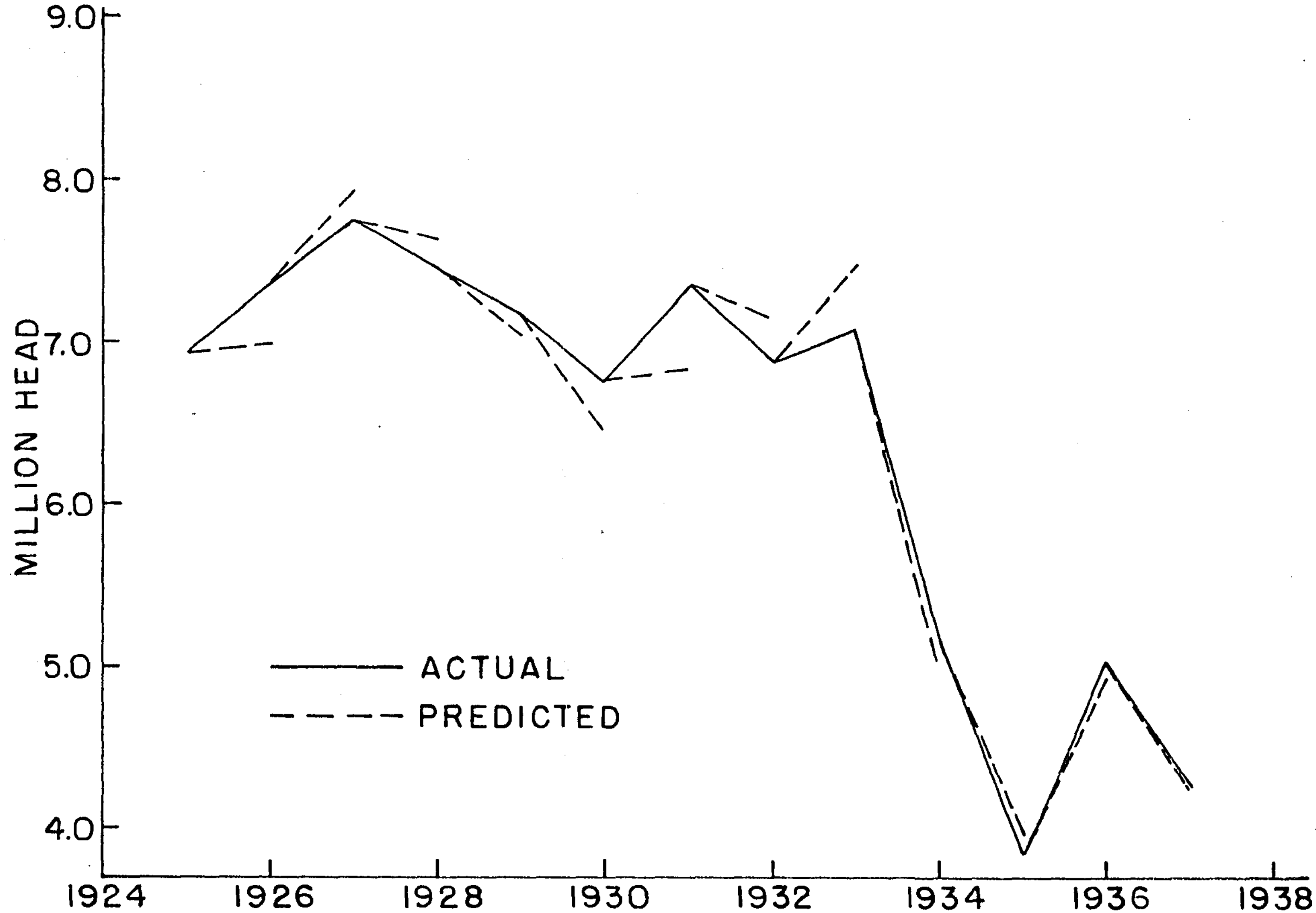


Figure 7. Actual spring farrowings in the North Central Region compared with predictions based on Equation 26

## Fall Farrowings in the United States

The fall farrowing period as defined by the United States Department of Agriculture extends from June 1 to November 30. Regression Equation 27 is computed for fall farrowings in the United States for the period 1937 to 1956 (omitting years 1941, 1942, 1943 and 1944). Regression Equation 28 becomes the prediction equation when variable $X_2$ is dropped from

$$(27)\quad \hat{Y} = 159.9057 + \underset{(0.0917)}{0.2898X_1} + \underset{(1.9933)}{0.7774X_2} + \underset{(1.0986)}{3.9769X_3} + \underset{(2.6162)}{8.1363X_4}$$

$$(28)\quad \hat{Y} = 237.9632 + \underset{(0.0879)}{0.2849X_1} + \underset{(1.0562)}{4.0030X_3} + \underset{(2.3911)}{8.4646X_4}$$

Equation 27. The variables in these equations are:

$\hat{Y}$ = Estimated number of sows farrowing in the fall (June-Nov.), United States.

$X_1$ = Number of sows farrowing in the preceding year (Dec.-May), United States.

$X_2$ = United States hog-corn ratio as an average of March, April, May and June.

$X_3$ = Tons of oats, barley and grain sorghum produced during the year. (An estimate of this quantity is available before the start of the fall farrowing season.)

$X_4$ = Ratio of the price of slaughter steers, all grades, at Chicago to the average price of corn at Chicago during March, April, May and June.

The hog-corn price ratio at breeding time (March, April, May and June) for fall farrowings has a non-significant regression coefficient in Equation 27. Thus, while the hog-corn price ratio at breeding time is the most important variable influencing spring farrowings, the corresponding factor does not significantly influence fall farrowings. More important than the hog-corn price ratio in determining fall farrowings are the number of spring farrowings, anticipated feed grain supplies and the competitive position of hogs with cattle. Many producers lay hog production plans during the

Table 5. Summary of statistics for regression Equations 27 and 28 for United States fall farrowings for the period 1937-1956 (omitting years 1941, 1942, 1943 and 1944) and for regression Equation 29 for United States fall farrowings for the period 1924-1936

| Equation | Value of $R^2$ | Value of d statistic | Ratios of regression coefficients to their standard errors | | | |
|---|---|---|---|---|---|---|
| 27 | 0.92 | -- | 3.16 | 0.39 | 3.62 | 3.11 |
| 28 | 0.92 | 1.70 | 3.24 | 3.79 | 3.54 | |
| 29 | 0.75 | 2.45 | 3.58 | 2.17 | 2.80 | |

fall months for the entire year ahead. That is, a certain number of sows are planned to farrow in the spring, then the same sows are carried over and farrow again in the fall. Since many farmers follow this two-litter system, the number of fall farrowings apparently is influenced more by the corn-hog ratio in the previous fall than by this ratio at breeding time for fall pigs (March, April, May and June). In this situation, the decision to farrow sows for the fall period is a "routine" or "automatic" decision not appreciably influenced by prices at breeding time.

In Equation 28 the relative profit position of beef cattle and hogs is expressed through a slaughter cattle-corn price ratio. According to Equation 28, relatively high cattle prices at breeding time for fall pigs are associated with a greater number of fall farrowings. Again, either a slaughter cattle-corn price ratio or a feeder cattle-corn price ratio is effective in raising the $R^2$ value in the regression equation for fall farrowings. Perhaps farmers are mainly influenced by feeder cattle prices. If so, a feeder cattle-corn ratio variable might be defended as follows: High prospective feeder cattle prices require a greater outlay and increase the risk associated with the beef cattle enterprise. Resources, then, are shifted into increased hog production. Conversely, when feeder cattle prices are relatively low, risk in cattle feeding is lessened and resources are diverted from hogs to cattle production.

Figure 8 compares the actual fall farrowings in the United States with the predicted farrowings from Equation 28. With the exception of 1951, the prediction is in the correct direction in every year. For Equation 28 the standard error of the estimate is 177,000 litters or 3.48 percent of the mean number of fall farrowings in the 1937 to 1956 period. The calculated d statistic for Equation 28 is 1.70. Once again the hypothesis of serial independence of the residuals is not rejected.

Regression Equation 29 is computed for fall farrowings in the United States, based on data for the period 1924 to 1936. Variables $\hat{Y}$, $X_1$ and $X_4$ are defined as above for Equations 27 and 28. Variable $X_5$ expresses the influence of feed grain supplies and is measured as the change in corn production from

$$(29)\quad \hat{Y} = 369.1266 + \underset{(0.0797)}{0.2852X_1} + \underset{(0.6372)}{1.3828X_5} + \underset{(4.1260)}{11.5529X_4}$$

the preceding to the current year. Again, the hog-corn ratio at breeding time for fall farrowings ($X_2$) has a non-significant regression coefficient and therefore is excluded from Equation 29. As shown by $R^2$ value of 0.75 in Table 5, the explanation of variance in the dependent variable (fall farrowings) by the chosen independent variables is less satisfactory than in Equations 27 and 28 for the later 1937 to 1956 period. Part of the explanation for this difficulty appears to be the uncertainty of, and wide

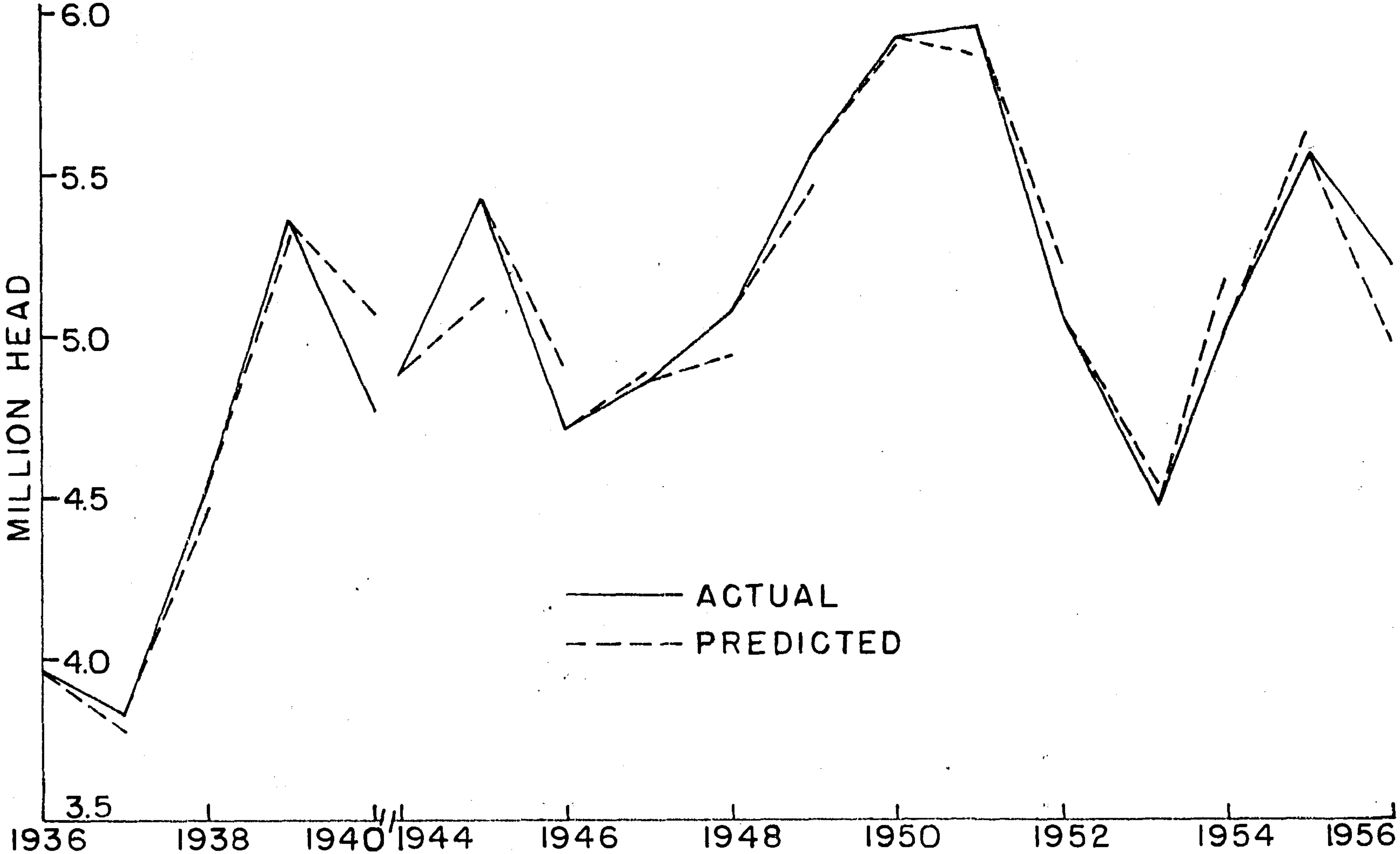


Figure 8. Actual fall farrowings in the United States compared with predictions based on Equation 28

fluctuations in, feed grain supplies during the later years of the 1924 to 1936 period. For example, in Figure 9 large errors in prediction occur in 1933, 1934 and 1936 -- all years in which feed grain supplies shifted drastically from the level of the previous year. Also, regression Equation 29 predicted the wrong direction in fall farrowings for the three years 1929, 1933 and 1936. The standard error of the estimate -- 346,000 litters or 8.04 percent of the mean -- is larger than in previous equations. The Durbin-Watson d statistic for Equation 29 is 2.45, which indicates an inconclusive test result. If Equation 29 were relevant for forecasting purposes it would be desirable to refine it further. However, the purpose of studying the earlier time period (1924 to 1936) is more nearly one of estimating regression and elasticity coefficients for the important variables. Comparisons of supply elasticities computed from the regression equations are presented in a later section.

## Fall Farrowings in the North Central Region

The 12-state North Central Region produces a somewhat smaller percentage of the total United States fall pig crop than spring pig crop; the percentage historically has been between 60 and 70 percent. However, from 1950 to 1956 the percentage of total fall farrowings produced in the North Central Region has increased to between 70 and 75 percent.

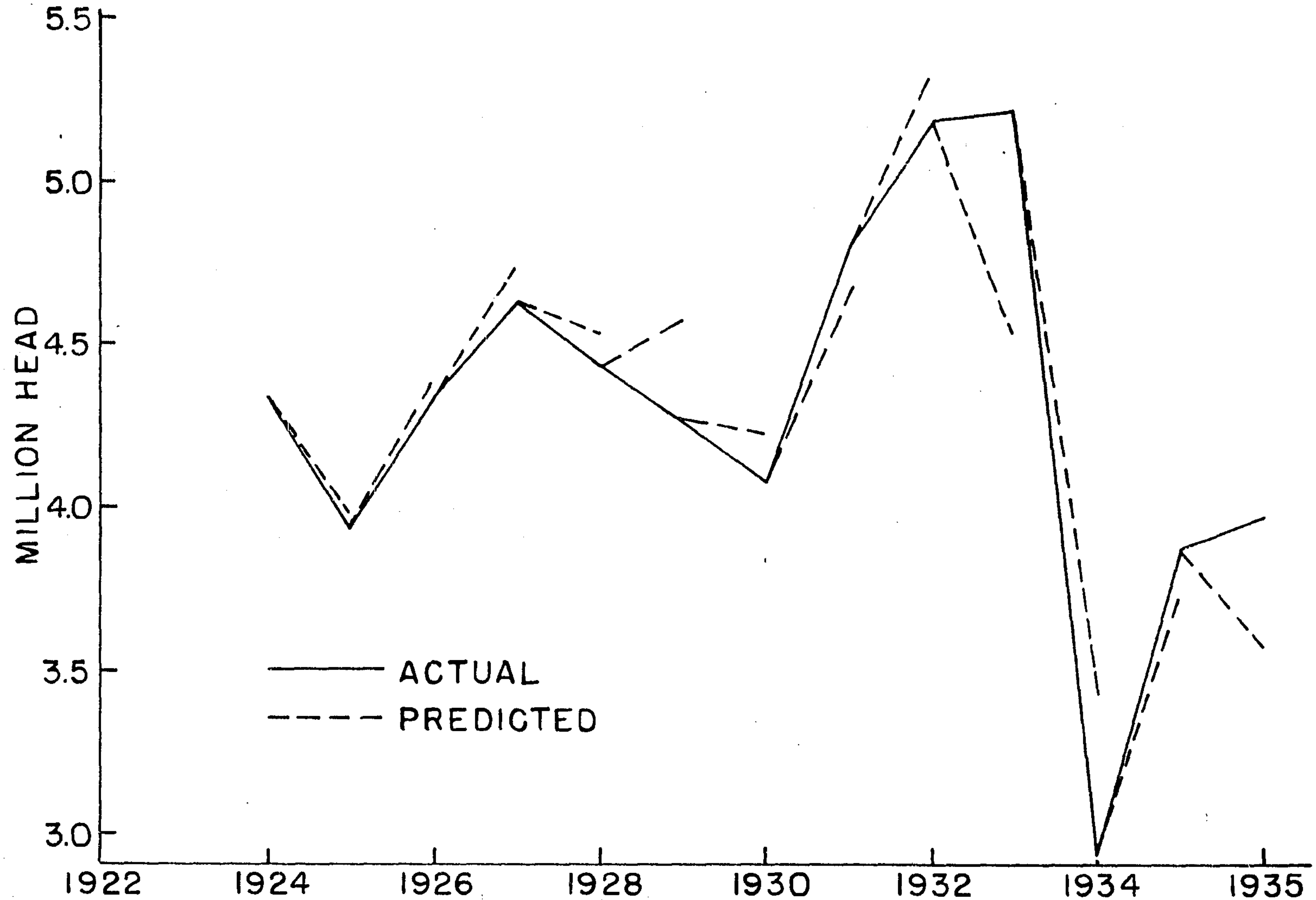


Figure 9. Actual fall farrowings in the United States compared with predictions based on Equation 29

Regression Equations 30 and 31 are computed for the 1937 to 1956 (omitting 1941, 1942, 1943 and 1944) and the

$$(30) \quad \hat{Y} = -941.8909 + \underset{(0.1270)}{0.2287X_5} + \underset{(1.3928)}{5.4596X_3} + \underset{(2.7880)}{8.1966X_4}$$

$$(31) \quad \hat{Y} = -390.1097 + \underset{(0.0480)}{0.3214X_5} + \underset{(0.2464)}{0.8352X_6} + \underset{(4.0312)}{8.5059X_4}$$

1924 to 1936 periods, respectively. The variables are defined as follows:

$\hat{Y}$ = Estimated number of sows farrowing in the fall (June-Nov.), North Central Region.

$X_5$ = Number of sows farrowing in the preceding spring (Dec.-May), North Central Region.

$X_3$ = Tons of oats, barley and grain sorghum produced during the year.

$X_6$ = Change in corn production from the preceding to the current year.

$X_4$ = Ratio of the price of slaughter steers, all grades, at Chicago to the average price of corn at Chicago during March, April, May and June.

The logic of the variables has been explained previously and will not be repeated. Figures 10 and 11 show that the predictions for the 1937 to 1956 period are more accurate, both in direction and in magnitude, than those for the 1924 to 1936 period. Regression Equation 30 predicts the direction of change correctly in every year except for 1940 (Figure 10), while Equation 31 predicts the incorrect direction of change four times in the earlier 13-year period (Figure 11). Again, Equation 31 is not further refined

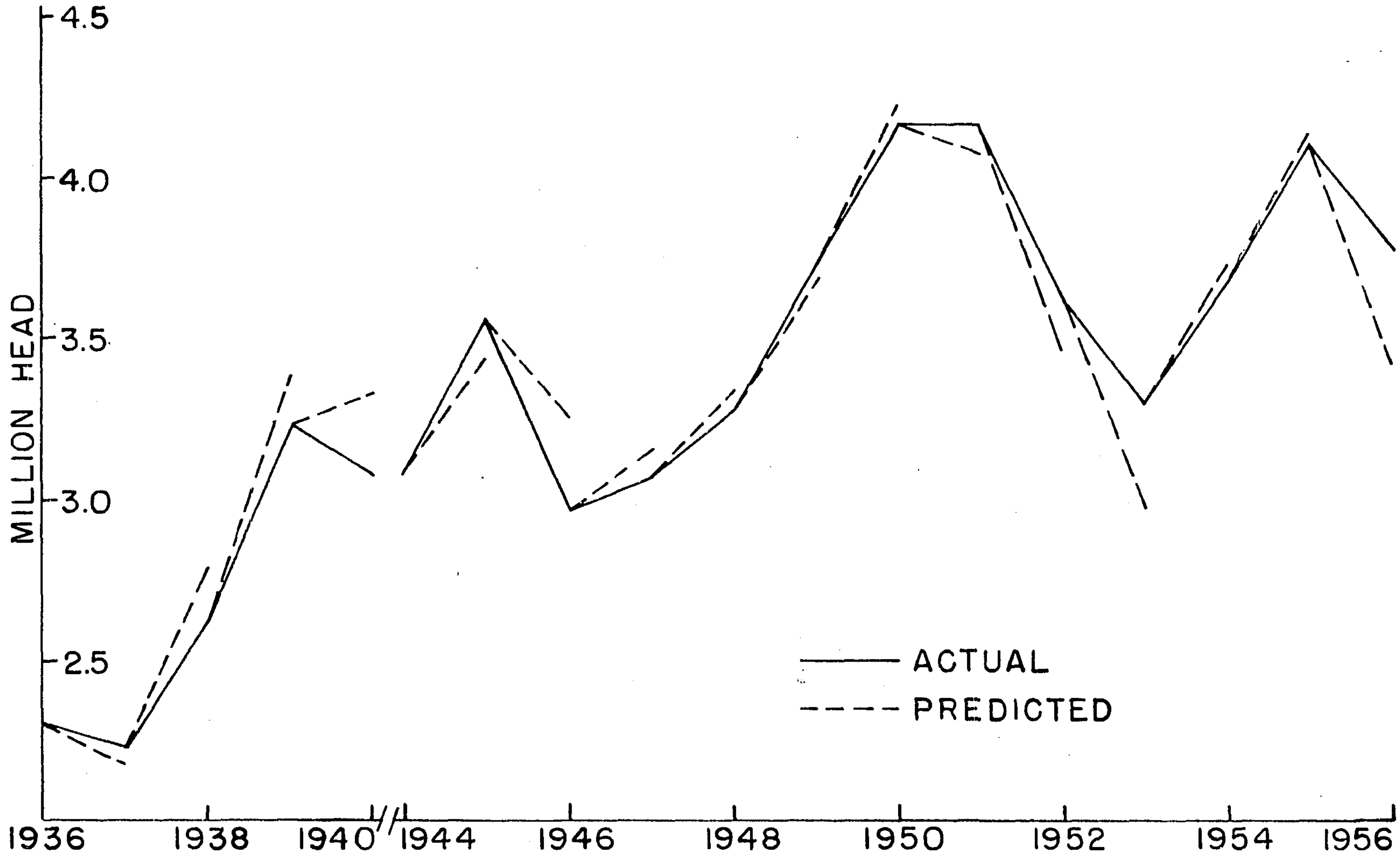


Figure 10. Actual fall farrowings in the North Central Region compared with predictions based on Equation 30

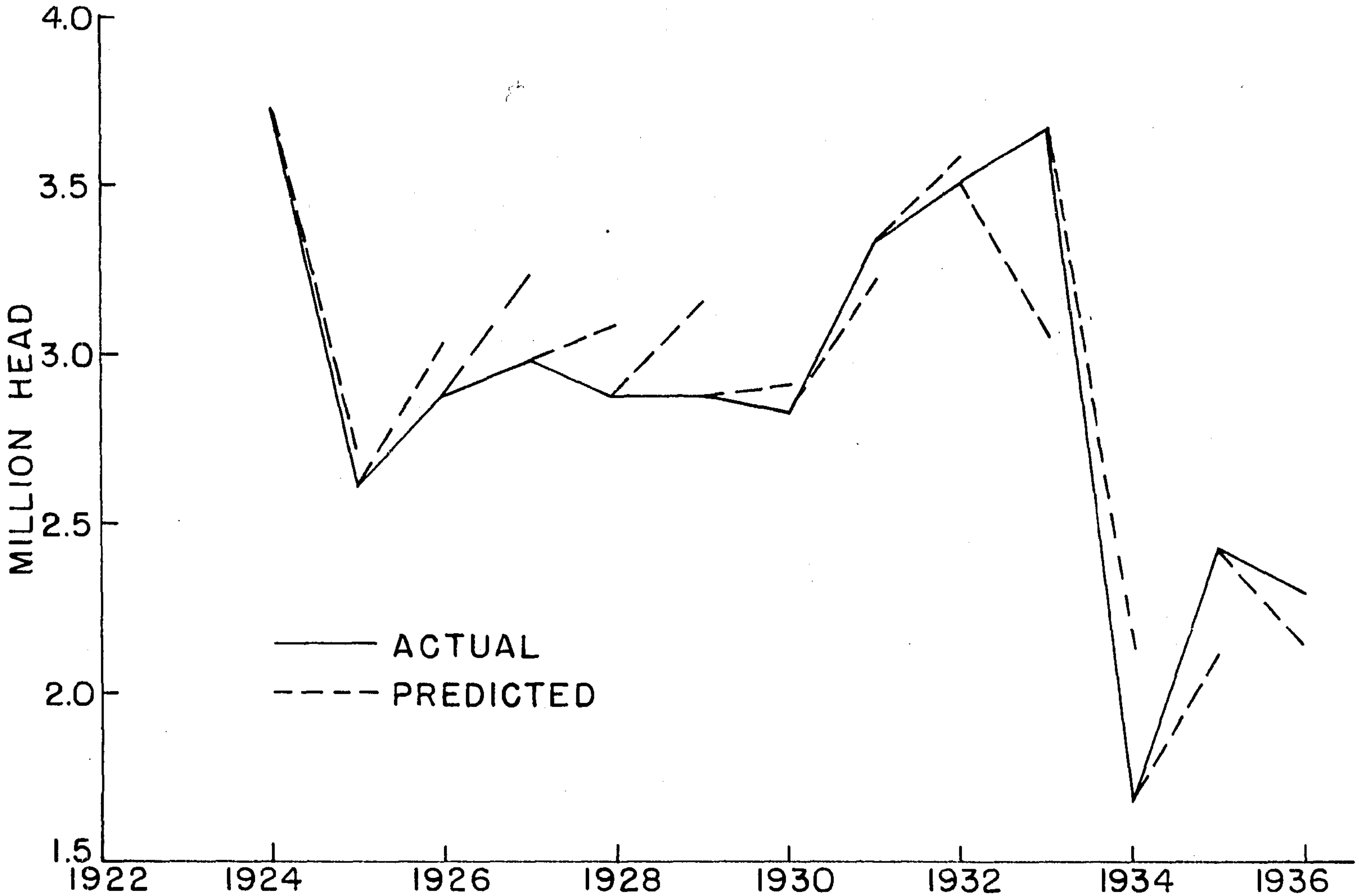


Figure 11. Actual fall farrowings in the North Central Region compared with predictions based on Equation 31

because interest in the earlier time period centers on measuring the influence of the major independent variables rather than on forecasting. The comparative precision of Equations 30 and 31 is revealed by their standard errors of estimate.

Table 6. Summary of statistics for regression Equations 30 and 31 for North Central Region fall farrowings for the periods 1937-1956 (omitting years 1941, 1942, 1943 and 1944) and 1924-1936, respectively

| Equation | Value of $R^2$ | Value of d statistic | Ratios of regression coefficients to their standard errors | | |
|---|---|---|---|---|---|
| 30 | 0.89 | 1.27 | 1.89 | 3.92 | 2.94 |
| 31 | 0.71 | 2.50 | 6.69 | 3.39 | 2.11 |

For Equation 30 the standard error of the estimate is 204,600 litters or 7.0 percent of the mean number of fall farrowings in the North Central States. For Equation 31, however, the standard error of the estimate is 380,600 litters or 13.1 percent of the mean number of farrowings. The calculated d statistic for Equation 30 is 1.27, which falls in the rejection region. That is, the hypothesis of serial independence in the residuals is rejected. For Equation 31 the d value is 2.50, which is an inconclusive result.

## Elasticities of Supply from Farrowing Equations

Elasticity of supply is defined as the percentage change in quantity associated with a one percent change in price. Equation 32 gives the various mathematical formulas often

$$(32)\quad E_s = \frac{\text{Percentage change in quantity}}{\text{Percentage change in price}} =$$

$$\frac{\Delta Q}{\Delta P} \times \frac{\partial P}{\partial Q} \doteq \frac{\partial Q}{\partial P} \times \frac{P}{Q} .$$

used in computing the elasticity of supply ($E_s$). In this study the last formula ($\partial Q/\partial P \times P/Q$) is used in computing elasticities. All elasticities will be evaluated at the means of the variables.

For the spring period, the elasticities measure the percentage change in number of farrowings associated with a one percent change in average hog price in October, November and December of the previous fall, i.e., at breeding time. However, elasticities for fall farrowings are not computed with respect to hog prices at breeding time for fall pigs (March, April, May and June). Because the regression coefficients for hog prices (expressed as a hog-corn ratio) are non-significant in the fall farrowing equations, supply elasticities based on these coefficients would be rather meaningless. Hence, as in the case of spring farrowings, elasticities for fall farrowings are computed with respect to average hog prices in October, November and December of the previous year. The computational procedure for this step is outlined later.

Table 7 presents the elasticities of supply for the various combinations of geographical areas, time periods and farrowing seasons analyzed in regression Equations 22 to 31. An example of computing the supply elasticity for spring farrowings is given below for regression Equation 22. Variable $\hat{Y}$ is the estimated year-to-year change in spring farrowings; i.e., $\hat{Y} = (\hat{Y}_t - Y_{t-1})$. Variable $X_1$ is the hog-corn ratio in the previous fall: i.e., $X_1$ = price hogs/price corn $= P_h/P_c$. Thus, Equation 22 may be rewritten as Equation 33. The partial derivative of quantity with respect to hog price $(\partial \hat{Y}_t / \partial P_h)$ is given in Equation 34.

$$(22) \quad \hat{Y} = -5{,}969.6423 + 392.3640X_1 + 59.8738X_2 - 104.5646X_3$$

$$(33) \quad \hat{Y}_t - Y_{t-1} = -5{,}969.6423 + 392.3640 \frac{P_h}{P_c} + 59.8738X_2 - 104.5646X_4$$

$$(34) \quad \frac{\partial \hat{Y}_t}{\partial P_h} = \frac{392.3640}{P_c}$$

$$(35) \quad E_s = \frac{\partial \hat{Y}_t}{\partial P_h} \times \frac{P_h}{Y_t} = \frac{392.3640}{P_c} \times \frac{P_h}{Y_t} = \frac{392.3640}{1.16} \times \frac{15.48}{8{,}173} = 0.64$$

Table 7. Elasticities of supply computed from Equations 21 to 31[a]

| Equation | Area | Time period | Farrowing period | Elasticity of supply at the mean |
|---|---|---|---|---|
| 22 | United States | 1938-1956[b] | Spring | 0.64 |
| 23 | United States | 1938-1956[b] | Spring | 0.60 |
| 24 | United States | 1925-1937 | Spring | 0.50 |
| 25 | North Central Region | 1938-1956[b] | Spring | 0.74 |
| 26 | North Central Region | 1925-1937 | Spring | 0.58 |
| 28 | United States | 1937-1956[c] | Fall | 0.29 |
| 29 | United States | 1924-1936 | Fall | 0.28 |
| 30 | North Central Region | 1937-1956[c] | Fall | 0.35 |
| 31 | North Central Region | 1924-1936 | Fall | 0.41 |

[a]Elasticity of supply measured as percentage change in number of sows farrowing per one percent change in the average price of hogs in the previous October, November and December period.

[b]Omitting years 1942, 1943 and 1944.

[c]Omitting years 1941, 1942, 1943 and 1944.

The definition of elasticity of supply ($E_s$) and the computation of the elasticity at the means of all variables are presented in Equation 35. Thus, at the mean, a 0.64 percent change in the number of spring farrowings is associated with a one percent change in the same direction of the average price of hogs in October, November and December of the previous fall. Several equations (for example, Equation 23) include both a hog-corn price ratio and a cattle-hog price ratio. For these equations, the partial derivative of farrowings with respect to hog price contains two terms. Otherwise, the elasticities of supply are computed in the manner illustrated above.

Elasticities of supply for fall farrowings are computed by a somewhat different procedure. As mentioned above, these elasticities are computed with respect to hog prices during the previous fall rather than at breeding time for fall pigs. However, the average hog price (or hog-corn ratio) in October, November and December is not included directly in the regression equations predicting farrowings for the next fall. Thus, two regression equations are combined to obtain elasticities for fall farrowings. To illustrate, the supply elasticity for Equation 28 is computed below. In Equation 28, the number of spring farrowings ($X_1$) is used as an independent variable in predicting fall farrowings ($\hat{Y}$). However, the number of spring farrowings is estimated, in turn, as $\hat{Y}_t$ in Equation 22. Substituting the estimate of spring farrowings ($\hat{Y}_t$) from Equation 22 for the actual number of spring farrowings ($X_1$) in Equation 28 gives Equation 36. By this substitution, fall farrowings are

$$(28) \quad \hat{Y} = 237.9632 + 0.2849X_1 + 4.0030X_3 + 8.4646X_4$$

$$(22) \quad \hat{Y}_t = -5{,}969.6423 + 392.3640 \frac{P_h}{P_c} + 59.8738X_2 - 104.5646X_3 + Y_{t-1}$$

$$(36) \quad \hat{Y} = 237.9632 + 0.2849 \left(-5{,}969.6423 + 392.3640 \frac{P_h}{P_c} + 59.8738X_2 - 104.5646X_3 + Y_{t-1}\right) + 4.0030X_3 + 8.4646X_4$$

$$(37) \quad \frac{\partial \hat{Y}}{\partial P_h} = \frac{0.2849(392.3640)}{P_c} = \frac{111.7850}{P_c}$$

$$(38) \quad E_s = \frac{\partial \hat{Y}}{\partial P_h} \times \frac{P_h}{Y} = \frac{111.7850}{P_c} \times \frac{P_h}{Y} = \frac{111.7850}{1.16} \; \frac{15.48}{5{,}085} = 0.29$$

expressed as a function of average hog prices (*i.e.*, through the hog-corn ratio) in the preceding October, November and December. (The variables in Equations 22 and 28 are defined as presented earlier; thus, variable $X_3$ in Equation 28 differs from $X_3$ in Equation 22). The partial derivative of fall farrowings ($\hat{Y}$( with respect to the average price of hogs in the previous fall ($P_h$) is given in Equation 37. Equation 38 indicates the computation of the supply elasticity at the means of the variables.

Table 7 summarizes the estimates of supply elasticities for the United States and North Central Region. For spring farrowings in both the United States and North Central Region the point estimates reveal higher elasticities of supply in the 1938 to 1956 period than in the 1924 to 1937 period. However, the elasticities computed for fall farrowings are inconsistent in this respect; for the United States the elasticity for fall farrowings is slightly higher in the 1938 to 1956 period while for the North Central Region the elasticity is slightly higher in the 1924 to 1937 period.

An important consideration, of course, is whether the elasticities between time periods are actually different or whether the observed differences might easily have occurred by chance. Fairly complicated statistical procedures are available for placing confidence limits on elasticity estimates. However, for the purposes here, a comparatively simple procedure appears sufficient to provide a rough approximation to the standard error of the elasticity figures. Upper and lower limits are computed for each elasticity, taking into account the standard errors of the regression coefficients on which the elasticities are based. Elasticities based on plus or minus one standard error of the regression coefficients are computed for the spring farrowing months. For the United States, the upper and lower limits are 0.70 and 0.58 for Equation 22, 0.69 and 0.51 for Equation 23 and 0.45 and 0.55 for Equation 24. The intervals for Equations 22 and 24 do not overlap, providing some evidence for the hypothesis of an increase in supply elasticity over time. However, the elasticity intervals for Equations 23 and 24 slightly overlap, due to the relatively wide interval for Equation 23. The elasticity computed from Equation 23 is subject to greater variation because it is derived from two regression coefficients, each of which is estimated with some error. Similar evidence exists for the hypothesis of an increase in supply elasticity for spring farrowings over time in the North Central Region. The upper and lower elasticity limits for Equation 25 are 0.83 and 0.65, while the limits for Equation 26 are 0.64 and 0.51. As mentioned above, more sophisticated statistical tests for comparing elasticities could be used. However, the above procedure provides a useful idea of the relative magnitudes of the elasticities and the errors with which they are estimated. The differences in point estimates over time are sufficiently large and consistent between areas to provide somewhat greater confidence in the results than might be indicated by statistical significance tests alone.

Several reasons for hypothesizing an increase in supply elasticity for hogs were mentioned earlier. Technological changes appear especially important in explaining this shift in "price responsiveness" on the part of farmers. Many producers now have the specialized facilities and technical knowledge required for successfully farrowing large litters in the winter months. For example, automatic heating and watering facilities, farrowing stalls and other specialized equipment now are quite common on midwest farms, while technical information directed toward producers undoubtedly results in more efficient swine management. Therefore, when hog prices in the fall months are favorable, producers possess the physical and managerial resources to easily increase winter farrowings (i.e., during the spring farrowing period, December to May). However, an increased supply elasticity also implies that as hog prices fall, producers restrict hog production relatively more than formerly. Ordinarily, a restriction in hog production is expected to be accompanied by a shift of resources to other enterprises. Perhaps the recent favorable capital position of farmers has contributed toward a willingness to shift, when hog prices are relatively low, from hog production into higher risk enterprises such as cattle feeding. The importance of technology also is indicated in comparing elasticities for the United States with those for the North Central Region. Greater technological change in hog production undoubtedly has occurred in the North Central Region compared with the United States as a whole. As expected, the point estimates of supply elasticities are higher for the North Central Region in both time periods studied (Table 7).

For fall farrowings, the statistical procedure for estimating elasticity intervals reveals no difference between time periods in the supply elasticities for either the

United States or the North Central Region. Also, the elasticities for fall farrowings are considerably lower than those for spring farrowings. Elasticities for fall farrowings probably are relatively low partly because of the time lag between the price and output variables; conditions often change markedly in the interim. As before, the elasticities of supply are higher for the North Central Region than for the United States as a whole.

## Elasticities of Supply from a Model Using Expected Prices

In the preceding analysis it is assumed that hog producers in planning spring farrowings for year t, react to prices prevailing in year t-1; i.e., at breeding time. However, an alternative hypothesis is that hog producers react, not to the price at breeding time, but rather to the price they expect when the hogs are to be sold. Nerlove (32) points out that expected prices may depend only to a limited extent on last year's price. He proposes a simple model representing expected price as a weighted moving average of past prices, where the annual weights decline going backward in time. The procedure of representing expected price by price lagged one year, then, is a special case of this general hypothesis in which the weight attached to last year's price is one and the weight attached to all other past prices is zero.

Nerlove assumes the following simple model:

$$(39)\quad Y_t = a_o + a_1 P_t^* + u_t .$$

Variable $Y_t$ is output in year t, $P_t^*$ is the expected price for year t and $u_t$ is a random residual. One possible hypothesis is that farmers revise their expected price in proportion to the error they made in predicting last year's price. This hypothesis, advanced by Nerlove (32), is stated mathematically in Equation 40. The B term is called the coefficient of expectation. Equation 40 is solved for $P_t^*$ to give Equation 41. Equation 39 is solved for $P_{t-1}^*$ (for year t-1) to give Equation 42. Substituting $P_{t-1}^*$ from Equation 42 into Equation 41, and the resulting expression for $P_t^*$ into Equation 39 gives Equation 43. Equation 43

$$(40)\quad P_t^* - P_{t-1}^* = B\ (P_{t-1} - P_{t-1}^*)$$

$$(41)\quad P_t^* = B\ P_{t-1} + (1 - B)\ P_{t-1}^*$$

$$(42)\quad P_{t-1}^* = \frac{Y_{t-1} - a_o - u_{t-1}}{a_1}$$

$$(43)\quad Y_t = (a_o\ B) + (a_1\ B)\ P_{t-1} + (1 - B)\ Y_{t-1} + V_t$$

expresses output as a function of last year's price and quantity while $v_t$ is a new residual term. The coefficients of Equation 43 are estimated by least squares, and from these are derived the estimates of $a_o$ and $a_1$ in Equation 39 and the coefficient of expectation, B.

A similar, although somewhat more complex model, is formulated in this study in deriving elasticities of spring farrowings using expected prices. In addition to the expected price of the single commodity (hogs), it is desirable to include the expected prices of the main inputs and alternative products. Thus, prices for corn ($P_c$) and beef cattle ($P_b$), expressed as ratios, now enter the model rather than hog prices alone. The type of model used is illustrated in Equation 44. The expectational model for each price ratio is the same as that shown in Equation 40 for a single price;

$$(44) \quad Y_t = a_o + a_1 \left(\frac{P_h}{P_c}\right)^*_t + a_2 \left(\frac{P_b}{P_h}\right)^*_t + u_t$$

producers are assumed to revise their expected price ratios in proportion to the error they made in predicting last year's ratios. Of course, other expectational patterns might be hypothesized. To keep the computations manageable, the same coefficient of expectation (B) is assumed for both the hog-corn price ratio and the beef cattle-hog price ratio. Starting with Equation 44, an algebraic transformation similar to that illustrated above for one price results in Equation 45, whose coefficients are fitted by least squares. Again, from the estimates of these coefficients, the estimates of $a_o$, $a_1$ and $a_2$ in Equation 44 are computed.

$$(45) \quad Y_t = a_o B + a_1 B \left(\frac{P_h}{P_c}\right)_{t-1} + a_2 B \left(\frac{P_b}{P_h}\right)_{t-1} + (1 - B) Y_{t-1} + v_t$$

The empirical estimates derived from this model are summarized in Table 8. Since previous estimates for spring farrowings (see Table 7) are computed using first differences of the dependent variable, the same procedure is used here.

Table 8. Estimates of supply elasticities and coefficients of expectation for spring farrowings, using the expected price model.

| Area | Time period | Elasticity of supply at the mean | Coefficient of expectation (B)[a] | Unadjusted $R^2$ |
|---|---|---|---|---|
| United States | 1938-1956[b] | 0.65 | 0.78 (0.18) | 0.76 |
| United States | 1924-1937 | 0.46 | 1.19 (0.09) | 0.91 |
| North Central Region | 1938-1956[b] | 0.73 | 0.81 (0.25) | 0.79 |
| North Central Region | 1924-1937 | 0.53 | 1.11 (0.11) | 0.87 |

[a]The figures in parentheses below the estimates are the standard errors of the estimates.

[b]Omitting years 1942, 1943 and 1944.

Also, as in the earlier analysis, beef cattle price margins rather than beef cattle-hog price ratios are used for the 1924 to 1937 period. The elasticities of supply in Table 8 are computed as the response in spring farrowings to the average hog price expected to prevail in October, November and December of the next year; i.e., at the time when the spring pig crop is marketed. It is interesting to note that the elasticities so obtained are very similar in magnitude to those based on lagged price (compare Tables 7 and 8). From this comparison, it appears that the assumption that farmers closely identify expected price with last year's price is quite reasonable, at least for hogs.[1] These results, then, lend support to the proposition that prices and quantities in hog production are generated by a cobweb mechanism. Specifically, support is provided for the crucial

[1]As additional evidence of the close relationship between price lagged one year and expected price, none of the coefficients of expectation (B) in Table 8 differ significantly from unity when tested at the 5 percent level. However, the B value for the United States from 1924-1937 is significantly different from 1.0 at the 10 percent level. For the price expectation model indicated by Equation 40, a B value of 1.0 implies that the expected price in year t is identical with the observed price in year t-1 (i.e., $P_t^* = P_{t-1}$). Nerlove (32) hypothesizes that the value of B is ordinarily less than one, based on the argument that farmers are noted for the strength of their convictions and thus will revise their future price expectations by only some fraction of the error made.

condition emphasized by Ezekiel (13) that, for the cobweb theory to be applicable, producers must base future output entirely on current prices.

## TWO-EQUATION DEMAND AND SUPPLY MODELS FOR HOGS

As mentioned previously, the total liveweight of hogs slaughtered in the United States is a direct function of the number of hogs slaughtered and their average slaughter weight. Numbers of hogs marketed are determined primarily by the number of sows farrowing in previous periods and secondarily by a technological factor, number of pigs saved per litter. The latter factor (pigs saved per litter) has shown a definite upward trend over time and hence can be predicted with reasonable accuracy from year to year. Minor fluctuations about the long-time trend in the number of pigs saved per litter appear to be related entirely to exogenous factors such as weather and disease. The preceding analysis of spring and fall farrowings, then, is important from the standpoint of forecasting; major changes in future hog marketings can be predicted from changes in the number of sows farrowing. Also, within the entire hog supply process, the most important changes in price responsiveness over time are expected in the period during which farrowing decisions are made.

The second major element determining total hog supplies is average marketing weight. To accurately forecast the total liveweight of hogs supplied, some notion is required of the responsiveness of marketing weights to price and other factors. Average marketing weights are jointly determined with influences prevailing within the slaughter period, such as prices for hogs, other livestock and feed. However, to aid in forecasting, an attempt was made to estimate hog marketing weights from predetermined variables alone. A preliminary regression analysis indicated that hog marketing weights were inversely related to the number of pigs saved in the preceding period and directly related to quantities of corn and other grains available for feeding. While logical, these relationships were not sufficiently stable to serve usefully in prediction.

Because hog prices and marketing weights are to some extent jointly determined, simultaneous equations appear to be an appropriate technique for investigating their interrelationship. While this type of analysis may be of limited value in prediction, it should provide estimates of the within-marketing-period elasticities of supply. As is explained below, an estimate of the quantity of hogs to be marketed based on predetermined variables alone is included in the model. This procedure is an attempt to isolate the extent to which farmers respond to price by varying marketing weights alone.

The following simple two-equation model is used in the analysis of marketing weights:[1]

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[1]This model was used by Fox (19, p. 31-32) for annual data on pork demand and supply.

(46) Demand: $p = b_1q + b_2y$

(47) Supply: $q = b_3p + b_4z$

The variables are briefly defined as:

p = Average price of hogs received by farmers in the United States divided by the Index of Prices Received by Farmers for Livestock and Livestock Products (in logs).

q = Total liveweight of hogs slaughtered under Federal inspection in the United States (in logs).[1]

y = Per capita disposable personal income divided by the Index of Consumer Prices (in logs).

z = Estimate of q based on predetermined variables (in logs).

Since the variables are in logarithmic form, coefficient $b_1$ in the demand equation is the reciprocal of the price elasticity of demand and $b_3$ in the supply equation is the elasticity of supply. Of course, $b_3$ is a different type of elasticity than the supply elasticities computed earlier for hog farrowings. Previous elasticity estimates indicated the relationship between the number of sows farrowing and hog prices prevailing at or before breeding time several months

[1]Total hog slaughter was not used since this series is not available on a monthly basis for the entire time period studied. However, little error is expected in using Federal inspected slaughter since the multiple correlation coefficient ($r^2$) between changes in total slaughter and changes in Federal inspected slaughter is 0.99 for 1924 through 1937 and 0.90 for 1938 through 1956.

prior. Supply elasticity estimates in the present analysis relate liveweight hog slaughter to hog prices prevailing at the time of slaughter.

The simple two-equation model presented above is just-identified and may be solved by the method of reduced forms outlined below. Substitute the right-hand side of Equation 47 for q in Equation 46. Equation 46 may then be solved for p in terms of the predetermined variables y and z to obtain Equation 48. Similarly, the right-hand side of Equation 46 may be substituted for p in Equation 47. Solving Equation 47

$$(48) \qquad p = \frac{b_2}{1 - b_1 b_3} y + \frac{b_1 b_4}{1 - b_1 b_3} z$$

$$(49) \qquad q = \frac{b_2 b_3}{1 - b_1 b_3} y + \frac{b_4}{1 - b_1 b_3} z$$

for q then gives Equation 49, which expresses q as a function of the same predetermined variables y and z. Fitting Equations 48 and 49 by least-squares regression results in unbiased estimates of their coefficients, which are themselves combinations of the structural coefficients $b_1$, $b_2$, $b_3$ and $b_4$. Coefficient $b_3$ is estimated as the ratio of the coefficient of y in Equation 49 to the coefficient of y in Equation 48. Coefficient $b_1$ is estimated as the ratio of the coefficient of z in Equation 48 to the coefficient of z in Equation 49. Given estimates of $b_3$ and $b_1$, coefficients $b_2$ and $b_4$ are estimated directly by algebraic substitution.

Two-equation Results for the Six-month Period
August 1 to February 1

August 1 to February 1 represents the period during which most of the spring pig crop moves to slaughter. On August 1 an estimate may be made of total slaughter during the next six months, based on predetermined variables. Regression Equations 50 and 51 are computed, respectively, for the two

$$(50)\quad \hat{Z} = 0.6876 + \underset{(0.1406)}{0.9910X_1} - \underset{(0.0940)}{0.1241X_2} - \underset{(0.0272)}{0.0174X_3}$$

$$R^2 = 0.87$$

$$(51)\quad \hat{Z} = -0.7128 + \underset{(0.1637)}{0.9762X_1} + \underset{(0.1630)}{0.1038X_2} + \underset{(0.0828)}{0.3010X_3}$$

$$R^2 = 0.95$$

periods 1924 to 1937 and 1938 to 1956 (omitting war years 1942 through 1946). Standard errors for each coefficient are placed in parentheses below the coefficients. The variables are defined as:

$\hat{Z}$ = Estimated total liveweight of hogs slaughtered under Federal inspection in the United States from August 1 to February 1 (in logs).

$X_1$ = Pigs saved from previous spring pig crop (in logs).

$X_2$ = Tons of feed grain produced in the current year (in logs). This variable is classed as predetermined on the basis of being a current variable determined outside of, or exogenous to, the model.

$X_3$ = Time (in logs).

The regression coefficients for $X_2$ and $X_3$ are not consistently significant in both equations. However, these variables are retained on grounds that they should logically influence the value of the dependent variable. Also, the estimates of Z differ little if the non-significant variables are excluded. As indicated by the $R^2$ values for Equations 50 and 51, a relatively high proportion of the variation in the liveweight of hogs slaughtered is associated with predetermined variables. This result is consistent with the earlier hypothesis that farmers can vary total slaughter relatively little once the number of hogs is established (i.e., once the size of the pig crop is known). Subsequent changes in total slaughter through variation in marketing weights is expected to be considerably less important. Thus, the elasticity of supply ($b_3$), which measures changes in total slaughter relative to price changes during the marketing period, should logically be positive but small in magnitude.

Equations 52 and 53 are the estimated demand and supply equations, respectively, for the August 1 to February 1 marketing period from 1924 to 1937. Variables p, q, y and z are defined as above except that they refer to the six-month

(52) Demand: $p = -0.6278q + 0.9789y$

(53) Supply: $q = 0.0419p + 1.0288z$

period August 1 to February 1.[1] All variables have signs consistent with logic; however, the elasticity of supply ($b_3$ = 0.0419) is not statistically significant, as is indicated by studying reduced form Equations 54 and 55 from which it is derived.

(56) Demand: $p = -1.5483q + 1.6156y$

(57) Supply: $q = 0.0836p + 1.0006z$

Structural Equations 56 and 57 are demand and supply equations, respectively, for the August 1 to February 1 marketing period from 1938 to 1956 (omitting the war years 1942 through 1946).[2] Again, the signs of all variables are consistent with theory, although the elasticity of supply ($b_3$ = 0.0836) is not statistically significant.

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[1]In the manner outlined earlier, structural Equations 52 and 53 are derived from least-squares Equations 54 and 55:

(54) $\underset{}{p = \underset{(0.2285)}{0.9538y} - \underset{(0.1800)}{0.6293z}}$ $\quad R^2 - 0.75$

(55) $q = \underset{(0.1469)}{0.0400y} + \underset{(0.1156)}{1.0024z}$ $\quad R^2 = 0.87$

[2]Equations 56 and 57 are derived from the least-squares Equations 58 and 59:

(58) $p = \underset{(0.3749)}{1.4304y} - \underset{(0.4062)}{1.3717z}$ $\quad R^2 = 0.57$

(59) $q = \underset{(0.1353)}{0.1196y} + \underset{(0.1466)}{0.8860z}$ $\quad R^2 = 0.95$

Two-equation Results for the Six-month Period
February 1 to August 1

A major portion of the fall pig crop is marketed during the six-month period from February 1 to August 1. Estimates of the total liveweight of hogs slaughtered during this period are first obtained from predetermined variables alone. Regression Equations 60 and 61 represent this prediction for the years 1924 to 1937 and 1938 to 1956 (omitting the war years 1942 through 1946), respectively. The variables are

$$(60) \quad \hat{Z} = -0.2665 + \underset{(0.2086)}{0.5214X_1} + \underset{(0.1712)}{0.5427X_2} - \underset{(0.0374)}{0.0617X_3}$$
$$R^2 = 0.87$$

$$(61) \quad \hat{Z} = 0.3856 + \underset{(0.1136)}{0.9303X_1} - \underset{(0.1426)}{0.0432X_2} + \underset{(0.0750)}{0.2820X_3}$$
$$R^2 = 0.96$$

similar or identical to those defined earlier:

$\hat{Z}$ = Estimated total liveweight of hogs slaughtered under Federal inspection in the United States from February 1 to August 1 (in logs).

$X_1$ = Pigs saved from previous fall pig crop (in logs).

$X_2$ = Tons of feed grain produced in the previous year (in logs).

$X_3$ = Time (in logs).

Again, all three variables are retained in the regression equations, even though some of the regression coefficients are statistically non-significant. High intercorrelation between explanatory or independent variables appears to account for the signs contrary to logic. However, the purpose of these equations is to predict Z as accurately as possible from predetermined variables; the reliability of the individual regression coefficients is of secondary importance.

Structural Equations 62 and 63 are the demand and supply equations, respectively, for the February 1 to August 1 marketing period for the years 1924 to 1937.[1] Variables

$$(62)\quad \text{Demand:}\quad p = -0.3634q + 0.8328y$$

$$(63)\quad \text{Supply:}\quad q = 0.0668p + 1.0285z$$

p, q, y and z refer to this six-month marketing period. Again, although all signs are consistent with logic, the elasticity of supply ($b_3 = 0.0668$) is statistically nonsignificant.

Demand and supply equations for the February 1 to August 1 marketing period for the years 1938 to 1956 (omitting the war years 1942 through 1946) are estimated by Equations 66

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[1]Equations 62 and 63 are derived from least-squares Equations 64 and 65:

$$(64)\quad p = \underset{(0.3031)}{0.8131y} - \underset{(0.1785)}{0.3619z} \qquad R^2 = 0.54$$

$$(65)\quad q = \underset{(0.1950)}{0.0543y} + \underset{(0.1148)}{1.0041z} \qquad R^2 = 0.88$$

and 67, respectively.[1] Once more, all signs are consistent with theory, but the elasticity of supply ($b_3 = 0.0538$) is

$$(66)\quad \text{Demand:}\quad p = -1.6138q + 1.4523y$$

$$(67)\quad \text{Supply:}\quad q = 0.0538p + 0.8478z$$

too small, relative to its standard error, for statistical significance.

## Elasticities Computed from the Two-equation Models

Table 9 presents the supply and demand elasticities derived from the preceding two-equation systems for six-month marketing periods. The individual supply elasticities are not measured with sufficient precision statistically to allow a high degree of confidence in interpretation. However, the logically consistent signs and magnitudes of the supply elasticities in all four models permit somewhat greater confidence in these estimates. (If the true supply elasticity were in fact zero, two positive and two negative signs for $b_3$ would be expected, on the average, in the

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[1]Equations 66 and 67 are estimated from least-squares regression Equations 68 and 69:

$$(68)\quad p = \underset{(0.1806)}{1.5902y} - \underset{(0.1793)}{1.4981z} \qquad R^2 = 0.88$$

$$(69)\quad q = \underset{(0.1209)}{0.0855y} + \underset{(0.1200)}{0.9283z} \qquad R^2 = 0.96$$

Table 9. Elasticities of supply and demand computed from the two-equation models

| Years | Six-month marketing period | Elasticity of supply | Price elasticity of demand | Income elasticity of demand |
|---|---|---|---|---|
| 1924-1937 | Aug. 1 - Feb. 1 | 0.04 | -1.59 | 1.56 |
| 1938-1956[a] | Aug. 1 - Feb. 1 | 0.08 | -0.65 | 1.04 |
| 1924-1937 | Feb. 1 - Aug. 1 | 0.07 | -2.75 | 2.29 |
| 1938-1956[a] | Feb. 1 - Aug. 1 | 0.05 | -0.62 | 0.90 |

[a]Omitting war years 1942 through 1946.

four equations.) It seems fairly safe to state that the short-run within-marketing period supply response is positive but quite inelastic. However, it is impossible to deduce from these estimates whether the elasticity of supply measured here has changed over time.

The price elasticities of demand presented in Table 9 show a marked decrease from the 1924 to 1937 period to the 1938 to 1956 period. However, the demand elasticities for the 1924 to 1937 period appear unreasonably high, at least in comparison with previous estimates for the interwar period. For example, using annual data for the 1922 to 1941 period, Fox obtained price elasticities of demand for pork of -1.18 based on retail prices and about -0.65 based on farm prices. The price elasticities obtained in this study should compare more nearly with the latter figure, since deflated farm prices are used. Alternative deflation and trend removal procedures might explain part of the differences between the estimates of this study and others. Also, the purpose of the simple two-equation model above is mainly one of estimating supply response through changes in marketing weights. Consequently, total production figures are used. For a study in which demand elasticities are of primary interest, per capita production or consumption figures are clearly more relevant. Failure to incorporate these refinements into the demand equations may account for the unusually high demand elasticity estimates for the 1924 to 1937 period. It appears that a more complex model is required to derive meaningful estimates of both demand and supply elasticities.

While the magnitude of the change in price elasticity of demand from 1924 to 1937 to 1938 to 1956 undoubtedly is over-estimated in Table 9, the results are at least consistent with the earlier hypothesis of a decrease in demand elasticity over time. The income elasticity figures in Table 9 also show a decrease over time. These results also are consistent with the hypothesis that pork has become more of a staple food in the diets of American families.

The results of the above two-equation models can be regarded as no more than preliminary estimates of price and income elasticities of demand. A more complex demand-supply model of the livestock economy in the following chapter is an attempt to refine estimates of the relationships hinted at in the simple two-equation model.

# A 21-EQUATION MODEL OF THE LIVESTOCK ECONOMY

## General Model

While the simple two-equation models investigated previously are helpful in making preliminary estimates, the difficulties encountered suggest the relevance of a more complex model. A number of economic forces theoretically influence the supply and demand relationships for hogs. The present model, involving 21 equations, is an attempt to obtain quantitative measurements of these influences. The 21 equations include demand and supply equations for five major farm products (hogs, beef cattle, dairy products, poultry products and eggs) and 11 additional equations to complete the system. Actually, economic interest and meaning centers only on the first ten structural demand and supply equations; the remaining 11 equations are required to provide as many equations as there are endogenous variables in the model. Annual time series data are used since data for many variables are not available monthly or quarterly. While the annual time period is not ideal for studying hogs, it appears to be a practical choice in a model of this size. Brief definitions for the variables used in the 21-equation model follow:

$Q_h$ = Total liveweight of hogs slaughtered in the United States in year t. Computed as the total number of hogs under Federal inspected, non-inspected, retail and farm slaughter multiplied by the average liveweight of hogs slaughtered under Federal inspection. (It is assumed that the average slaughter weight is equal for Federal inspected and other types of slaughter.)

$Q_b$ = Total liveweight of cattle slaughtered in the United States in year t. Computed as the total number of cattle under Federal inspected, non-inspected, retail and farm slaughter multiplied by the average liveweight of cattle slaughtered under Federal inspection. (It is assumed that the average slaughter weight is equal for Federal inspected and other types of slaughter.)

$Q_d$ = Total production of milk on farms in year t, United States.

$Q_p$ = Total liveweight of poultry slaughtered in year t, United States. (Total of farm chickens, commercial broilers and turkeys.)

$Q_e$ = Total production of eggs on farms in year t, United States.

$P_h$ = Price received by farmers for hogs in year t, per 100 pounds, United States average.

$P_b$ = Price received by farmers for beef cattle in year t, per 100 pounds, United States average.

$P_d$ = Price of milk delivered to plants and dealers in year t, per 100 pounds, United States average.

$P_p$ = Price received by farmers for poultry in year t, per pound, United States average. (Weighted average of prices of farm chickens, commercial broilers and turkeys.)

$P_e$ = Price received by farmers for eggs in year t, per dozen, United States average.

$I_f$ = Index of Prices Received by Farmers for Livestock and Livestock Products in year t, United States.

$I_c$ = Index of Consumer Prices for All Goods and Services for Moderate-Income Families in Large Cities in year t, United States.

$N$ = Total population of the United States, including Armed Forces overseas, July 1, year t.

$S_{t-1}$ = Number of pigs saved from spring pig crop in year t-1, United States.

$F_{t-1}$ = Number of pigs saved from fall pig crop in year t-1, United States.

$G_s$ = Stocks of corn and oats on farms, January 1, year t, United States.

$G_p$ = Total production of all feed grains (corn, oats, barley and all sorghums for grain), year t, United States.

$A$ = Total animal units of grain-consuming livestock on farms, January 1, year t, United States.

$T$ = Time, where "time" takes values from 1 to N. (N is the number of years in the period investigated.)

$B_s$ = Animal units of beef cattle on farms, January 1, year t, United States. (Components of beef cows two years and over, cattle on feed and other cattle weighted to give total animal units.)

$R_{t-1}$ = Production of all kinds of hay, year t-1, United States.

$R_t$ = Production of all kinds of hay, year t, United States.

$D_s$ = Animal units of dairy cattle on farms, January 1, year t, United States. (Components of milk cows two years and over, milk heifers one to two years and heifer calves weighted to give total animal units.)

$P_s$ = Animal units of poultry (farm chickens, commercial broilers and turkeys) produced, year t-1, United States. This variable is used instead of numbers on farms January 1, year t, which is not a meaningful variable for poultry production.

$H_s$ = Hens and pullets on farms, January 1, year t, United States.

$Y_d$ = Total disposable personal income, year t, United States.

$P_o$ = Index of food product prices other than meat, dairy products and eggs, year t, United States average.

$P_n$ = Index of Consumer Prices for Non-Food Products, year t, United States average.

$M_h$ = Margin between farm and retail prices for hogs, per pound, year t, United States average. When divided by the Index of Consumer Prices ($I_c$), this variable is used as an index of marketing costs for hogs.

$M_f$ = Marketing bill per unit of all farm foods sold, year t, United States average. Computed as the total marketing bill for all farm foods divided by the index of volume of total farm marketings and home consumption of all food. When divided by the Index of Consumer Prices ($I_c$), this variable is used as index of marketing costs for all farm foods.

$M_b$ = Margin between farm and retail prices for beef cattle, per pound, year t, United States average. When divided by the Index of Consumer Prices ($I_c$), this variable is used as an index of marketing costs for cattle.

$M_d$ = Marketing bill per unit of dairy products marketed, year t, United States average. Computed as the total marketing bill for dairy products divided by the index of volume of total farm marketings and home consumption of dairy products. When divided by the Index of Consumer Prices ($I_c$), this variable is used as an index of marketing costs for dairy products.

$M_p$ = Marketing bill per unit of poultry and eggs marketed, year t, United States average. Computed as the total marketing bill for poultry and eggs divided by the index of volume of total farm marketings and home consumption of poultry and eggs. When divided by the Index of Consumer Prices ($I_c$), this variable is used as an index of marketing costs for poultry and eggs.

The general 21-equation model is outlined below in functional notation. The variables to the left of the semicolon in each equation are designated as endogenous variables; variables to the right of the semicolon are classed as predetermined. In conventional simultaneous equations notation, the G endogenous variables would be designated by $Y_i$ (i=1,....G); the K predetermined variables would be designated by $Z_j$ (j=1,....K). However, it is felt that letter designations which indicate the definitions for the particular variables allow the entire model to be more easily comprehended. Linear equations in the actual data are used to express all relationships. Again, to allow comparisons of coefficients over time, the analysis is divided into the 1924 to 1937 and 1938 to 1956 time periods.

Supply equations for the five livestock product categories are as follows:

(70) Hogs $$Q_h = f\left(\frac{P_h}{I_f}, \frac{P_b}{I_f}, \frac{P_d}{I_f}, \frac{P_p}{I_f}, \frac{P_e}{I_f}; S_{t-1}, F_{t-1}, G_s, G_p, A, T\right)$$

(71) Beef cattle $$Q_b = f\left(\frac{P_h}{I_f}, \frac{P_b}{I_f}, \frac{P_d}{I_f}, \frac{P_p}{I_f}, \frac{P_e}{I_f}; B_s, G_s, G_p, R_{t-1}, R_t, A, T\right)$$

(72) Dairy products $$Q_d = f\left(\frac{P_h}{I_f}, \frac{P_b}{I_f}, \frac{P_d}{I_f}, \frac{P_p}{I_f}, \frac{P_e}{I_f}; D_s, G_s, G_p, R_{t-1}, R_t, A, T\right)$$

(73) Poultry products $Q_p = f\left(\frac{P_h}{I_f}, \frac{P_b}{I_f}, \frac{P_d}{I_f}, \frac{P_p}{I_f}, \frac{P_e}{I_f}; P_s, G_s, G_p, A, T\right)$

(74) Eggs $Q_e = f\left(\frac{P_h}{I_f}, \frac{P_b}{I_f}, \frac{P_d}{I_f}, \frac{P_p}{I_f}, \frac{P_e}{I_f}; H_s, G_s, G_p, A, T\right)$

Demand equations for the five livestock product categories are as follows:

(75) Hogs $\frac{P_h}{I_c} = f\left(\frac{Q_h}{N}, \frac{P_b}{I_c}, \frac{P_d}{I_c}, \frac{P_p}{I_c}, \frac{P_e}{I_c}; \frac{Y_d}{NI_c}, \frac{P_o}{I_c}, \frac{P_n}{I_c}, \frac{M_h}{I_c}, \frac{M_f}{I_c}, T\right)$

(76) Beef cattle $\frac{P_b}{I_c} = f\left(\frac{Q_b}{N}, \frac{P_h}{I_c}, \frac{P_d}{I_c}, \frac{P_p}{I_c}, \frac{P_e}{I_c}; \frac{Y_d}{NI_c}, \frac{P_o}{I_c}, \frac{P_n}{I_c}, \frac{M_b}{I_c}, \frac{M_f}{I_c}, T\right)$

(77) Dairy products $\frac{P_d}{I_c} = f\left(\frac{Q_d}{N}, \frac{P_h}{I_c}, \frac{P_b}{I_{cc}}, \frac{P_p}{I_c}, \frac{P_e}{I_c}; \frac{Y_d}{NI_c}, \frac{P_o}{I_c}, \frac{P_n}{I_c}, \frac{M_d}{I_c}, \frac{M_f}{I_c}, T\right)$

(78) Poultry products $\frac{P_p}{I_c} = f\left(\frac{Q_p}{N}, \frac{P_h}{I_c}, \frac{P_b}{I_c}, \frac{P_d}{I_c}, \frac{P_e}{I_c}; \frac{Y_d}{NI_c}, \frac{P_o}{I_c}, \frac{P_n}{I_c}, \frac{M_p}{I_c}, \frac{M_f}{I_c}, T\right)$

(79) Eggs $\frac{P_e}{I_c} = f\left(\frac{Q_e}{N}, \frac{P_h}{I_c}, \frac{P_b}{I_c}, \frac{P_d}{I_c}, \frac{P_p}{I_c}; \frac{Y_d}{NI_c}, \frac{P_o}{I_c}, \frac{P_n}{I_c}, \frac{M_p}{I_c}, \frac{M_f}{I_c}, T\right)$

The equations required to complete the system (*i.e.*, to provide as many equations as endogenous variables) are as follows:

(80) $\frac{P_h}{I_f} = f\left(\frac{P_h}{I_c}, I_f; I_c\right)$

(81) $\frac{P_b}{I_f} = f\left(\frac{P_b}{I_c}, I_f; I_c\right)$

(82) $\frac{P_d}{I_f} = f\left(\frac{P_d}{I_c}, I_f; I_c\right)$

(83) $\frac{P_p}{I_f} = f\left(\frac{P_p}{I_c}, I_f; I_c\right)$

(84) $\frac{P_e}{I_f} = f\left(\frac{P_e}{I_c}, I_f; I_c\right)$

(85) $\frac{Q_h}{N} = f\left(Q_h; N\right)$

(86) $\frac{Q_b}{N} = f\left(Q_b; N\right)$

(87) $\frac{Q_d}{N} = f\left(Q_d;\ N\right)$

(88) $\frac{Q_p}{N} = f\left(Q_p;\ N\right)$

(89) $\frac{Q_e}{N} = f\left(Q_e;\ N\right)$

(90) $I_f = f\left(Q_h,\ Q_b,\ Q_d,\ Q_p,\ Q_e;\ N\right)$

In the supply equations, the quantities supplied are expressed as functions of prices of competing products, feed grain and livestock inventories on January 1, current grain production, lagged and current roughage production and "time". Current year prices of livestock are deflated by the Index of Prices Received by Farmers for Livestock and Livestock Products. In other words, it is supposed that farmers adjust total supplies of individual livestock products according to their relative farm prices or price ratios. Livestock inventories on January 1 are the result, to some extent, of prices in the previous year or years. Logically, the lagged prices should probably be included directly since this procedure would allow estimates of supply response relative to prices in previous time periods. However, the difficulty of selecting relevant lagged prices, and the increased number of variables which would be required, makes the alternative procedure of using inventories seem advisable.

In the demand equations, prices are deflated by the Index of Consumer Prices while quantities of livestock and livestock products are defined on a per capita basis for the United States. The Index of Consumer Prices is used as a deflater in the demand equations because consumers presumably shift purchases between products on the basis of relative consumer prices or price ratios. A strong upward trend in total production of livestock products over time can be largely eliminated by expressing production in per capita terms.

Because of the different deflation procedures in the demand and supply equations, 20 rather than 10 endogenous variables appear in Equations 70 through 79. Thus, 10 additional equations, relating farm to retail prices and total to per capita production, are required to complete the system. (Equation 90 will be explained later.) In a more complete model of the economy, farm and retail prices could be related by structural equations. Since the purpose of this study is not one of explaining the entire marketing system, a simple alternative procedure is used. By way of explanation, consider the Identity 91. This identity may be fitted statistically by Linear Approximation 92.[1] A high $R^2$ value

$$(91)\quad \frac{P_h}{I_f} = \frac{P_h}{I_c} \times \frac{I_c}{I_f}$$

[1]A discussion of linear approximations is given by Friedman and Foote (20, p. 67-68).

ordinarily is obtained from fitting this type of equation. Equations 80 through 84 in the model are of this type. Equations 85 through 89 may be explained by considering Identity 93, which is fitted by Linear Approximation 94. Again, a high

$$(92) \quad \frac{P_h}{I_f} = a_o + a_1 \frac{P_h}{I_c} + a_2 I_c + a_3 I_f$$

$$(93) \quad \frac{Q_h}{N} = Q_h \div N$$

$$(94) \quad \frac{Q_h}{N} = a_o + a_1 Q_h + a_2 N$$

$R^2$ value should be obtained. Equation 90 is needed to complete the model because the Index of Prices Received by Farmers for Livestock and Livestock Products ($I_f$) occurs as an endogenous variable in Equations 80 through 84. Equation 90 expresses $I_f$ as a function of the quantities rather than of the prices of the individual livestock products because the prices do not occur elsewhere in the system except in deflated form.

Some analysts would undoubtedly claim that the 21-equation model is too complex. Clearly, in a model of this size, non-significant coefficients will be obtained for a large number of the variables. However, it is difficult and somewhat arbitrary to specify in advance those few important variables which are expected to exert a statistically significant effect. Other analysts might argue that the present model is too simple. For example, a more complete model might include feed grain production as an endogenous variable. Prices of livestock early in year t could influence to some extent acreages planted or fertilizer and seeding rates in the same year. However, this influence is expected to be slight. Obviously, all of the predetermined variables are not completely free of influence by the endogenous variables. The decision to classify variables as endogenous or predetermined is therefore somewhat arbitrary, depending upon the type of analysis desired and upon the viewpoint of the analyst. The present model falls somewhere between the very simple and the highly "complete" econometric models.

## Modifications of the General Model

Since the analysis is divided into the 1924 to 1937 and 1938 to 1956 time periods, only 14 annual observations are available for each period. To provide determinate results, at least two more observations than the number of predetermined variables in the model are required (20, p. 66). Thus, for computational purposes, the number of predetermined variables used in fitting each equation must be reduced to 12 or fewer. A different set of predetermined variables may be used in fitting each equation; however, to simplify computations, a single set of predetermined variables is specified. The criterion used in simplifying the model is to delete those variables which are judged to be least important to the model on an a priori basis. In the demand equations the following variables are deleted: deflated price of food products other than meat, dairy products and eggs ($P_o/I_c$); deflated price of non-food products ($P_n/I_c$); and deflated marketing costs for each product ($M_h/I_c$, $M_b/I_c$, $M_d/I_c$ and $M_p/I_c$). In the supply equations variables $R_t$ and $R_{t-1}$ (roughage production in the current and previous year) are deleted. In addition, variables $S_{t-1}$ and $F_{t-1}$ (number of pigs from spring and fall farrowings in the previous year, respectively) are replaced by a single variable, $S_s$ (number of hogs and pigs on farms, January 1 of year t).

As computations proceeded, high correlations between certain variables necessitated additional revisions in the model. In the 1924 to 1937 period, two more predetermined variables were deleted on this account. A simple correlation of -0.97 was obtained between the Index of Consumer Prices ($I_c$) and dairy cattle on farms, January 1 ($D_s$); the simple correlation between the number of hogs and pigs on farms, January 1 ($S_s$) and the number of animal units on farms, January 1 (A) was 0.94. As a result of these high correlations, it was impossible to obtain the inverse of matrix $\overline{M}_{zz}$ (7, p. 242).[1] Thus, it was necessary to delete one variable of each highly correlated pair. Variables $I_c$ and A were deleted, again on the basis of being less important to this particular model than variables $D_s$ and $S_s$. Deletion of $I_c$, however, required a modification in Equations 80 through 90. In these equations, the time variable (T) was substituted for $I_c$, primarily on the basis that the two are quite highly correlated (r = -0.87). The problem of singularity again occurred in obtaining the $R_{\Delta\Delta}^{-1}$ matrices (7, p. 243) for the supply equations for hogs and beef cattle in the 1924 to 1937 period. Hence, variables $P_p/I_f$ and $P_e/I_f$ (deflated prices of poultry and eggs, respectively) were eliminated in these equations.

Similar problems of singularity of the $\overline{M}_{zz}$ and $R_{\Delta\Delta}$ matrices occurred for the 1938 to 1956 period. The strong upward trend in many variables over this period produced a number of high correlations; beef cattle on farms ($B_s$), the Index of Consumer Prices ($I_c$) and deflated per capita disposable income ($Y_d/NI_c$) all had simple correlations of 0.94 or higher with time (T). After some debate, variables $B_s$, $I_c$ and T were deleted, since disposable income

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[1]The high correlations resulted in a condition approaching singularity in the matrix $\overline{M}_{zz}$. The matrix $\overline{M}_{zz}$ is non-singular if and only if there exists a matrix $\overline{M}_{zz}^{-1}$ such that $\overline{M}_{zz}\,\overline{M}_{zz}^{-1} = I$, where I is an identity matrix.

$(Y_d/NI_c)$ appeared to be essential in all demand equations. However, deletion of time (T) undoubtedly was a serious omission for the 1938 to 1956 period. In the individual supply equations, several of the deflated price variables also were deleted because of near-singularity in the $R_{\Delta\Delta}$ matrices. Specific deletions are apparent from the equations presented in the following section.

## Presentation and Analysis of Estimated Equations

Maximum-likelihood estimates of all the equations for both the 1924 to 1937 and 1938 to 1956 period were obtained, using the limited-information single-equation method (7, p. 240-246).[1] This large-scale computational task was made manageable by use of a high-speed electronic computer (IBM 650). Letters a and b following the equation numbers below refer to the 1924 to 1937 and 1938 to 1956 period, respectively. Otherwise, the equations carry the same numbers as presented in the general model above. For example, Equation 70a is the estimated hog supply function for 1924 to 1937, while Equation 70b is the estimated hog supply function for 1938 to 1956.

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[1]However, the supply functions for dairy cattle and poultry are not presented because an error was discovered in the latter stages of the calculations for the individual equations; it appeared economically infeasible to recompute the required coefficients.

Following are the estimated equations for the 1924 to 1937 period:

$$(70a)\quad Q_h = \underset{(254.7423)}{-107.7941}\frac{P_h}{I_f} + \underset{(382.2269)}{668.3694}\frac{P_b}{I_f} - \underset{(2,470.0843)}{810.2740}\frac{P_d}{I_f} + \underset{(0.1563)}{0.0636}S_s + \underset{(0.0350)}{0.0742}G_s - \underset{(0.0190)}{0.0092}G_p + \underset{(0.4802)}{0.6822}B_s - \underset{(226.2596)}{206.5152}T - 800.8813$$

$$(71a)\quad Q_b = \underset{(867.1363)}{-134.0294}\frac{P_h}{I_f} - \underset{(1,035.0412)}{1,450.8450}\frac{P_b}{I_f} - \underset{(13,663.5543)}{7,806.2947}\frac{P_d}{I_f} + \underset{(0.4126)}{0.3877}S_s - \underset{(0.0691)}{0.0418}G_s - \underset{(0.0558)}{0.0283}G_p - \underset{(0.9221)}{0.5732}B_s + \underset{(587.5465)}{602.8039}T + 60,127.7992$$

$$(74a)\quad Q_e = \underset{(1,130.4827)}{-150.0342}\frac{P_h}{I_f} - \underset{(1,176.6147)}{540.7558}\frac{P_b}{I_f} - \underset{(5,149.9195)}{3,432.3141}\frac{P_d}{I_f} + \underset{(311.9032)}{167.6265}\frac{P_p}{I_f} - \underset{(221.6718)}{116.6297}\frac{P_e}{I_f} + \underset{(0.0298)}{0.1157}H_s + \underset{(0.0584)}{0.0059}G_s + \underset{(0.0266)}{0.0181}G_p + \underset{(0.2727)}{0.0024}S_s + \underset{(367.4374)}{378.6697}T + 13,239.0509$$

$$(75a)\quad \frac{P_h}{I_c} = \underset{(0.1789)}{-0.2489}\frac{Q_h}{N} - \underset{(1.4944)}{1.0901}\frac{P_b}{I_c} - \underset{(12.7196)}{8.8661}\frac{P_d}{I_c} - \underset{(1.4151)}{0.2020}\frac{P_p}{I_c} - \underset{(0.7586)}{0.5943}\frac{P_e}{I_c} + \underset{(0.0594)}{0.0407}\frac{Y_d}{NI_c} + \underset{(1.8142)}{0.5634}\frac{M_f}{I_c} - \underset{(1.0078)}{0.7611}T + 67.7175$$

(76a) $$\frac{P_b}{I_c} = \underset{(0.0120)}{-0.1063}\frac{Q_b}{N} + \underset{(0.0651)}{0.0448}\frac{P_h}{I_c} + \underset{(0.8214)}{3.7483}\frac{P_d}{I_c} - \underset{(0.1028)}{0.0231}\frac{P_p}{I_c} + \underset{(0.0457)}{0.0940}\frac{P_e}{I_c} + \underset{(0.0044)}{0.0026}\frac{Y_d}{NI_c} - \underset{(0.1675)}{0.4041}\frac{M_f}{I_c} + \underset{(0.0376)}{0.1243}\,T + 1{,}368.6753$$

(77a) $$\frac{P_d}{I_c} = \underset{(0.0062)}{-0.0138}\frac{Q_d}{N} - \underset{(0.0302)}{0.0049}\frac{P_h}{I_c} + \underset{(0.0558)}{0.1200}\frac{P_b}{I_c} + \underset{(0.0491)}{0.0012}\frac{P_p}{I_c} - \underset{(0.0250)}{0.0151}\frac{P_e}{I_c} + \underset{(0.0006)}{0.0006}\frac{Y_d}{NI_c} + \underset{(0.0911)}{0.1468}\frac{M_f}{I_c} - \underset{(0.0204)}{0.0360}\,T + 10.5299$$

(78a) $$\frac{P_p}{I_c} = \underset{(6.6261)}{0.2505}\frac{Q_p}{N} + \underset{(1.4733)}{0.1205}\frac{P_h}{I_c} + \underset{(6.3064)}{2.7423}\frac{P_b}{I_c} - \underset{(76.2249)}{24.0981}\frac{P_d}{I_c} + \underset{(4.3920)}{1.1792}\frac{P_e}{I_c} + \underset{(0.0797)}{0.0256}\frac{Y_d}{NI_c} - \underset{(5.1339)}{0.2937}\frac{M_f}{I_c} - \underset{(1.0951)}{0.4436}\,T + 12.8068$$

(79a) $$\frac{P_e}{I_c} = \underset{(0.0438)}{-0.1933}\frac{Q_e}{N} + \underset{(0.2896)}{0.3624}\frac{P_h}{I_c} + \underset{(0.6925)}{0.6106}\frac{P_b}{I_c} + \underset{(4.5750)}{5.8706}\frac{P_d}{I_c} + \underset{(0.4427)}{0.4573}\frac{P_p}{I_c} - \underset{(0.0203)}{0.0057}\frac{Y_d}{NI_c} + \underset{(0.7304)}{0.0737}\frac{M_f}{I_c} - \underset{(0.3088)}{0.7564}\,T + 71.5433$$

(80a) $$\frac{P_h}{I_f} = 1.3546\frac{P_h}{I_c} - 0.2033\,I_f - 0.1771\,T + 12.6059$$

(81a) $$\frac{P_b}{I_f} = 1.8202\frac{P_b}{I_c} - 0.3516\,I_f - 0.3497\,T + 15.6037$$

(82a) $$\frac{P_d}{I_f} = 0.5783\frac{P_d}{I_c} - 0.0522\,I_f + 0.0542\,T + 4.8997$$

(83a) $\frac{P_p}{I_f} = 1.9963 \frac{P_p}{I_c} - 0.9808\ I_f - 0.1908\ T + 33.0162$

(84a) $\frac{P_e}{I_f} = 1.2368 \frac{P_e}{I_c} - 0.8819\ I_f - 0.8612\ T + 57.0308$

(85a) $\frac{Q_h}{N} = 0.0081\ Q_h - 1.0408\ T + 7.9298$

(86a) $\frac{Q_b}{N} = 0.0088\ Q_b - 1.0161\ T - 1.4328$

(87a) $\frac{Q_d}{N} = 0.0057\ Q_d - 4.5532\ T + 267.6874$

(88a) $\frac{Q_p}{N} = 0.0068\ Q_p - 0.1616\ T + 4.6096$

(89a) $\frac{Q_e}{N} = 0.0068\ Q_e + 2.7391\ T + 23.6152$

(90a) $I_f = 0.0010\ Q_h - 0.0235\ Q_b - 0.0166\ Q_d + 0.1390\ Q_p - 0.0062\ Q_e + 12.5146\ T + 1{,}723.2378$

Following are the estimated equations for the 1938 to 1956 period:

(70b) $Q_h = \underset{(1,045.5738)}{-204.1331} \frac{P_h}{I_f} - \underset{(1,766.8923)}{303.6869} \frac{P_b}{I_f} - \underset{(10,261.3259)}{1,882.4604} \frac{P_d}{I_f} - \underset{(0.4797)}{0.0648} S_s - \underset{(0.7270)}{0.1271} G_s + \underset{(0.8011)}{0.1514} G_p + \underset{(2.0833)}{0.5575} A - 42,619.6233$

$$(71b)\quad Q_b = \underset{(365.7868)}{443.1916}\ \frac{P_h}{I_f} + \underset{(618.2396)}{743.6245}\ \frac{P_b}{I_f} + \underset{(3,590.2753)}{4,565.4483}\ \frac{P_d}{I_f} - \underset{(1.3485)}{0.4088}\ S_s + \underset{(2.5266)}{0.4098}\ G_s - \underset{(2.7959)}{0.2891}\ G_p - \underset{(7.2659)}{0.4440}\ A + 61,258.2277$$

$$(74b)\quad Q_e = \underset{(818.0089)}{-2,568.4517}\ \frac{P_p}{I_f} + \underset{(410.2727)}{755.3249}\ \frac{P_e}{I_f} + \underset{(0.0539)}{0.0900}\ H_s - \underset{(0.1708)}{0.1229}\ G_s + \underset{(0.0895)}{0.0884}\ G_p - \underset{(0.2865)}{0.3857}\ A + 111,583.1989$$

$$(75b)\quad \frac{P_h}{I_c} = \underset{(0.4137)}{-0.0791}\ \frac{Q_h}{N} - \underset{(1.0542)}{0.0862}\ \frac{P_b}{I_c} - \underset{(15.7050)}{8.5159}\ \frac{P_d}{I_c} + \underset{(1.9689)}{1.2234}\ \frac{P_p}{I_c} + \underset{(1.1411)}{0.9336}\ \frac{P_e}{I_c} + \underset{(0.0386)}{0.0196}\ \frac{Y_d}{NI_c} + \underset{(4.5856)}{0.4927}\ \frac{M_f}{I_c} - 39.8029$$

$$(76b)\quad \frac{P_b}{I_c} = \underset{(0.0911)}{-0.3272}\ \frac{Q_b}{N} + \underset{(0.5274)}{0.6229}\ \frac{P_h}{I_c} - \underset{(5.4962)}{1.1120}\ \frac{P_d}{I_c} - \underset{(0.8483)}{0.3150}\ \frac{P_p}{I_c} + \underset{(0.4571)}{0.3657}\ \frac{P_e}{I_c} + \underset{(0.0189)}{0.0252}\ \frac{Y_d}{NI_c} + \underset{(1.1523)}{0.1254}\ \frac{M_f}{I_c} + 6,287.2632$$

$$(77b)\quad \frac{P_d}{I_c} = \underset{(0.0051)}{-0.0105}\ \frac{Q_d}{N} - \underset{(0.0389)}{0.0301}\ \frac{P_h}{I_c} - \underset{(0.0284)}{0.0251}\ \frac{P_b}{I_c} + \underset{(0.0559)}{0.1261}\ \frac{P_p}{I_c} + \underset{(0.0371)}{0.0246}\ \frac{P_e}{I_c} + \underset{(0.0013)}{0.0035}\ \frac{Y_d}{NI_c} - \underset{(0.1638)}{0.2830}\ \frac{M_f}{I_c} + 10.0077$$

$$(78b)\quad \frac{P_p}{I_c} = \underset{(17.5143)}{-12.5888}\frac{Q_p}{N} - \underset{(14.4191)}{9.6966}\frac{P_h}{I_c} + \underset{(0.2022)}{0.0412}\frac{P_b}{I_c} - \underset{(129.1244)}{85.9604}\frac{P_d}{I_c} + \underset{(23.4406)}{16.1710}\frac{P_e}{I_c} + \underset{(0.4594)}{0.3173}\frac{Y_d}{NI_c} + \underset{(30.3661)}{21.0188}\frac{M_f}{I_c} - 505.6139$$

$$(79b)\quad \frac{P_e}{I_c} = \underset{(0.2818)}{0.2345}\frac{Q_e}{N} - \underset{(1.1267)}{0.0440}\frac{P_h}{I_c} - \underset{(0.9085)}{0.5082}\frac{P_b}{I_c} + \underset{(11.2429)}{7.2470}\frac{P_d}{I_c} - \underset{(1.8500)}{0.5203}\frac{P_p}{I_c} - \underset{(0.0446)}{0.0189}\frac{Y_d}{NI_c} - \underset{(2.7205)}{2.0679}\frac{M_f}{I_c} + 15.1143$$

$$(80b)\quad \frac{P_h}{I_f} = 1.0845\frac{P_h}{I_c} - 0.1732\, I_f + 1.5613\frac{M_f}{I_c} - 14.8944$$

$$(81b)\quad \frac{P_b}{I_f} = 0.9335\frac{P_b}{I_c} - 0.1301\, I_f + 1.0204\frac{M_f}{I_c} - 5.1602$$

$$(82b)\quad \frac{P_d}{I_f} = 2.2716\frac{P_d}{I_c} - 0.0726\, I_f + 0.5389\frac{M_f}{I_c} - 8.6586$$

$$(83b)\quad \frac{P_p}{I_f} = -0.1268\frac{P_p}{I_c} - 0.1097\, I_f + 1.4034\frac{M_f}{I_c} + 14.9469$$

$$(84b)\quad \frac{P_e}{I_f} = -1.336\frac{P_e}{I_c} + 0.1023\, I_f - 1.5739\frac{M_f}{I_c} + 119.0264$$

$$(85b)\quad \frac{Q_h}{N} = 0.0113\, Q_h - 0.0873\frac{Y_d}{NI_c} + 20.0040$$

$$(86b)\quad \frac{Q_b}{N} = 0.0663\, Q_b + 1.2553\frac{Y_d}{NI_c} - 2{,}669.5587$$

(87b) $\frac{Q_d}{N} = 0.5344\ Q_d - 15.1899\ \frac{Y_d}{NI_c} - 42{,}764.6552$

(88b) $\frac{Q_p}{N} = 0.0037\ Q_p + 0.0076\ \frac{Y_d}{NI_c} + 4.4742$

(89b) $\frac{Q_e}{N} = 0.0069\ Q_e - 0.1490\ \frac{Y_d}{NI_c} + 162.9140$

(90b) $I_f = 0.0055\ Q_h + 0.0042\ Q_b - 0.0037\ Q_d - 0.0159\ Q_p + 0.0038\ Q_e + 0.0289\ \frac{Y_d}{NI_c} + 169.0633$

Several general observations are in order regarding the equations estimated for the large-scale model. First, a large number of the structural coefficients have signs incompatible with economic theory. Second, the standard errors of the coefficients are, in general, large relative to the magnitudes of the coefficients. Third, the results for the 1924 to 1937 period appear more reasonable than those for the 1938 to 1956 period. Fourth, in both time periods the demand equations appear more consistent with theory than the supply equations.

A structural coefficient should exceed twice its standard error to be judged significant; relatively few of the coefficients meet this approximate criterion for significance. One reason for the large standard errors is that relatively few observations are available in each time period. Given the number of variables considered, the two time periods probably should be combined to provide more degrees of freedom in estimating standard errors. However, such a procedure would not allow comparisons of relationships over time.

A second reason for large standard errors, and a problem encountered in the analysis generally, is the high correlation among variables. This problem is particularly acute in the 1938 to 1956 period when the time series for a number of variables trended upward together. Perhaps the use of first differences, which often reduces the correlation between "independent" variables, would provide more reasonable results. At any rate, the analysis clearly emphasizes the problems encountered in combining pre-war and post-war data, or in projecting results of pre-war studies to post-war conditions.

In general, the supply equations are unsuccessful in providing useful estimates of supply elasticities. In fact, negative supply elasticities are obtained for most products, a result inconsistent with prior knowledge and theory. The supply elasticities in the model measure response in total output to price within the marketing year. High negative correlations between annual price and total quantity for most products probably account for the failure to obtain positive supply elasticities. As mentioned earlier, inclusion of lagged prices in the supply equations probably would provide more meaningful estimates of supply elasticities. Because of inconsistent signs and non-significant coefficients the supply equations in the model provide little enlightenment on the question of shifts in supply elasticities over time.

The model is somewhat more successful in measuring demand relationships. Price elasticities of demand for hogs, beef cattle and dairy products for 1924 to 1937 compare closely with those obtained by Learn (30, p. 1487) and others. From the above model, the computed elasticities of demand for hogs, beef cattle and dairy products are -0.39, -0.87 and -0.27, respectively. For the same products Learn obtained demand elasticities of -0.43, -0.74 and -0.30. The demand elasticity for eggs from the above model (-0.60) is high relative to previous estimates while the demand elasticity for poultry has a positive sign, which is incompatible with theory. While most of the demand elasticities for the 1924 to 1937 period appear quite reasonable, those for the 1938 to 1956 period are questionable. The elasticities of demand for hogs, beef cattle and dairy products in the later time period are -1.69, -0.40 and -0.46, respectively. The demand elasticity for hogs appears unreasonably high; however, the estimate is probably unreliable since it is computed from a coefficient whose standard error is relatively large. Thus, the complex model fails to provide useful estimates of changes in the demand elasticity for hogs over time.

In summary, the complex model provides little additional information regarding the demand and supply relationships for hogs -- the main interest of the study. Inferences from the model are limited because of large standard errors and "wrong" signs for many of the coefficients. The major emphasis in the above discussion, therefore, has been on problems encountered in model construction and statistical estimation. It is anticipated that some of the avenues explored may be helpful in directing future research efforts in the general area.

# SUMMARY AND CONCLUSIONS

Demand relationships for many agricultural products have been examined extensively. Supply analysis has received much less attention by agricultural researchers. Yet a knowledge of both demand and supply functions is required for an adequate understanding of the price mechanism. This study explores the supply function for hogs, particularly in relation to recent increased fluctuations in hog prices.

Recurring cycles in the price and production of hogs suggests the validity of a general cobweb theory underlying the hog market. According to the cobweb theory, a decline in demand elasticity and/or an increase in supply elasticity leads to wider price fluctuations, other things equal. The major hypothesis advanced in this study is that part of the recent increased fluctuations in hog prices is attributable to increases in the supply elasticity for hogs. Objectives of the study are to obtain evidence on the magnitudes and directional shifts in supply elasticities for hogs over time. Interest also centers on developing forecasting equations. To allow estimates of structural changes over time the analysis is divided into two periods; one period extends from 1924 to 1937, the other from 1938 to 1956.

The total liveweight of hogs supplied is a direct function of the number of hogs marketed and their average marketing weight. Major changes in total hog supplies result from changes in hog numbers rather than in marketing weights. Numbers of hogs marketed are, in turn, determined primarily by the number of sows farrowed in preceding time periods. Single-equation least-squares methods were employed in analyzing spring and fall farrowings in the United States and North Central Region for the periods 1924 to 1937 and 1938 to 1956. Factors which appeared important in explaining spring farrowings were (in order of importance) the hog-corn price ratio at breeding time, production of oats, barley and grain sorghum as a percentage of corn production in the previous year and various measures of the relative profitability of hogs and beef cattle at breeding time. Adjusted coefficients of determination ($\overline{R}^2$ values) of about 0.90 were obtained for all spring farrowing equations. Estimated elasticities of supply (i.e., changes in farrowings in response to hog prices at breeding time) for the United States increased from 0.50 in the 1924 to 1937 period to about 0.62 in the 1938 to 1956 period. For the North Central Region the corresponding increase in supply elasticity was from 0.58 to 0.74. Thus, these results supported the hypothesis of an increase in supply elasticity for hogs over time.

Factors which appeared important in determining fall farrowings were the number of sows farrowing in the spring, production of oats, barley and grain sorghum and the comparative profitability of hogs and beef cattle. Coefficients of determination were considerably lower for fall farrowings than for the spring farrowings. The supply elasticities for fall farrowings were relatively low and did not change appreciably over time.

Estimates of supply elasticities also were obtained using an expected price model. Again, the response in spring farrowings to changes in hog prices expected in the future marketing period increased over time. The magnitudes of the elasticities computed from expected prices were comparable to those computed with respect to hog prices at breeding time.

In addition to changes in hog numbers, total hog supplies vary somewhat from changes in marketing weights. Simple two-equation simultaneous equation models were used in estimating the responsiveness of farmers to price during the marketing period (i.e., by varying marketing weights). The within-marketing-period supply elasticities derived from this model were, as expected, relatively low -- between 0.04 and 0.08; no appreciable changes occurred over time.

To study the influence of competing livestock products on the demand and supply of hogs, a more complex simultaneous equations model was constructed. This model consisted of 21 equations, including complex demand and supply functions for hogs, beef cattle, dairy products, poultry products and eggs. In general, the results of the 21-equation model were unsatisfactory, particularly for the supply equations. Demand elasticities for hogs, beef cattle and dairy products for the 1924 to 1937 period corresponded closely with previous estimates. However, demand elasticity estimates for the 1938 to 1956 period appeared unreliable, perhaps because of high intercorrelations among variables. Possible improvements in the model may have been made by using first differences, increasing the number of degrees of freedom and by using alternative deflation procedures. Lagged livestock prices rather than January 1 livestock inventories may have been used with greater success in the supply equations. Little additional information was obtained from this complex model regarding the demand and relationships for hogs.

In summary, the study provided support for the hypothesis of an increase over time in the supply elasticity for hogs, at least with regard to the number of sows farrowing in response to hog prices at breeding time. Other studies have indicated a decrease in the demand elasticity for hogs over time. Recent observed wide fluctuations in hog prices, therefore, may be a result of both an increase in the supply elasticity and a decrease in the demand elasticity for hogs.

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# APPENDIX

Table A. Basic data used in predicting spring farrowings in the United States and North Central Region, 1938-1956

| Year | No. of sows farrowing, Dec. - May, U. S. (Refs. 51,52,57) | Hog-corn price ratio, Oct. - Dec., U. S. (Refs. 47,48) | Production of oats, barley and grain sorghum, U. S. (Ref. 48) | Production of corn, U. S. (Ref. 48) | Price of feeder cattle, Oct. - Dec., Omaha (Ref. 38) | Price of slaughter cattle, Oct. - Dec., Chicago (Ref. 25) |
|---|---|---|---|---|---|---|
| | (x $10^3$) | (Index) | (Tons x $10^3$) | (Tons x $10^3$) | (Dollars/cwt.) | (Dollars/cwt.) |
| 1936 | -- | -- | 17,014 | 42,159 | -- | -- |
| 1937 | 6,177 | 16.5 | 25,972 | 74,003 | 7.84 | 13.37 |
| 1938 | 6,795 | 17.2 | 25,336 | 71,365 | 8.43 | 11.01 |
| 1939 | 8,692 | 12.0 | 23,385 | 72,268 | 9.05 | 9.96 |
| 1940 | 8,247 | 10.0 | 29,645 | 68,800 | 9.62 | 12.66 |
| 1941 | 7,760 | 15.3 | 30,574 | 74,253 | 10.91 | 12.05 |
| 1942 | 9,684 | 17.4 | 34,641 | 85,920 | 13.11 | 15.76 |
| 1943 | 12,174 | 12.3 | 28,835 | 83,047 | 12.34 | 15.51 |
| 1944 | 9,246 | 12.5 | 29,828 | 86,463 | 12.48 | 16.92 |
| 1945 | 8,302 | 12.8 | 33,287 | 80,326 | 13.59 | 17.16 |
| 1946 | 8,077 | 16.7 | 32,759 | 90,078 | 17.28 | 28.41 |
| 1947 | 8,548 | 11.3 | 28,007 | 65,933 | 22.50 | 31.78 |
| 1948 | 7,833 | 17.6 | 34,192 | 100,942 | 25.93 | 32.77 |
| 1949 | 8,820 | 14.8 | 29,072 | 90,657 | 22.95 | 32.86 |
| 1950 | 9,179 | 13.1 | 35,270 | 86,098 | 30.52 | 32.58 |
| 1951 | 9,484 | 11.3 | 30,850 | 81,921 | 34.02 | 36.80 |
| 1952 | 8,311 | 11.4 | 27,314 | 92,176 | 24.82 | 33.18 |
| 1953 | 7,045 | 15.8 | 27,381 | 89,877 | 18.03 | 26.43 |
| 1954 | 7,669 | 12.8 | 37,773 | 85,621 | 20.47 | 27.26 |
| 1955 | 8,359 | 11.0 | 39,984 | 90,433 | 18.65 | 21.69 |
| 1956 | 7,650 | -- | -- | -- | -- | -- |

Table A. (Continued)

| Year | Index of Wholesale Prices, U. S. (Refs. 41,42) | Price of hogs, Oct. - Dec., U. S. (Refs. 49,59,61) | No. of sows farrowing, Dec. - May, North Central Region (Refs. 51,52,57) | Hog-corn ratio, Oct. - Dec., Chicago (Refs. 47,48) | Price of hogs, Oct. - Dec., Chicago (Ref. 49) |
|---|---|---|---|---|---|
| | (1910-14 = 100) | (Dollars/cwt.) | (x $10^3$) | (Index) | (Dollars/cwt.) |
| 1936 | -- | -- | -- | -- | -- |
| 1937 | 126 | 8.52 | 4,269 | 15.17 | 8.86 |
| 1938 | 115 | 7.14 | 4,755 | 16.13 | 7.58 |
| 1939 | 113 | 5.81 | 6,221 | 11.93 | 6.07 |
| 1940 | 115 | 5.68 | 6,094 | 9.80 | 6.21 |
| 1941 | 127 | 9.98 | 5,826 | 14.47 | 10.41 |
| 1942 | 144 | 13.61 | 7,141 | 17.47 | 14.32 |
| 1943 | 151 | 13.23 | 8,944 | 12.70 | 13.87 |
| 1944 | 152 | 13.57 | 6,717 | 12.67 | 14.27 |
| 1945 | 154 | 14.17 | 6,240 | 12.73 | 14.69 |
| 1946 | 177 | 22.83 | 6,030 | 15.63 | 23.25 |
| 1947 | 222 | 25.53 | 6,541 | 10.77 | 26.36 |
| 1948 | 241 | 22.47 | 5,829 | 16.40 | 23.06 |
| 1949 | 226 | 16.00 | 6,713 | 13.83 | 16.26 |
| 1950 | 236 | 18.27 | 7,122 | 11.87 | 18.66 |
| 1951 | 264 | 18.63 | 7,385 | 10.37 | 18.71 |
| 1952 | 256 | 17.07 | 6,356 | 11.03 | 17.28 |
| 1953 | 253 | 21.53 | 5,624 | 14.87 | 22.01 |
| 1954 | 253 | 17.97 | 6,135 | 11.97 | 18.01 |
| 1955 | 253 | 12.43 | 6,651 | 10.40 | 12.23 |
| 1956 | -- | -- | 5,877 | -- | -- |

Table B. Basic data used in predicting spring farrowings in the United States and North Central Region, 1924-1937

| Year | No. of sows farrowing, Dec. - May, U. S. (Refs. 51,52,57) | Hog-corn ratio, Oct. - Dec., U. S. (Refs. 47,48) | Production of oats, barley and grain sorghum, U. S. (Ref. 48) | Production of corn, U. S. (Ref. 48) | Price of slaughter cattle, Aug. - Dec., Chicago (Refs. 49,59,61) |
|---|---|---|---|---|---|
| | ($x\ 10^3$) | (Index) | (Tons $x\ 10^3$) | (Tons $x\ 10^3$) | (Dollars/cwt.) |
| 1923 | -- | -- | 25,098 | 80,508 | -- |
| 1924 | 9,799 | 8.43 | 28,267 | 62,247 | 9.25 |
| 1925 | 8,334 | 14.15 | 28,634 | 78,354 | 10.56 |
| 1926 | 9,048 | 16.93 | 24,323 | 71,315 | 9.64 |
| 1927 | 9,754 | 11.51 | 25,396 | 73,251 | 12.95 |
| 1928 | 9,301 | 11.01 | 30,941 | 74,634 | 14.50 |
| 1929 | 8,854 | 10.62 | 25,842 | 70,446 | 13.54 |
| 1930 | 8,278 | 11.85 | 28,609 | 58,244 | 10.34 |
| 1931 | 8,971 | 12.36 | 24,664 | 72,126 | 8.17 |
| 1932 | 8,811 | 14.73 | 28,977 | 82,050 | 6.92 |
| 1933 | 9,123 | 8.89 | 16,863 | 67,133 | 5.49 |
| 1934 | 6,825 | 6.48 | 12,025 | 40,570 | 7.51 |
| 1935 | 5,467 | 14.99 | 27,790 | 64,382 | 10.15 |
| 1936 | 6,954 | 9.34 | 17,014 | 42,159 | 9.50 |
| 1937 | 6,177 | 16.49 | -- | -- | 12.06 |

Table B. (Continued)

| Year | Price of feeder cattle, Aug. - Dec., Chicago (Refs. 49,59,61) | Index of Wholesale Prices (Refs. 41,42) | No. of sows farrowing, Dec. - May, North Central Region (Refs. 51,52,57) | Hog-corn ratio, Oct. - Dec., Chicago (Refs. 47,48) |
|---|---|---|---|---|
| | (Dollars/cwt.) | (1910-14 = 100) | (x $10^3$) | (Index) |
| 1923 | -- | -- | -- | -- |
| 1924 | 6.11 | 143 | 8,658 | 8.27 |
| 1925 | 7.04 | 151 | 6,935 | 10.57 |
| 1926 | 7.09 | 146 | 7,380 | 16.23 |
| 1927 | 9.03 | 139 | 7,741 | 10.83 |
| 1928 | 10.95 | 141 | 7,446 | 10.27 |
| 1929 | 10.00 | 139 | 7,184 | 10.30 |
| 1930 | 7.05 | 126 | 6,764 | 11.63 |
| 1931 | 5.13 | 107 | 7,328 | 11.83 |
| 1932 | 4.57 | 95 | 6,882 | 13.40 |
| 1933 | 3.70 | 96 | 7,098 | 9.03 |
| 1934 | 3.90 | 109 | 5,147 | 6.77 |
| 1935 | 7.06 | 117 | 3,836 | 14.40 |
| 1936 | 6.02 | 118 | 5,013 | 9.13 |
| 1937 | 7.61 | 126 | 4,269 | 15.17 |

Table C. Basic data used in predicting fall farrowings in the United States and North Central Region, 1937-1956

| Year | No. of sows farrowing, June - Nov., U. S. (Refs. 51,52,57) | No. of sows farrowing, Dec. - May, U. S. (Refs. 51,52,57) | Hog-corn ratio, Mar. - June, U. S. (Refs. 47,48) | Production of oats, barley and grain sorghum, U. S. (Ref. 48) | Beef steer-corn ratio, Mar. - June, Chicago (Refs. 47,48) | No. of sows farrowing, June - Nov., N. Central Region (Refs. 51,52,57) |
|---|---|---|---|---|---|---|
| | (x $10^3$) | (x $10^3$) | (Index) | (Tons x $10^3$) | (x $10^{-1}$) | (x $10^3$) |
| 1937 | 3,845 | 6,177 | 8.15 | 25,972 | 89 | 2,228 |
| 1938 | 4,517 | 6,795 | 15.07 | 25,336 | 153 | 2,608 |
| 1939 | 5,352 | 8,692 | 13.99 | 23,385 | 198 | 3,234 |
| 1940 | 4,763 | 8,247 | 8.25 | 29,645 | 153 | 3,065 |
| 1941 | 5,535 | 7,760 | 12.79 | 30,574 | 151 | 3,618 |
| 1942 | 6,840 | 9,684 | 16.35 | 34,641 | 156 | 4,399 |
| 1943 | 7,565 | 12,174 | 14.03 | 28,835 | 150 | 4,710 |
| 1944 | 4,882 | 9,246 | 11.19 | 29,828 | 133 | 3,080 |
| 1945 | 5,429 | 8,302 | 13.00 | 33,287 | 139 | 3,553 |
| 1946 | 4,704 | 8,077 | 11.34 | 32,759 | 125 | 2,962 |
| 1947 | 4,866 | 8,548 | 14.56 | 28,007 | 130 | 3,087 |
| 1948 | 5,070 | 7,833 | 9.82 | 34,192 | 131 | 3,299 |
| 1949 | 5,568 | 8,820 | 15.60 | 29,072 | 184 | 3,741 |
| 1950 | 5,927 | 9,179 | 13.24 | 35,270 | 195 | 4,153 |
| 1951 | 5,955 | 9,484 | 12.83 | 30,850 | 202 | 4,156 |
| 1952 | 5,067 | 8,311 | 10.58 | 27,314 | 180 | 3,616 |
| 1953 | 4,479 | 7,045 | 14.83 | 27,381 | 139 | 3,301 |
| 1954 | 5,014 | 7,669 | 16.70 | 37,773 | 148 | 3,671 |
| 1955 | 5,586 | 8,359 | 11.97 | 39,984 | 166 | 4,102 |
| 1956 | 5,215 | 7,650 | 10.80 | 32,714 | 150 | 3,790 |

Table D. Basic data used in predicting fall farrowings in the United States and North Central Region, 1924-1936

| Year | No. of sows farrowing, June - Nov., U. S. (Refs. 51,52,57) | No. of sows farrowing, Dec. - May, U. S. (Refs. 51,52,57) | Production of corn, U. S. (Ref. 48) | Beef steer-corn ratio, Mar. - June, Chicago (Refs. 47,48) | No. of sows farrowing, June - Nov., N. Central Region (Refs. 51,52,57) | No. of sows farrowing, Dec. - May, N. Central Region (Refs. 51,52,57) |
|---|---|---|---|---|---|---|
| | (x $10^3$) | (x $10^3$) | (Tons x $10^3$) | (x $10^{-1}$) | (x $10^3$) | (x $10^3$) |
| 1923 | -- | -- | 80,508 | -- | -- | -- |
| 1924 | 4,344 | 9,799 | 62,247 | 120 | 3,723 | 8,658 |
| 1925 | 3,939 | 8,334 | 78,354 | 89 | 2,603 | 6,935 |
| 1926 | 4,330 | 9,048 | 71,315 | 131 | 2,870 | 7,380 |
| 1927 | 4,609 | 9,754 | 73,251 | 133 | 2,995 | 7,741 |
| 1928 | 4,429 | 9,301 | 74,634 | 127 | 2,883 | 7,446 |
| 1929 | 4,264 | 8,854 | 70,446 | 149 | 2,866 | 7,184 |
| 1930 | 4,074 | 8,278 | 58,244 | 144 | 2,844 | 6,764 |
| 1931 | 4,797 | 8,971 | 72,126 | 133 | 3,321 | 7,328 |
| 1932 | 5,180 | 8,811 | 82,050 | 199 | 3,503 | 6,882 |
| 1933 | 5,208 | 9,123 | 67,133 | 152 | 3,656 | 7,098 |
| 1934 | 2,935 | 6,825 | 40,570 | 129 | 1,688 | 5,147 |
| 1935 | 3,857 | 5,467 | 64,382 | 125 | 2,432 | 3,836 |
| 1936 | 3,957 | 6,954 | 42,159 | 131 | 2,300 | 5,013 |

Table E. Basic data used for Equations 50, 54 and 55 of the two-equation models, 1924-1937

| Year | Liveweight of hogs slaughtered under Federal inspection, Aug. - Jan., U. S. (Refs. 49,59,61) | Pigs saved from spring pig crop, U. S. (Ref. 49) | Production of feed grains, U. S. (Ref. 48) | Time | Hog price, Aug. - Jan., U. S. (Refs. 49,59,61) |
|---|---|---|---|---|---|
| | (Lbs. x $10^5$) | (x $10^3$) | (Tons x $10^3$) | (Index) | (Dollars/cwt.) |
| 1924 | 57,968 | 50,218 | 90,514 | 1 | 8.80 |
| 1925 | 48,577 | 47,859 | 106,988 | 2 | 11.17 |
| 1926 | 47,494 | 50,579 | 95,638 | 3 | 11.53 |
| 1927 | 51,512 | 54,502 | 98,647 | 4 | 9.02 |
| 1928 | 56,234 | 52,390 | 105,575 | 5 | 9.22 |
| 1929 | 56,763 | 50,479 | 96,288 | 6 | 9.19 |
| 1930 | 52,858 | 49,332 | 86,853 | 7 | 8.38 |
| 1931 | 53,623 | 53,984 | 96,790 | 8 | 4.54 |
| 1932 | 52,616 | 51,031 | 111,027 | 9 | 3.30 |
| 1933 | 54,743 | 53,460 | 83,996 | 10 | 3.56 |
| 1934 | 43,789 | 39,698 | 52,595 | 11 | 5.48 |
| 1935 | 32,164 | 32,884 | 92,172 | 12 | 9.37 |
| 1936 | 45,023 | 41,422 | 59,173 | 13 | 9.33 |
| 1937 | 40,909 | 38,525 | 99,975 | 14 | 9.20 |

Table E. (Continued)

| Year | Index of Prices Received for All Livestock, Aug. - Jan., U. S. (Ref. 43) | Total disposable personal income, average of last two quarters, U. S. (Refs. 41,54) | Total population, average of July 1 and Jan. 1, U. S. (Refs. 41,54) | Index of Consumer Prices, average of last two quarters, U. S. (Refs. 41,54) |
|---|---|---|---|---|
| | (1947-49 = 100) | (Dollars x $10^9$) | (x $10^6$) | (1947-49 = 100) |
| 1924 | 47 | 70.6 | 116.2 | 73.6 |
| 1925 | 53 | 74.4 | 117.9 | 75.2 |
| 1926 | 53 | 76.5 | 119.4 | 75.3 |
| 1927 | 52 | 77.2 | 121.1 | 74.0 |
| 1928 | 55 | 79.8 | 122.6 | 73.3 |
| 1929 | 54 | 80.9 | 123.8 | 72.8 |
| 1930 | 43 | 69.7 | 125.1 | 69.8 |
| 1931 | 31 | 58.8 | 126.0 | 63.4 |
| 1932 | 25 | 44.6 | 126.8 | 57.6 |
| 1933 | 25 | 47.8 | 127.6 | 55.8 |
| 1934 | 32 | 52.3 | 128.4 | 57.6 |
| 1935 | 41 | 59.6 | 129.2 | 58.8 |
| 1936 | 42 | 68.2 | 130.0 | 59.8 |
| 1937 | 43 | 70.4 | 130.9 | 60.1 |

Table F. Basic data used for Equations 51, 58 and 59 of the two-equation models, 1938-1956

| Year | Liveweight of hogs slaughtered under Federal inspection, Aug. - Jan., U. S. (Refs. 49,59,61) | Pigs saved from spring pig crop, U. S. (Ref. 49) | Production of feed grains, U. S. (Ref. 48) | Time | Hog price, Aug. - Jan., U. S. (Refs. 49,59,61) |
|---|---|---|---|---|---|
| | (Lbs. x $10^5$) | (x $10^3$) | (Tons x $10^3$) | (Index) | (Dollars/cwt.) |
| 1938 | 47,722 | 43,289 | 96,701 | 15 | 7.38 |
| 1939 | 56,440 | 53,238 | 95,653 | 16 | 5.88 |
| 1940 | 61,232 | 49,567 | 98,445 | 17 | 6.05 |
| 1941 | 62,602 | 49,455 | 104,827 | 18 | 10.33 |
| 1942 | 71,162 | 61,093 | 120,561 | 19 | 13.76 |
| 1943 | 89,901 | 74,223 | 111,882 | 20 | 13.38 |
| 1944 | 68,423 | 55,754 | 116,291 | 21 | 13.60 |
| 1945 | 57,043 | 52,216 | 113,613 | 22 | 14.12 |
| 1946 | 57,012 | 52,191 | 122,837 | 23 | 21.17 |
| 1947 | 65,537 | 52,199 | 93,940 | 24 | 25.58 |
| 1948 | 65,096 | 50,468 | 135,134 | 25 | 23.63 |
| 1949 | 73,656 | 56,969 | 119,729 | 26 | 17.07 |
| 1950 | 78,401 | 57,958 | 121,368 | 27 | 19.63 |
| 1951 | 83,375 | 61,298 | 112,771 | 28 | 18.98 |
| 1952 | 78,179 | 55,135 | 119,490 | 29 | 18.12 |
| 1953 | 65,383 | 47,940 | 117,258 | 30 | 22.75 |
| 1954 | 74,578 | 52,852 | 123,394 | 31 | 18.62 |
| 1955 | 85,923 | 57,690 | 130,417 | 32 | 13.27 |
| 1956 | 78,442 | 53,136 | 129,350 | 33 | 15.82 |

Table F. (Continued)

| Year | Index of Prices Received for All Livestock, Aug. - Jan., U. S. (Ref. 43) | Total disposable personal income, average of last two quarters, U. S. (Refs. 41,54) | Total population, average of July 1 and Jan. 1, U. S. (Refs. 41,54) | Index of Consumer Prices, average of last two quarters, U. S. (Refs. 41,54) |
|---|---|---|---|---|
| | (1947-49 = 100) | (Dollars x $10^9$) | (x $10^6$) | (1947-49 = 100) |
| 1938 | 38 | 66.0 | 131.9 | 60.1 |
| 1939 | 38 | 71.8 | 133.0 | 59.5 |
| 1940 | 40 | 78.2 | 134.3 | 60.6 |
| 1941 | 52 | 98.5 | 135.6 | 64.6 |
| 1942 | 63 | 126.9 | 137.2 | 70.8 |
| 1943 | 68 | 134.2 | 139.0 | 74.3 |
| 1944 | 68 | 148.3 | 140.7 | 75.6 |
| 1945 | 73 | 148.4 | 142.2 | 78.5 |
| 1946 | 94 | 163.4 | 144.1 | 86.4 |
| 1947 | 105 | 173.2 | 146.8 | 97.3 |
| 1948 | 107 | 192.2 | 149.4 | 102.6 |
| 1949 | 91 | 186.8 | 152.0 | 102.0 |
| 1950 | 104 | 212.4 | 154.5 | 104.8 |
| 1951 | 114 | 230.4 | 157.2 | 111.6 |
| 1952 | 101 | 241.4 | 160.0 | 113.7 |
| 1953 | 92 | 251.6 | 162.6 | 114.5 |
| 1954 | 83 | 256.2 | 165.4 | 114.7 |
| 1955 | 79 | 276.1 | 168.3 | 114.9 |
| 1956 | 81 | 290.8 | 171.2 | 116.2 |

Table G. Basic data used for Equations 60, 64 and 65 of the two-equation models, 1924-1937

| Year | Liveweight of hogs slaughtered under Federal inspection, Feb. - July, U. S. (Refs. 49,59,61) | Pigs saved from fall pig crop, U. S. (Ref. 49) | Production of feed grains, U. S. (Ref. 48) | Time | Hog price, Feb. - July, U. S. (Refs. 49,59,61) |
|---|---|---|---|---|---|
| | (Lbs. x $10^5$) | (x $10^3$) | (Tons x $10^3$) | (Index) | (Dollars/cwt.) |
| 1923 | -- | 30,674 | 105,606 | -- | -- |
| 1924 | 59,433 | 23,847 | 90,514 | 1 | 6.62 |
| 1925 | 46,354 | 22,451 | 106,988 | 2 | 11.12 |
| 1926 | 47,812 | 24,865 | 95,638 | 3 | 12.06 |
| 1927 | 52,372 | 26,744 | 98,647 | 4 | 9.81 |
| 1928 | 58,512 | 26,292 | 105,575 | 5 | 8.34 |
| 1929 | 54,027 | 25,646 | 96,288 | 6 | 9.86 |
| 1930 | 50,657 | 24,803 | 86,853 | 7 | 9.12 |
| 1931 | 49,300 | 29,192 | 96,790 | 8 | 6.48 |
| 1932 | 50,748 | 31,494 | 111,027 | 9 | 3.50 |
| 1933 | 55,718 | 30,740 | 83,996 | 10 | 3.53 |
| 1934 | 47,654 | 17,068 | 52,595 | 11 | 3.65 |
| 1935 | 28,260 | 23,260 | 92,172 | 12 | 7.96 |
| 1936 | 36,285 | 24,303 | 59,173 | 13 | 9.09 |
| 1937 | 32,655 | 23,994 | 99,975 | 14 | 9.58 |

Table G. (Continued)

| Year | Index of Prices Received for All Livestock, Feb. - July, U. S. (Ref. 43) | Total disposable personal income, average of first two quarters, U. S. (Refs. 41,54) | Total population, average of Jan. 1 and July 1, U. S. (Refs. 41,54) | Index of Consumer Prices, average of first two quarters, U. S. (Refs. 41,54) |
|---|---|---|---|---|
| | (1947-49 = 100) | (Dollars x $10^9$) | (x $10^6$) | (1947-49 = 100) |
| 1923 | -- | -- | -- | -- |
| 1924 | 41 | 69.4 | 115.2 | 73.0 |
| 1925 | 49 | 72.7 | 117.1 | 74.5 |
| 1926 | 51 | 75.7 | 118.6 | 75.4 |
| 1927 | 48 | 76.6 | 120.3 | 74.6 |
| 1928 | 51 | 78.2 | 121.8 | 73.5 |
| 1929 | 55 | 82.0 | 123.2 | 73.3 |
| 1930 | 47 | 77.6 | 124.5 | 71.9 |
| 1931 | 34 | 67.3 | 125.6 | 66.6 |
| 1932 | 24 | 51.0 | 126.4 | 60.0 |
| 1933 | 23 | 42.6 | 127.2 | 56.1 |
| 1934 | 26 | 51.0 | 128.0 | 56.7 |
| 1935 | 38 | 56.6 | 128.8 | 58.3 |
| 1936 | 40 | 64.0 | 129.6 | 59.2 |
| 1937 | 42 | 71.7 | 130.4 | 60.9 |

Table H. Basic data used for Equations 61, 68 and 69 of the two-equation models, 1938-1956

| Year | Liveweight of hogs slaughtered under Federal inspection, Feb. - July, U. S. (Refs. 49,59,61) | Pigs saved from fall pig crop, U. S. (Ref. 49) | Production of feed grains, U. S. (Ref. 48) | Time | Hog price, Feb. - July, U. S. (Refs. 49,59,61) |
|---|---|---|---|---|---|
| | (Lbs. x $10^5$) | (x $10^3$) | (Tons x $10^3$) | (Index) | (Dollars/cwt.) |
| 1937 | -- | 23,994 | 99,975 | -- | -- |
| 1938 | 36,357 | 28,566 | 96,701 | 15 | 7.96 |
| 1939 | 43,872 | 33,714 | 95,653 | 16 | 6.58 |
| 1940 | 53,971 | 30,273 | 98,445 | 17 | 5.12 |
| 1941 | 52,994 | 35,580 | 104,827 | 18 | 8.30 |
| 1942 | 60,839 | 43,810 | 120,561 | 19 | 12.98 |
| 1943 | 77,361 | 47,584 | 111,882 | 20 | 14.06 |
| 1944 | 93,554 | 30,905 | 116,291 | 21 | 12.83 |
| 1945 | 51,084 | 34,611 | 113,613 | 22 | 14.05 |
| 1946 | 58,245 | 30,503 | 122,837 | 23 | 14.67 |
| 1947 | 57,542 | 31,090 | 93,940 | 24 | 23.50 |
| 1948 | 55,812 | 33,358 | 135,134 | 25 | 21.90 |
| 1949 | 58,341 | 36,275 | 119,729 | 26 | 19.03 |
| 1950 | 62,847 | 39,423 | 121,368 | 27 | 17.62 |
| 1951 | 69,465 | 39,288 | 112,771 | 28 | 20.92 |
| 1952 | 71,779 | 33,694 | 119,490 | 29 | 18.07 |
| 1953 | 59,167 | 29,974 | 117,258 | 30 | 21.68 |
| 1954 | 56,557 | 33,978 | 123,394 | 31 | 23.88 |
| 1955 | 64,197 | 38,029 | 130,417 | 32 | 16.48 |
| 1956 | 73,558 | 36,535 | 129,350 | 33 | 14.15 |

Table H. (Continued)

| Year | Index of Prices Received for All Livestock, Feb. - July, U. S. (Ref. 43) | Total disposable personal income, average of first two quarters, U. S. (Refs. 41,54) | Total population, average of Jan. 1 and July 1, U. S. (Refs. 41,54) | Index of Consumer Prices, average of first two quarters, U. S. (Refs. 41,54) |
|---|---|---|---|---|
| | (1947-49 = 100) | (Dollars x $10^9$) | (x $10^6$) | (1947-49 = 100) |
| 1937 | -- | -- | -- | -- |
| 1938 | 38 | 65.2 | 131.4 | 60.6 |
| 1939 | 36 | 68.8 | 132.4 | 59.6 |
| 1940 | 36 | 73.7 | 133.6 | 59.8 |
| 1941 | 44 | 86.2 | 135.0 | 62.2 |
| 1942 | 56 | 107.5 | 136.4 | 68.0 |
| 1943 | 68 | 132.0 | 138.2 | 72.9 |
| 1944 | 66 | 144.7 | 139.9 | 74.9 |
| 1945 | 71 | 153.0 | 141.4 | 76.5 |
| 1946 | 76 | 152.7 | 143.0 | 81.8 |
| 1947 | 95 | 166.5 | 145.4 | 92.5 |
| 1948 | 106 | 185.8 | 148.1 | 101.0 |
| 1949 | 94 | 189.6 | 150.7 | 102.0 |
| 1950 | 92 | 199.9 | 153.2 | 102.6 |
| 1951 | 116 | 221.8 | 155.8 | 109.0 |
| 1952 | 106 | 232.2 | 158.6 | 112.9 |
| 1953 | 94 | 249.1 | 161.3 | 114.2 |
| 1954 | 90 | 252.6 | 164.0 | 114.7 |
| 1955 | 82 | 264.0 | 166.9 | 114.6 |
| 1956 | 78 | 282.6 | 169.8 | 115.8 |

Table I. Basic data used for the 21-equation model, 1924-1937

| Year | $Q_h$ (Refs. 49,59,61) | $Q_b$ (Refs. 49,59,61) | $Q_d$ (Refs. 44,45) | $Q_p$ (Refs. 53,56) | $Q_e$ (Ref. 53) | $P_h$ (Refs. 49,59,61) |
|---|---|---|---|---|---|---|
| | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (No. x $10^6$) | (Dollars/cwt.) |
| 1924 | 17,075 | 14,007 | 89,240 | 2,401 | 34,592 | 7.34 |
| 1925 | 14,772 | 14,029 | 90,699 | 2,472 | 34,969 | 10.91 |
| 1926 | 14,714 | 14,236 | 93,325 | 2,537 | 37,248 | 11.79 |
| 1927 | 15,443 | 12,689 | 95,172 | 2,688 | 38,627 | 9.64 |
| 1928 | 16,713 | 11,401 | 95,843 | 2,640 | 38,659 | 8.54 |
| 1929 | 16,453 | 11,491 | 98,988 | 2,664 | 37,921 | 9.42 |
| 1930 | 15,553 | 11,524 | 100,158 | 2,861 | 39,067 | 8.84 |
| 1931 | 16,117 | 11,587 | 103,029 | 2,651 | 38,532 | 5.73 |
| 1932 | 16,413 | 11,296 | 103,810 | 2,746 | 36,298 | 3.34 |
| 1933 | 16,925 | 12,511 | 104,762 | 2,889 | 35,514 | 3.53 |
| 1934 | 15,210 | 13,984 | 101,621 | 2,685 | 34,429 | 4.14 |
| 1935 | 10,431 | 13,252 | 101,205 | 2,576 | 33,609 | 8.65 |
| 1936 | 13,273 | 14,638 | 102,410 | 2,882 | 34,534 | 9.37 |
| 1937 | 12,113 | 13,707 | 101,908 | 2,745 | 37,564 | 9.50 |

Table I. (Continued)

| Year | $P_b$ (Refs. 49,59,61,62) | $P_d$ (Ref. 43,45) | $P_p$ (Refs. 53,56,58) | $P_e$ (Ref. 53) | $I_f$ (Ref. 43) | $I_c$ (Refs. 41,54) |
|---|---|---|---|---|---|---|
| | (Dollars/cwt.) | (Dollars/cwt.) | (Cents/lb.) | (Cents/doz.) | (1947-49=100) | (1947-49=100) |
| 1924 | 5.84 | 2.22 | 19.7 | 26.7 | 44 | 73.1 |
| 1925 | 6.53 | 2.38 | 21.2 | 30.4 | 51 | 75.0 |
| 1926 | 6.75 | 2.38 | 22.8 | 28.9 | 52 | 75.6 |
| 1927 | 7.62 | 2.51 | 21.1 | 25.1 | 50 | 74.2 |
| 1928 | 9.52 | 2.52 | 22.1 | 28.1 | 53 | 73.3 |
| 1929 | 9.47 | 2.53 | 22.9 | 29.8 | 54 | 73.3 |
| 1930 | 7.71 | 2.21 | 18.5 | 23.7 | 46 | 71.4 |
| 1931 | 5.53 | 1.69 | 16.1 | 17.6 | 34 | 65.0 |
| 1932 | 4.25 | 1.28 | 11.8 | 14.2 | 25 | 58.4 |
| 1933 | 3.75 | 1.30 | 9.7 | 13.8 | 24 | 55.3 |
| 1934 | 4.13 | 1.55 | 12.0 | 17.0 | 28 | 57.2 |
| 1935 | 6.04 | 1.72 | 15.7 | 23.4 | 39 | 58.7 |
| 1936 | 5.82 | 1.88 | 15.4 | 21.8 | 41 | 59.3 |
| 1937 | 7.00 | 1.99 | 16.7 | 21.3 | 43 | 61.4 |

Table I. (Continued)

| Year | N (Refs. 41,54) | $S_s$ (Ref. 49) | $G_s$ (Ref. 48) | $G_p$ (Refs. 46,47) | A (Refs. 49,55,60,61) | T |
|---|---|---|---|---|---|---|
| | (x $10^6$) | (x $10^3$) | (Tons x $10^3$) | (Tons x $10^3$) | (Animal units) | (Index) |
| 1924 | 115.7 | 66,576 | 62,032 | 90,640 | 129,277 | 1 |
| 1925 | 117.5 | 55,770 | 51,707 | 107,105 | 119,309 | 2 |
| 1926 | 119.0 | 52,105 | 62,989 | 95,784 | 115,348 | 3 |
| 1927 | 120.7 | 55,496 | 51,900 | 98,815 | 118,921 | 4 |
| 1928 | 122.2 | 61,873 | 49,900 | 105,733 | 125,661 | 5 |
| 1929 | 123.5 | 59,042 | 52,036 | 96,387 | 123,391 | 6 |
| 1930 | 124.8 | 55,705 | 49,131 | 86,928 | 122,728 | 7 |
| 1931 | 125.8 | 54,835 | 43,705 | 96,935 | 122,800 | 8 |
| 1932 | 126.6 | 59,301 | 54,124 | 111,159 | 127,316 | 9 |
| 1933 | 127.3 | 62,127 | 64,122 | 84,105 | 130,946 | 10 |
| 1934 | 128.1 | 58,621 | 48,792 | 52,633 | 129,495 | 11 |
| 1935 | 129.0 | 39,066 | 28,718 | 92,287 | 107,832 | 12 |
| 1936 | 129.8 | 42,975 | 51,664 | 59,234 | 111,298 | 13 |
| 1937 | 130.6 | 43,083 | 30,493 | 100,115 | 111,016 | 14 |

Table I. (Continued)

| Year | $B_s$ (Refs. 49,55,61) | $D_s$ (Refs. 49,55,61) | $P_s$ (Refs. 49,55) | $H_s$ (Ref. 49) | $Y_d$ (Refs. 41,54) | $M_f$ (Refs. 41,54) |
|---|---|---|---|---|---|---|
| | (Animal units) | (Animal units) | (Animal units) | (No. x $10^3$) | (Dollars x $10^9$) | (Index) |
| 1924 | 11,173 | 25,749 | 12,501 | 389,626 | 69.6 | 11.84 |
| 1925 | 10,338 | 25,968 | 13,005 | 390,517 | 73.7 | 12.80 |
| 1926 | 9,500 | 25,788 | 13,067 | 393,849 | 76.4 | 13.10 |
| 1927 | 8,763 | 25,671 | 13,387 | 414,875 | 76.7 | 13.03 |
| 1928 | 8,453 | 25,775 | 14,110 | 427,139 | 78.7 | 12.61 |
| 1929 | 8,812 | 26,225 | 14,779 | 403,774 | 83.1 | 13.32 |
| 1930 | 10,193 | 27,052 | 13,895 | 420,451 | 74.4 | 13.45 |
| 1931 | 10,193 | 27,880 | 14,923 | 401,776 | 63.8 | 11.35 |
| 1932 | 10,111 | 29,084 | 15,309 | 385,826 | 48.7 | 9.88 |
| 1933 | 10,942 | 30,306 | 14,157 | 390,743 | 45.7 | 9.86 |
| 1934 | 11,011 | 31,354 | 14,936 | 385,341 | 52.0 | 10.56 |
| 1935 | 9,113 | 30,192 | 15,268 | 350,407 | 58.3 | 10.99 |
| 1936 | 11,032 | 29,297 | 13,637 | 362,619 | 66.2 | 11.66 |
| 1937 | 9,996 | 28,731 | 13,921 | 379,754 | 71.0 | 11.08 |

Table J. Basic data used for the 21-equation model, 1938-1956

| Year | $Q_h$ (Refs. 49,59,61) | $Q_b$ (Refs. 49,59,61) | $Q_d$ (Refs. 44,45) | $Q_p$ (Refs. 53,56) | $Q_e$ (Ref. 53) | $P_h$ (Refs. 49,59,61) |
|---|---|---|---|---|---|---|
| | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (Lbs. x $10^6$) | (No. x $10^6$) | (Dollars/cwt.) |
| 1938 | 13,736 | 13,653 | 105,807 | 2,697 | 37,356 | 7.74 |
| 1939 | 15,662 | 13,783 | 106,792 | 3,029 | 38,843 | 6.23 |
| 1940 | 18,044 | 14,067 | 109,412 | 3,157 | 39,707 | 5.39 |
| 1941 | 17,207 | 15,777 | 115,088 | 3,437 | 41,894 | 9.09 |
| 1942 | 19,275 | 17,194 | 118,533 | 3,945 | 48,610 | 13.00 |
| 1943 | 24,235 | 17,038 | 117,017 | 4,843 | 54,547 | 13.70 |
| 1944 | 23,958 | 18,344 | 117,023 | 4,694 | 58,537 | 13.10 |
| 1945 | 19,022 | 20,555 | 119,828 | 5,119 | 56,221 | 14.00 |
| 1946 | 19,386 | 18,688 | 117,697 | 4,592 | 55,962 | 17.50 |
| 1947 | 18,789 | 20,780 | 116,814 | 4,324 | 55,384 | 24.10 |
| 1948 | 17,923 | 18,115 | 112,671 | 4,060 | 54,899 | 23.10 |
| 1949 | 18,569 | 18,322 | 116,103 | 4,859 | 56,154 | 18.10 |
| 1950 | 19,372 | 18,411 | 116,602 | 5,189 | 58,954 | 18.00 |
| 1951 | 21,026 | 16,951 | 114,681 | 5,683 | 58,063 | 20.00 |
| 1952 | 21,002 | 18,442 | 114,671 | 5,831 | 58,068 | 17.80 |
| 1953 | 17,729 | 23,726 | 120,221 | 5,967 | 57,891 | 21.40 |
| 1954 | 17,438 | 24,807 | 122,094 | 6,372 | 58,933 | 21.60 |
| 1955 | 19,519 | 25,922 | 123,523 | 6,110 | 59,486 | 15.00 |
| 1956 | 20,009 | 27,460 | 126,739 | 7,188 | 61,042 | 14.40 |

Table J. (Continued)

| Year | $P_b$ (Refs. 49,59,61,62) | $P_d$ (Ref. 43,45) | $P_p$ (Refs. 53,56,58) | $P_e$ (Ref. 53) | $I_f$ (Ref. 43) | $I_c$ (Refs. 41,54) |
|---|---|---|---|---|---|---|
| | (Dollars/cwt.) | (Dollars/cwt.) | (Cents/lb.) | (Cents/doz.) | (1947-49=100) | (1947-49=100) |
| 1938 | 6.54 | 1.73 | 15.6 | 20.3 | 38 | 60.3 |
| 1939 | 7.14 | 1.69 | 14.0 | 17.4 | 37 | 59.4 |
| 1940 | 7.55 | 1.82 | 13.9 | 18.0 | 37 | 59.9 |
| 1941 | 8.80 | 2.19 | 16.7 | 23.5 | 47 | 62.9 |
| 1942 | 10.62 | 2.58 | 20.6 | 30.0 | 59 | 69.7 |
| 1943 | 11.90 | 3.12 | 25.9 | 37.1 | 68 | 74.0 |
| 1944 | 10.80 | 3.21 | 25.9 | 32.5 | 67 | 75.2 |
| 1945 | 12.10 | 3.19 | 27.8 | 37.7 | 72 | 76.9 |
| 1946 | 14.50 | 3.99 | 30.0 | 37.6 | 83 | 83.4 |
| 1947 | 18.50 | 4.27 | 29.2 | 45.3 | 99 | 95.5 |
| 1948 | 22.20 | 4.88 | 34.0 | 47.2 | 108 | 102.8 |
| 1949 | 19.80 | 3.95 | 27.8 | 45.2 | 93 | 101.8 |
| 1950 | 23.30 | 3.89 | 25.8 | 36.3 | 96 | 102.8 |
| 1951 | 28.70 | 4.58 | 28.6 | 47.7 | 115 | 111.0 |
| 1952 | 24.30 | 4.85 | 27.2 | 41.6 | 105 | 113.5 |
| 1953 | 16.30 | 4.31 | 26.5 | 47.7 | 93 | 114.4 |
| 1954 | 16.00 | 3.96 | 22.2 | 36.6 | 87 | 114.8 |
| 1955 | 15.60 | 4.02 | 24.3 | 38.9 | 81 | 114.5 |
| 1956 | 14.90 | 4.16 | 20.1 | 38.7 | 79 | 116.2 |

Table J. (Continued)

| Year | N (Refs. 41,54) | $S_s$ (Ref. 49) | $G_s$ (Ref. 48) | $G_p$ (Refs. 46,47) | A (Refs. 49,55,60,61) | T |
|---|---|---|---|---|---|---|
| | (x $10^6$) | (x $10^3$) | (Tons x $10^3$) | (Tons x $10^3$) | (Animal units) | (Index) |
| 1938 | 131.6 | 44,525 | 58,130 | 96,836 | 113,351 | 15 |
| 1939 | 132.7 | 50,012 | 62,126 | 95,760 | 117,690 | 16 |
| 1940 | 134.0 | 61,165 | 63,085 | 98,617 | 130,839 | 17 |
| 1941 | 135.3 | 54,353 | 64,129 | 105,054 | 127,788 | 18 |
| 1942 | 136.7 | 60,607 | 68,080 | 120,780 | 136,868 | 19 |
| 1943 | 138.6 | 73,881 | 75,988 | 112,101 | 156,367 | 20 |
| 1944 | 140.3 | 83,741 | 65,366 | 116,661 | 169,419 | 21 |
| 1945 | 141.8 | 59,373 | 69,619 | 113,806 | 149,688 | 22 |
| 1946 | 143.4 | 61,306 | 67,245 | 123,049 | 146,075 | 23 |
| 1947 | 146.1 | 56,810 | 73,264 | 94,126 | 141,992 | 24 |
| 1948 | 148.7 | 54,590 | 53,186 | 135,397 | 132,909 | 25 |
| 1949 | 151.3 | 56,257 | 83,933 | 120,601 | 133,438 | 26 |
| 1950 | 153.8 | 58,937 | 76,248 | 122,002 | 135,659 | 27 |
| 1951 | 156.5 | 62,269 | 72,804 | 112,906 | 141,911 | 28 |
| 1952 | 159.2 | 62,117 | 66,368 | 119,734 | 143,309 | 29 |
| 1953 | 161.9 | 51,755 | 72,665 | 117,624 | 139,064 | 30 |
| 1954 | 164.7 | 45,114 | 72,059 | 123,394 | 133,643 | 31 |
| 1955 | 167.6 | 50,474 | 73,246 | 130,417 | 139,041 | 32 |
| 1956 | 170.5 | 55,173 | 77,080 | 129,350 | 143,173 | 33 |

Table J. (Continued)

| Year | $B_s$ (Refs. 49,55,61) | $D_s$ (Refs. 49,55,61) | $P_s$ (Refs. 49,55) | $H_s$ (Ref. 49) | $Y_d$ (Refs. 41,54) | $M_f$ (Refs. 41,54) |
|---|---|---|---|---|---|---|
| | (Animal units) | (Animal units) | (Animal units) | (No. x $10^3$) | (Dollars x $10^9$) | (Index) |
| 1938 | 11,008 | 28,589 | 15,604 | 352,964 | 65.7 | 10.62 |
| 1939 | 10,930 | 29,010 | 13,552 | 376,141 | 70.4 | 10.37 |
| 1940 | 11,797 | 29,537 | 14,695 | 392,655 | 76.1 | 10.37 |
| 1941 | 13,007 | 30,225 | 16,297 | 381,315 | 93.0 | 10.82 |
| 1942 | 13,660 | 31,323 | 15,622 | 427,911 | 117.5 | 11.29 |
| 1943 | 14,726 | 32,379 | 18,093 | 488,959 | 133.5 | 11.33 |
| 1944 | 14,351 | 33,125 | 20,291 | 523,587 | 146.8 | 11.07 |
| 1945 | 15,236 | 33,002 | 23,732 | 473,880 | 150.4 | 12.14 |
| 1946 | 14,697 | 31,332 | 20,705 | 472,820 | 159.2 | 15.29 |
| 1947 | 14,803 | 30,578 | 23,456 | 431,446 | 169.0 | 17.45 |
| 1948 | 13,550 | 29,237 | 19,663 | 417,570 | 187.6 | 20.20 |
| 1949 | 15,035 | 28,425 | 19,068 | 399,380 | 188.2 | 20.80 |
| 1950 | 14,890 | 28,494 | 17,692 | 423,773 | 206.1 | 21.41 |
| 1951 | 15,793 | 28,300 | 21,680 | 399,338 | 226.1 | 22.35 |
| 1952 | 17,538 | 27,930 | 21,951 | 397,234 | 237.4 | 23.46 |
| 1953 | 19,908 | 28,498 | 25,115 | 373,013 | 250.2 | 24.15 |
| 1954 | 19,347 | 28,802 | 25,842 | 370,970 | 254.5 | 24.63 |
| 1955 | 20,426 | 28,222 | 26,208 | 368,595 | 270.2 | 25.36 |
| 1956 | 20,725 | 27,823 | 26,808 | 360,298 | 287.2 | 25.13 |