DYNAMICS OF THE HOG MARKET WITH EMPHASIS ON DISTRIBUTED LAGS IN SUPPLY RESPONSE

By

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A THESIS

Submitted to the School for Advanced Graduate Studies of
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AN ABSTRACT

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ABSTRACT

Instability has been a trademark of the hog industry. The instability has tended to be cyclical, a phenomenon explained most simply by Ezekiel's Cobweb Theorem. The hog market, for the most part, fulfills the conditions specified as necessary for the Cobweb Theorem to apply.

Ezekiel presumes in his Cobweb Theorem that producers expect present prices to continue through the production period. However, it seems unrealistic to believe that farmers naively expect present prices to continue in a market characterized by widely fluctuating prices. The Cobweb Theorem was modified in this study by applying a more general assumption that expected price is some positive function of past prices.

The effort was directed toward testing two hypotheses: (1) The response of hog production to actual prices is a distributed lag extending over more than one year with the response in the first year greater than that in the second, the response in the second greater than that in the third, etc., and (2) The hog market has cyclical tendencies and is convergent.

Two techniques were used to estimate distributed lags in supply response. One was the traditional regression approach of F. L. Alt and the other was the method proposed by Marc Nerlove. Estimates were obtained for three periods, 1908 to 1924, 1925 to 1941, and 1947 to 1958. The price of hogs and the price of corn in the previous fall and early winter periods were the main independent variables

and spring farrowings (1924-41 and 1947-1958) and hog slaughter (1908-1924) were the dependent variables.

Least squares estimates obtained by both Alt's and Nerlove's procedures gave substantial support to the first hypothesis. There was difficulty in obtaining reasonable estimates on the parameters of the Nerlove model, however.

A retail demand equation was estimated using quarterly data on the retail price of pork as the dependent variable and disposable income, supply of pork, supply of competing meats, time, population and dummy variables representing the seasons as independent variables. An estimating technique was used to mitigate the effect of autocorrelation in the residuals. Price flexibilities of the retail demand for pork at the means were found to be -.80, -.77, -.84, and -.73 for quarters one through four, respectively.

Equations representing the marketing margin for pork were estimated for each quarter. Combining these equations with the retail demand equation, the price flexibilities of the demand for hogs were estimated to be -2.09, -1.12, -1.33, and -1.56 for the four quarters, respectively.

By combining three equations, (1) the fourth quarter demand for hogs equation, (2) an equation relating spring farrowings to the fall supply of pork, and (3) a supply equation, a complete model of the hog market was constructed. By setting the exogenous variables at their means, a second order difference equation was constructed. Four such models were constructed using four alternative supply equations. From the solution of the difference equations, it was determined that all four models were cyclical and convergent, substantiating the second hypothesis. A cycle of five to six years was indicated.

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CHAPTER I

INTRODUCTION

The Problem

Instability has long been a trademark of the hog industry. The "invisible hand" which guides hog producers has been something less than satisfactory in achieving a stable supply of pork. With some degree of regularity, periods of relatively low production and attendant high prices have been followed within two or three years by periods of high production and low prices. This has triggered contractions which have proceeded for two or three years, completing the cycle. FIGURE 1 attests to this characteristic of the hog industry.

To say that instability is a problem is not to say that absence of change is desirable. New technology which modifies the cost structure in production, increasing population, changing consumer tastes and similar trends do require changes in hog production. It is believed, however, that the endogenous mechanism of the hog industry has certain oscillatory tendencies which represent a problem. This problem extends from the producer, through the markets and meat packers and to the consumer.

Producers

The instability of hog prices contributes to the uncertainty of selling prices. Optimum allocation of resources is difficult to achieve under conditions of uncertainty. This is because (1) farmers must

FIGURE 1. Total United States hog slaughter and the average annual price of medium weight barrows and gilts at Chicago, 1907 to 1958.

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use certain informal insurance schemes to cope with uncertainty and (2) expected prices used in allocating resources are often incorrect.

D. Gale Johnson, drawing from Hart's analysis of anticipation and business planning, lists four methods farmers use to cope with uncertainty--diversification, flexibility, liquidity and "risk aversion and combination of factors."[1] In brief, diversification is used to take advantage of offsetting price variations in different commodities and thereby reduce the variation in gross income. Flexibility allows adjustments to changing price relationships, based on the assumption that price can be predicted with more certainty as the selling time is approached. Liquidity permits the farmer to take advantage of favorable situations which require readjustment of plans involving purchases or to reduce the possibilities of loss of assets should an unfavorable circumstance arise. "Risk aversion and combination of factors" refers to the tendency to place a greater emphasis on the use of labor than other resources which may require fixed payments. The farmer can absorb a certain reduction in labor income but would be faced with loss of part of his total assets should a contingency develop.

To obtain liquidity, farmers place restrictions on themselves in borrowing money, a practice known as internal credit rationing. That is, they do not borrow all the money that is available to them. For similar reasons, credit agencies do not extend to farmers all the credit available to the agencies. This external credit rationing enables the lending agency to take advantage of unexpected favorable opportunities or adjust to contingencies.

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[1]D. Gale Johnson, Forward Prices for Agriculture (Chicago: The University of Chicago Press, 1947), pp. 44-46.

A. G. Hart, "Anticipations, Business Planning and the Cycle," Quarterly Journal of Economics, Vol. 51, (1937).

Survival is an important objective of a farming operation. A particular enterprise may offer higher long run profit than any other. But if the selling price is so unstable as to jeopardize the solvency of the farm in the short run, the long run profits would never be realized. Therefore, the farmer may select an enterprise which promises more stable profits than another enterprise though lower profits in the long run.

Uncertainty then results in certain inefficiencies in the selection of enterprises and allocation of resources. Heady states "Precautions which are taken to meet uncertainty almost always necessitate a sacrifice; they either result in a less-than-maximum product from given resources, or, conversely, do not allow a minimum cost for a given output."[2]

Although the informal insurance schemes mitigate the undesirable consequences of uncertainty, there are still the inefficiencies resulting from inaccurate expectations. Consider a farmer who could alternatively feed hogs or cattle. In any year he would select the enterprise which promised the greatest net profit. If the prices are highly uncertain, he would frequently make the wrong choice. His allocation of resources would be less than optimum in those years.

Market Agencies, Meat Packers, Consumers

Marketing agencies and meat packers in particular have fixed costs of land, plant, equipment and, to a certain extent, labor. They are interested in obtaining a steady flow of livestock to cover these costs. Yet, as can be observed in FIGURE 1, annual supplies of hogs have fluctuated over relatively wide ranges in past years.

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[2]Earl O. Heady, Economics of Agricultural Production and Resource Use, (New York: Prentice-Hall, Inc., 1952), p. 530.

There is reason to believe that consumers would prefer more steady supplies of pork from year to year in comparison with the prevailing situation. Consumer tastes do change, but changes are usually gradual and monotonic, not cyclical. Problems arise in rebuilding demand for pork when consumers have previously been forced to substitute other meat and poultry for scarce pork supplies.

Purpose of Study

The task of this study is to investigate the endogenous mechanism of the hog industry, employing some of the commonly held theories which have been used to explain the "hog cycle" and employing some new approaches as well. Previous explanations and tools of analysis are considered and used as a starting point.

Some Previous Explanations

Previous studies of factors causing cyclical tendencies in hog production have attributed this phenomenon to some combination of corn and hog prices in an earlier period.

One of the first and most comprehensive studies of hog prices was by Haas and Ezekiel.[3] They supported the theory of hog production cycles and pointed out that the main reason had been the failure of farmers to look ahead. They contended that farmers tended to expect present prices of hogs and corn to continue at present levels. In adjusting to this expectation, their collective efforts resulted in "overproduction" following periods of a favorable relationship between hog

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[3]G. C. Haas and Mordecai Ezekiel, Factors Affecting the Price of Hogs, U. S. Department of Agriculture, Bulletin No. 1440, (Washington: U. S. Government Printing Office, 1926).

and corn prices. The over-production and concomitant low or negative profit in feeding hogs then would cause farmers to cut back hog production unduly, since they would expect the low hog prices to continue. This tendency was termed the "self perpetuating mechanism" in the hog cycle.

In explaining this tendency, Haas and Ezekiel pointed out that hog production lagged hog and corn prices by about a year and a half. Using data from the 1903-1915 period they successively correlated monthly hog prices adjusted for seasonal variation with the "corn-hog differential" lagged 10 months, 12 months, 14 months, etc. on up to 22 months.[4] The correlation coefficient for an 18 month lag was -.504. The correlation coefficients for shorter lags were successively smaller negative numbers declining to -.131 for a 10 month lag. The correlation coefficients were also smaller negative numbers for longer lags declining to -.474 for a 22 month lag.

Elliott was the first to experiment with the response of farmers to the hog-corn ratio lagged by more than one time period in the same equation.[5] In analyzing the 1898 to 1916 period, he included the December hog-corn ratio, the previous June to November hog-corn ratio and the following January to March hog-corn ratio in explaining the receipts of hogs at Chicago in the following September to April period. In addition, other independent variables were "index of climate at farrowing time," "time," December steer-hog ratio, change in percentage of non-merchantable corn in Illinois and Iowa from the previous year, disease loss and estimated number of breeding sows on farms. The December

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[4]Ibid., p. 47, The "corn-hog differential" was computed by multiplying the price of corn by 11.42 (an average corn-hog ratio) and subtracting the result from the price of hogs.

[5]F. F. Elliott, Adjusting Hog Production to Market Demand, University of Illinois Agricultural Experiment Station, Bulletin No. 293, (Urbana: June, 1927).

and the previous June to November hog-corn ratios were by far the most important in explaining changes in receipts.

Wells considered lags which extended over a longer period than the time lags investigated by either Haas and Ezekiel or Elliott.[6] By graphical analysis for the 1919 to 1930 period, Wells observed that percent changes in federally-inspected hog slaughter were apparently related to the hog-corn ratio lagged one and two years.

Mordecai Ezekiel published his classic article on "The Cobweb Theorem" in 1938.[7] He assumed that hog production responded to prices two years before; that is, that farmers expect to receive the same price for their hogs as they did two years before. Ezekiel explained the hog cycle by means of the supply-demand chart shown in FIGURE 2.

He assumed the industry to be initially out of adjustment at (Q_1, P_1), with prices below equilibrium and production above. He also assumed that production was technically restricted to Q_2 in year 2, so that farmers could only partly adjust production in response to P_1 within a year's time. In year 3, farmers would continue to expect P_1 and would decrease production from Q_2 to Q_3. But Q_3 would bring a price of P_3. In year 4, production would increase to Q_4, as given by the technical restriction, and then to Q_5 in year 5 as the response to P_3 is completed. But Q_5 only brings price P_5 and the next cycle begins.

In this model, the slopes of the supply and demand curves are equal except for sign and account for the constant amplitude of variation

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[6]Oris V. Wells, Farmers' Response to Price in Hog Production and Marketing, U. S. Department of Agriculture, Technical Bulletin No. 359, (Washington: U. S. Government Printing Office, April, 1933).

[7]Mordecai Ezekiel, "The Cobweb Theorem," Quarterly Journal of Economics, Volume 51, (February, 1938), pp. 255-280.

in production and price and the continuous fluctuations through time.

Ezekiel explained two other theoretical cases. For simplification, these are illustrated with time lags of one year. One was a situation in which the slope of the supply curve is greater than the slope of the demand curve (FIGURE 3). This leads to convergency over time to the equilibrium price and quantity.

The other case is divergent and would theoretically exist if the slope of the supply curve was less than the slope of the demand curve (FIGURE 4).

The three cases of the Cobweb Theorem were delineated by the comparison of the slopes of the supply and demand curves. The same delineation can be made by comparing the elasticities of supply and demand at the intersection of the two curves.

Linear demand and and supply equations were assumed in these illustrations. The Cobweb Theorem also applies to non-linear functions. But since the slopes of non-linear functions are not constant throughout, such models may not be easily classified into one of the three above cases. One case may apply to one section of the supply and demand curves, and another case may apply to a different section.

Ezekiel set forth the following conditions which must be fulfilled for the Cobweb Theorem to apply:

(1) Production is completely determined by the producers' response to price, under conditions of perfect competition (where the producer bases plans for future production on the assumption that present prices will continue, and that his own production plans will not affect the market).

(2) The time needed for production requires at least one full period before production can be changed, once the plans are made.

(3) The price is set by the supply available.[8]

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[8]Mordezai Ezekiel, op. cit., pp. 437-438.

FIGURE 2. Case I of Ezekiel's Cobweb Theorem: Continuous fluctuation with a two year lag.

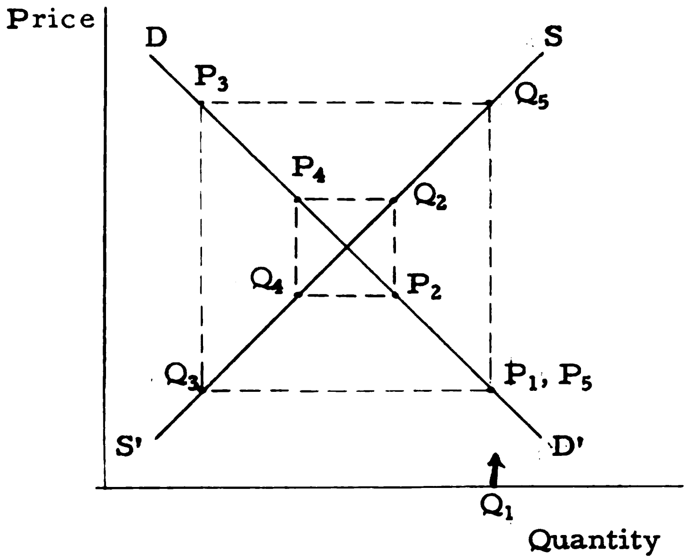


FIGURE 3. Case II of Ezekiel's Cobweb Theorem: Convergent fluctuation with a one year lag.

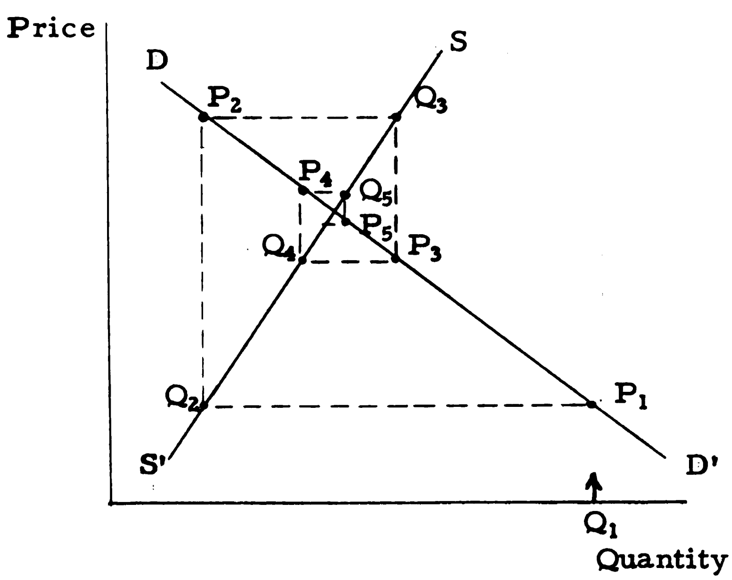
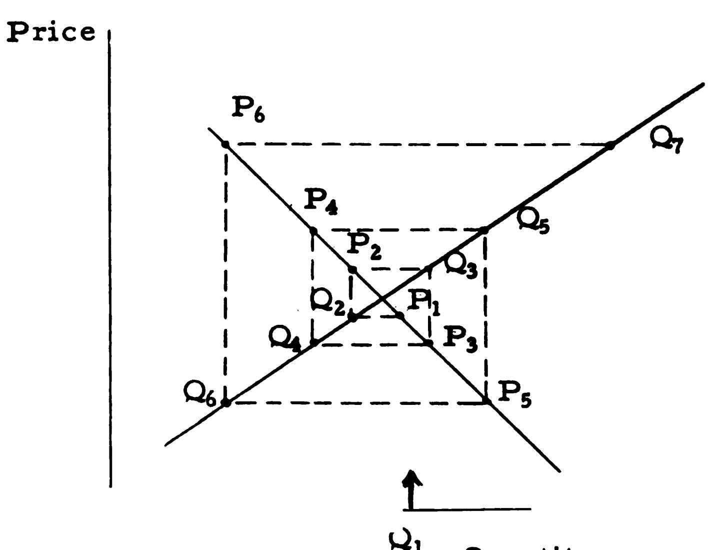


FIGURE 4. Case III of Ezekiel's Cobweb Theorem: Divergent fluctuation with a one year lag.



Kohls and Paarlberg explained changes in spring farrowings by September to November hog prices and September to November corn prices, these prices being considered separately.[9] These variables were deflated by the index of prices received by farmers. The application of the hog-corn ratio as a single variable involves the assumption that the effect of hog prices is equivalent to the effect of corn prices in causing farmers to react. There is no a priori reason to believe this is true. To avoid this difficulty, Kohls and Paarlberg separated hog and corn prices in their analysis.

Prominent among recent attempts to quantify the supply response for hogs is a study by G. E. Brandow at Pennsylvania.[10] Brandow used the hog-corn ratio in October to December to explain the number of sows farrowing in December to May. He also included a variable to account for changes in production of minor feed grains and a variable to account for differences between 1926-1941 to 1947-1956. He obtained an $\bar{R}^2$ of .83 in this equation, and found all estimates of the coefficients significant at the 5 percent level.

Gerald Dean, in his Ph. D. dissertation at Iowa, used an approach similar to Brandow but added a variable to account for the relative profitability of feeding beef cattle.[11] Dean analyzed two periods, 1924-1937 and 1938-1956, omitting 1942-1944. He studied the supply response in the North Central region in addition to the United States as a whole.

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[9] R. L. Kohls and Don Paarlberg, Short Time Response of Agricultural Production to Price and Other Factors, Purdue University Agricultural Experiment Station Bulletin 555, (Wast Lafayette: 1950).

[10] G. E. Brandow, Factors Associated with Numbers of Sows Farrowing in the Spring and Fall Seasons, Pennsylvania State University Agricultural Experiment Station, A. E. and R. S. #7, (University Park: August 1956).

[11] Gerald Wallace Dean, "Supply Function for Hogs," Unpublished Ph. D. dissertation, Iowa State College, (Ames: 1957).

Dean obtained highly significant regression coefficients on the hog-corn ratio in October to December and change in production of minor feed grains, using the first difference of sows farrowing in the following spring as the dependent variable.

His equations also included a variable to measure cattle feeding profits. In one equation, he tried the price margin between feeder cattle and slaughter cattle in the fall of the previous year. The sign on this variable was negative as expected for the 1938-56 period but positive in 1924-37. He tried another variable in its place, the price ratio between feeder cattle prices and hog prices in the fall of the year prior to farrowings. The sign on this variable was positive in the 1938-56 period and contrary to the expected sign.

Dean also considered distributed lags in the supply response of farrowings to the hog-corn ratio, using an approach suggested by Marc Nerlove.[12] Dean concluded that the production response was almost entirely to the hog-corn ratio in the fall prior to farrowings; that the hog-corn ratio in earlier years had no significant effect.

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[12]Nerlove's technique will be discussed in Chapter III.

CHAPTER II

STRUCTURE OF THE INDUSTRY AND THEORETICAL BASIS

The Characteristics of Hog Production and Marketing

This section is devoted to a presentation of some facts about hog production and marketing. These facts are relevant to the discussion of the competitive structure of the hog industry in the second section of this chapter and the development of the supply and demand equations in subsequent chapters.

Producer Level

The 1954 Census of Agriculture reported hogs were being produced on 2, 365, 708 farms in the United States, a large number although considerably less than the 3, 011, 807 farms with hogs in 1950.[1] In 1920, 4, 805, 807 farms were reported raising hogs. During this same period, the total number of farms in the United States declined from 6, 448, 343 in 1920 to 4, 782, 416 in 1954. The decline in the number of farms with hogs has been even more striking than the downward trend in the total number of farms.

The shift to fewer farms raising hogs has involved an increase in the number of hogs per farm. The average number sold per farm in 1954 was 40 as compared to 32 in 1944.[2]

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[1]U. S. Department of Commerce, Bureau of the Census, Census of Agriculture: 1954 (Washington: U. S. Government Printing Office), Vol. II, General Report, p. 434.

[2]Ibid., p. 509.

Half of the farms producing hogs sold fewer than 20 hogs in 1954. Only 11 percent sold more than 100 hogs.[3]

Hog production is concentrated in the Corn Belt. The North Central states have accounted for nearly three-fourths of the pigs saved. (See TABLE 1)

Most of the corn produced has been fed out on the same farm where it was grown. Typically, hogs are produced in combination with other livestock, principally beef or dairy cattle.

TABLE 1. Proportion of total pigs saved in the United States by regions, 1930 to 1958.[a]

	Percent of Total					
	Region					
Time Period	North Atlantic	North Central	South Atlantic	South Central	West	Total U. S.
1930-34	1.7	75.6	6.5	12.3	3.9	100.0
1935-39	2.4	67.8	8.9	16.4	4.5	100.0
1940-44	2.1	70.9	7.8	14.7	4.5	100.0
1945-49	2.2	72.4	8.4	13.8	3.2	100.0
1950-54	2.0	76.2	8.2	11.2	2.4	100.0
1955-58	1.7	76.7	8.4	11.0	2.1	100.0

[a]Calculated from: U. S. Department of Agriculture, Agricultural Marketing Service, Pig Crops by States, 1930-54 (Statistical Bulletin No. 187, July, 1956) and Pig Crop Reports of December 1956, 1957 and 1958 (Washington: U. S. Government Printing Office)

Average fixed costs in hog production have been low relative to average total costs. Feed has been, by far, the most important cost, typically representing 70 to 80 percent of the total cost in commercial hog operations. A study of Central Illinois farms in 1924-1926 indicated

[3]*Ibid.*, p. 505.

that feed and pasture comprised 84 percent of the cost of producing 100 pounds of marketable pork.[4] A study by Haver in 1950 showed feed costs on a 20-sow herd operation to represent 71 percent of the total cost in production.[5] He found labor costs were about 8 percent of the total, and fixed costs only 7 percent of the total.

Information is scarce on the role played by "inners and outers" in hog production though they are believed important in changes. Wells reported on a survey in 1926 which indicated that 80 percent of the increase in farrowings intended for the spring of 1927 was from farmers who had no sows in the previous spring.[6]

The organization of the hog enterprise on Corn Belt farms has been predominantly based on the one or the two litter systems. A trend is evident toward more two litter systems. In 1924, 21 percent of the farrowings was in the fall season. In 1958, 44 percent of the total farrowings was in the fall.[7]

Markets

Several different market outlets have taken a sizeable share of total hog marketings during the period of this study (1907 to 1958). Early in this period, the terminal market was predominant. In 1923, 77 percent of the hogs slaughtered under federal inspection were purchased from terminal markets.[8] By 1956, this percentage had

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[4]R. H. Wilcox, W. E. Carroll, and T. G. Hornung, Some Important Factors Affecting Costs in Hog Production, University of Illinois Agricultural Experiment Station Bulletin 390, (Urbana: June 1933), p. 11.

[5]Cecil B. Haver, Economic Aspects of Hog Production in North Dakota, North Dakota Agricultural Experiment Station Bulletin No. 391, (Fargo: June 1954), p. 15.

[6]Oris V. Wells, *op. cit.*, p. 34.

[7]Calculated from the source noted in TABLE 1.

[8]U. S. Department of Agriculture, Market Outlets for Livestock Producers, Marketing Research Report No. 216, (Washington, D. C.: U. S. Government Printing Office, March 1958), p. 5.

declined to about 37 percent. The percentage purchased from terminal markets by non-federally inspected slaughtering plants has been somewhat less than by federally inspected plants. The proportion of all hogs sold through the major channels in 1955 is shown in TABLE 2.

TABLE 2. Hogs and pigs sold by farmers through different market outlets, United States, 1955.[a]

Outlet	Percentage
Terminal public markets	30.8
Auctions	16.5
Country sales	
Direct to packers	21.4
Local dealers	25.3
Farmers	4.9
Total country sales	51.6
All others	1.1
Total	100.0

[a]*Market Outlets for Livestock Producers*, *op. cit.*, p. 11.

Auction markets have increased rapidly in number over the last 30 years. An estimated 200 were in operation in 1930, 1,345 in 1937, 2,500 in 1952 and about 2,322 in 1955.[9]

"Country selling" has become relatively important. Included in this category is direct selling to packers which has become the dominant method of marketing hogs in many parts of the Corn Belt.

Since 1921, the Packers and Stockyards Branch of the Agricultural Marketing Service has had jurisdiction over the 64 terminal markets, nearly 500 other "posted" markets, 1300 livestock commission firms

[9]*Ibid.*, p. 8.

and about 200 livestock dealers, with the responsibility of preventing unfair trade practices.[10]

Packer Level

The meat packing industry is characterized by a few large firms along with many small independent firms. The number of meatpacking establishments increased from 1221 to 1909 to 1478 in 1939 to 2367 in 1954.[11] A sizeable portion of the total hog slaughter has been handled by 4 companies. These 4 companies processed 51 percent of the total commercial hog slaughter in 1916. Since 1921, they have handled remarkably close to 40 percent of the total commercial hog slaughter each year.

The recent rapid expansion in the number of packing plants has been mainly in non-federally inspected plants slaughtering over two million pounds of livestock per year. The number of these plants increased by a third in 1950 to 1955.[12] These were owned almost exclusively by independent operators. In this same period, the number of plants owned by dominant firms have remained the same or declined. At the same time, there has been a trend toward geographic decentralization of the meat packing industry.

Meat packers obtain about 71 pounds of edible pork products from 100 pounds of liveweight of hogs. About 47 pounds of the edible products are major fresh and cured cuts sold in the wholesale trade to retailers.

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[10]United States Senate, Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, Unfair Trade Practices in the Meat Industry, (85th Congress, First Sess., 1957), p. 71.

[11]United States House of Representatives, Subcommittees of the Committee on the Judiciary and Committee on Interstate and Foreign Commerce, Hearings, Meatpackers, (85th Congress, First Sess., 1957), p. 141.

[12]Willard F. Williams, "Structural Changes in the Meat Wholesaling Industry," Journal of Farm Economics, XL (May 1958), p. 317.

Hams, loins, bacon, picnic, butts and spareribs are included in these cuts. About 9 pounds are minor edible products, which are mostly processed into sausage in the same plant where the hogs are slaughtered. Packers render about 15 pounds of lard from 100 pounds of live hog.[13]

Some wholesale cuts (loins, spareribs, butts, neckbone) are sold immediately to the retail trade. Some pork is cured or frozen (bellies, jowls, hams, picnics) and stored from fall and winter into the spring and summer. The amount stored from season to season has been relatively small. In 1948 to 1958, the additions to cold storage stocks of pork during October to December amounted to an average of 7 percent of total commercial production in those months. Additions in January to March represented 4 percent of commercial production in those months.

The labor cost represents about one-half of the gross margin of packers. Transportation costs have been about 10 percent of the gross margin.

Wholesale Level

Early in the 1907 to 1958 period covered in this study, a large proportion of the red meat moved from slaughter plants to retailers through packer branch houses. Most of these branch houses were owned by national packers. By 1929, about one-half of the total meat sales was handled by packer branches.[14]

Since 1929, the operations of the packer branch houses have declined and the importance of independent (non slaughtering) meat wholesalers has increased. Between 1929 and 1954, the number of packing

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[13] U. S. Department of Agriculture, Pork Marketing Margins and Costs, Miscellaneous Publication 711, (Washington: U. S. Government Printing Office, April 1956), pp. 29-30.

[14] Willard F. Williams, *op. cit.*, pp. 322-323.

house branches declined from 1157 to 664 as the number of wholesalers increased from 2225 to 4357.[15] Sales of wholesalers (deflated by price level) have doubled in this period and, in 1954, were about equal to the sales of packing house branches.

Direct sales have increased since the pre World War II period along with the expansion in the retail food chains. Some reversal of this trend is evident in recent years, but direct selling has remained an important marketing channel.[16]

Retail Level

In 1958, there were 175,500 independents (one to ten stores), 16,300 chains (eleven or more units) and 22,500 specialty stores (chains and independent) retailing meat.[17] In a recent year, the chains accounted for 38 percent of total sales. Of the super markets belonging to the Super Market Institute, 29 percent owned their central warehouse, 34 percent belonged to a cooperative, 18 percent belonged to a voluntary and 23 percent had no central warehouse or affiliation.[18]

Labor has been the most important cost item in retailing pork. A study by Farstad and Brensike showed that 65 percent of the total operating costs in retailing meat was labor.[19] None of the other items of expense amounted to more than 8 percent of the total.

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[15] Ibid., p. 323.

[16] Ibid., p. 324.

[17] Facts in Grocery Distribution (Progressive Grocer; 1958), p. F-3.

[18] The Supermarket Industry Speaks--1958 (Super Market Institute; Chicago: 1958), p. 16.

[19] E. Farstad and U. Brensike, Costs of Retailing Meats in Relation to Volume, Marketing Research Report No. 24, U. S. Department of Agriculture (Washington: U. S. Government Printing Office, August, 1952).

Relative Importance of Marketing Functions

The marketing margin on pork averaged 51 percent of the retail price in 1925 to 1941 and 39 percent in 1947 to 1958. TABLE 3 presents the relative importance of the various marketing functions to the total marketing margin.

TABLE 3. Distribution of the total marketing margin for pork and all meat in 1925-34 and for all meat in 1947.[a]

Marketing Function	1925-34 Pork (percent)	1925-34 All Meat (percent)	1947 All Meat (percent)
Retailing	38.2	50.2	44.9
Wholesaling	10.4	9.7	11.6
Meat Packing	42.4	31.7	37.1
Marketing of Livestock	9.0	8.4	6.4
Total Margin	100.0	100.0	100.0

[a]Kathryn Parr, Farm-to-Retail Margins for Livestock and Meat, (Washington, D. C.: U. S. Department of Agriculture, B.A.E., June 1949), p. 4 and 29.

The Competitive Structure

Producer Supply of Hogs

The characteristics of hog production outlined in the previous section suggest that the perfect competition model would be appropriate for analysis. The short run supply curve in the perfect competition model of static economic theory traces the relationship between price and the production which price brings forth. The supply curve is derived by aggregating the marginal cost curves of individual firms in the industry with allowance for possible economies or diseconomies of scale.

The aggregation includes the rising portion of the individual marginal cost curves above the intersection of the marginal cost curve and the average variable cost curve for producing firms and above the average total cost curve for potential producing firms.

A farmer would not rationally go into the hog business unless the price he expected was above his average total costs. On the other hand, if he were in, he would continue to produce as long as he covered average variable costs, even though hog prices may drop below average total costs. He would lose more by not producing hogs than by staying in and paying off at least part of his fixed costs.

This suggests that, within the lower ranges, there may be two aggregate supply curves, one when hog prices are increasing and another to the right of the first when hog prices are declining. However, this difference would be expected to be small, since the fixed costs in producing hogs are only a small part of the total.

The classical supply function involves the assumption that all other product prices are unchanged. To isolate the supply function for hogs, prices of other farm products must be taken into account.

Firms producing more than one commodity will adjust production in such a way that the ratio between the marginal cost in producing one commodity and its price is equal to this ratio for all other commodities. The adjustment will proceed to the point where the marginal cost of producing each commodity is equal to the price of that commodity.

In the perfect competition model, each firm attempts to allocate its inputs among several alternative enterprises in such a way that the marginal physical product of inputs times the price of the product of one enterprise is equal to the marginal physical product of these inputs times the price of the product of each of the other enterprises. This is a necessary though not sufficient condition for maximizing profits.

The sufficient condition is attained when the marginal physical product of the inputs times the price of the product is equal to the marginal factor cost of the inputs for each enterprise. If no firm is large enough to employ more than a small fraction of the total supply of inputs available, then each firm deals with a perfectly elastic supply curve for inputs. The marginal factor cost then equals the price of the inputs.

Livestock Markets

This segment of the marketing chain has features of a competitive market. In the major hog producing areas, farmers have several alternative market outlets. Entry into and exit from the livestock marketing trade is not difficult. These characteristics would tend to prevent livestock dealers, commission firms and stockyards from receiving large abnormal profits over an extended period. In any case, imperfections in competition would have only a small effect on the average price of hogs. The cost of livestock marketing has represented less than 10 percent of the total marketing margin.

The Meat Packing Industry

The assumptions of the perfect competition model do not fit the meat packing industry. This industry is characterized by a few dominant firms and many small relatively competitive firms.

According to Nicholls, evidence has been strong that the dominant meat packers have been price leaders but have not resorted to aggressive pricing policies among themselves or against the small packers.[20] Rather, they have followed market sharing practices with buying prices approaching the collusive-oligopsony level. At this level, the market share of each dominant firm has adjusted in such a way that any further

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[20]William H. Nicholls, Imperfect Competition Within Agricultural Industries, (Ames, Iowa: The Iowa State College Press, 1941), pp. 114-131.

change would have reduced the profits of at least one of the firms. Abnormal profits have likely persisted but have been limited by the threat of entry of new firms and anti-trust action, according to Nicholls.

Williams, in his evaluation of the meat wholesaling industry (packers and distributors), claims that the competitive structure of the industry has changed since Nicholls made his study; that it has taken on more of the attributes of the perfect market.[21] He cites that the increased use of uniform grade standards and market news has more equalized knowledge throughout the industry, tending to eliminate quality as a variable factor in bargaining. These developments along with decentralization and reduced concentration have resulted in more price competition, according to Williams.

To account for changing margins at the packer level, the analyses of Nicholls and Williams suggest an investigation of major cost items of meat packing firms. It will be assumed that abnormal profits have not been persistently large in the meat packing business and can be neglected in studying margins at the packer level. As packers face falling, then rising average cost curves with increasing supplies, the volume of slaughter would also affect the margins taken by packers. Margins at the packer level, then, are considered to depend mainly on the marginal costs of the most efficient firm or firms. Rising costs of operation, both fixed and variable, would adjust the total average cost curve of each firm upward and increase the minimum margin which firms would accept over any extended period of time. For short periods, the minimum could drop below the average total cost but not below the average variable cost. Increasing supplies of hogs at levels in excess of the minimum of the average total cost curves would tend to widen margins as marginal costs would be increasing in this range. On the

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[21]Willard F. Williams, op. cit., p. 328.

other hand, margins would tend to be inversely related to supplies at supply levels below the minimum of the average cost curve.

Retail Margins

The pricing of meat at retail has been based primarily on wholesale prices though modified by local competition. According to a U. S. Department of Agriculture publication on pork marketing margins, "The combined effect of price leadership by some retailers and the actual changes in wholesale prices themselves tend to bring about a general change in the level of retail pork prices."[22]

A North Central Regional study of principal methods of pricing retail cuts of meat found that 70 percent of the retailers were using "cents per pound markup," "percentage markup over cost," or "percentage of selling price (for margin)."[23] About 15 percent used meat pricing charts or guides and 15 percent used competitors prices only. Most used some combination of these methods.

These studies indicate that the focal point in pricing pork is at the packer level rather than at the retail level. This is also supported by the lag of retail prices behind changes in wholesale prices. This lag has generally been about one to two weeks.[24]

The Competitive Structure in Summary

The competitive structure of the hog market generally fulfills the conditions set forth by Ezekiel for the applicability of the Cobweb

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[22]U. S. Department of Agriculture, Pork Marketing Margins and Costs, op. cit., pp. 20-21.

[23]North Central Regional Livestock Marketing Research Committee, Retailing Meat in the North Central States, North Central Regional Publication No. 55; Purdue University, Station Bulletin 622, (Lafayette: March 1955), pp. 23-24.

[24]Hershel W. Little and Albert L. Meyers, Estimated Lags Between Farm, Wholesale and Retail Prices for Selected Foods, (U. S. Department of Agriculture Mimeograph), (Washington: June 1943), p. 5.

Theorem. The characteristics of hog production are compatible with the perfect competition model. Certain imperfections in competition in the marketing of hogs, particularly at the packer level, are recognized. However, the previous studies cited in this chapter suggest that the error would not be serious in regarding hog prices as set by the supply available in the short run. At least, supply could be considered the predominant factor.

CHAPTER III

EXPECTATIONS AND LAGS IN SUPPLY RESPONSE

The supply curve described on page 19, as applied to hog production, is a construction composed of the supply response curves of the individual hog producers and potential hog producers. This curve relates total production of hogs to prices expected for hogs. The individual supply curves are constructs involving production functions, expected prices of inputs, expected prices of alternative outputs in each farm situation, and a specified length of time. A change in any of these variables would change the industry supply curve.

A problem to be investigated is how to identify these expected prices, which are paramount to the determination of a supply curve (or curves), and supply elasticities.

Time Series Approach

In most studies of supply response in hogs, the assumption has been made that the expected price is equivalent to the actual price at the time or immediately preceding the time when the sows are bred and the production decision is made. Most of the attention has been directed toward predicting year to year changes in supply. Consequently the supply response has been measured in terms of the adjustments in one production period, usually within a year.

Ezekiel, in applying his Cobweb Theorem to hogs, considered that the production period could extend over two or more years.

Using a two year lag as an example, he assumed a given adjustment in production during the first year. The change in production during the second year completed the adjustment to the actual price of two years before, which Ezekiel assumed to be the expected price.

There are economic, technical and subjective reasons for lags in adjustment which extend over more than one production period. Some of the inputs in hog production are fixed for the enterprise in the span of one production period. This would include such items as hog houses, feeder equipment and breeding stock. For certain marginal hog producers, a drop in hog prices (or, more properly, expected hog prices) may encourage a shift to a business or enterprise which promises greater long run returns. However, they may delay the shift until the worth of their fixed assets in hog production has declined to a certain point. This point would theoretically be the level where the scrap value was equal to or greater than the discounted expected return from the asset during the remainder of its life, i.e.,

$$Vs \geq \sum_{i=1}^{n} \frac{Ei}{(1 + r)^i}$$

where Vs is the scrap value, i is the year, n is number of remaining years of the lifetime of the asset, Ei is the expected return in year i and r is the rate of return available to the farmer in an alternative investment of comparable risk.

Certain technical factors may limit expansion within one production period. A farmer expanding his hog enterprise or going into hogs for the first time may first decide to build a central farrowing house. Constructing a central farrowing house requires a certain amount of time. Because of this, his adjustment to expected price would not necessarily be registered within one production period.

In addition to the economic and technical restrictions, there are certain subjective reasons why the adjustment to price isn't immediate in one production period. Farmers are often reluctant to shift from one enterprise to another or adjust levels of production because of resistance to change or personal preferences, even when they know the profit alternatives.

Another reason which could be classified as subjective is the element of uncertainty and its effect on expectations. A given price change in a market characterized by frequent and extreme changes in price would likely involve a lagged response, even if, in fact, the price did remain stable at the new level for a long period of time. It would take some time before entrepreneurs would become confident that the new price level would be maintained.

Hicks was concerned with this problem and introduced the concept of elasticity of expectations. This he defined as the ratio of the proportional rise in expected future prices of a commodity to the proportional rise in its current price.[1] The elasticity would be one if the change in price expectation were equal to the change in price at the time the production decision was made. The price change would be expected to be permanent. The elasticity would be less than one if part of the price change was considered to be transitory and not likely to persist.

To summarize, the lag between supply and price involves two separate lags, (1) between a change in actual price and expected price and (2) between expected price and the adjustment to this expected price.

The response to an actual price change, then, involves an expectation lag and an adjustment lag, and may be considered as a function

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[1]J. R. Hicks, Value and Capital (Second Edition, Oxford: Oxford University Press, 1953), p. 205.

of time. This function may be assumed to be of various forms. A realistic example is given by Koyck as shown in FIGURE 5.[2]

In period t = 0, actual price (P) is allowed to rise instantaneously from a to b. The response in production (Y) is very small at first. The rate of response ($\frac{dY_t}{dt}$) reaches a maximum at the end of the first period (t = 1) and then tapers off. Production approaches the new equilibrium level (Y= k) asymptotically as t increases.

The function $\frac{dY_t}{dt}$ gives the distribution of the lag between price P and production response Y over the 8 time periods shown in FIGURE 5. If price P lagged only one year were used to explain supply response Y, it is evident that only part of the adjustment would be explained.

A drop in Pt would generate a downward reaction in production. If the parameters of the production response function to a price decrease are the negative of the response function to an increase, the function would be considered symmetrical. It is not necessary to assume this and in many cases it is more realistic to assume an asymmetrical relationship as pointed out in Chapter II. However, because of the relatively low fixed costs in hog production, asymmetry is likely to be negligible.

FIGURE 6 is a representation of the $\frac{dY_t}{dt}$ of FIGURE 5 in discrete changes. Statistical analysis of economic relations often involves discrete variables as a representation of continuous variables. The a_i represent the distributed lags, i.e., the change in Y in each production period in response to a change in price.

Multiple regression methods have been used to estimate the a_i, using Y_t as the dependent variable and the P_{t-i} as the explanatory variables.

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[2]L. M. Koyck, Distributed Lags and Investment Analysis (Amsterdam: North Holland Publishing Company, 1954), pp. 9-10.

FIGURE 5. Continuous time path of production response (Y) to a change in price (P).

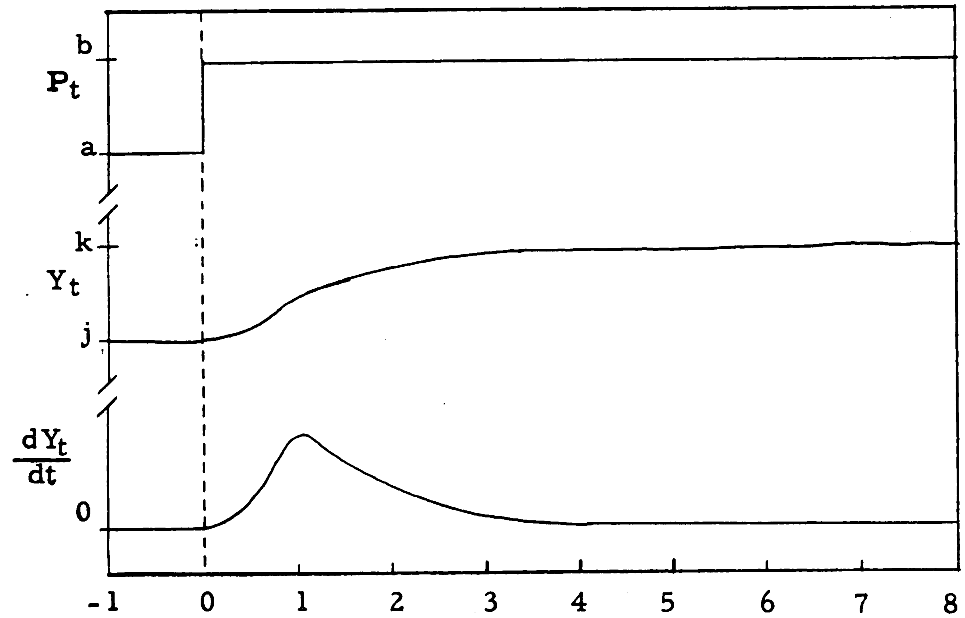
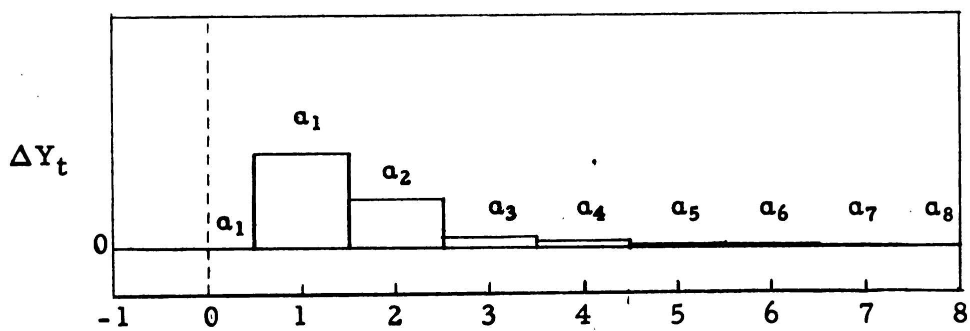


FIGURE 6. Discrete changes in the rate of production response (ΔY) to a change in price (P) in FIGURE 5.



Alt's Approach

Alt developed a method for estimating distributed lags with regression methods.[3] His approach was to successively compute the regression coefficients for $Y_t = f(P_t)$, $Y_t = f(P_t, P_{t-1})$, $Y_t = f(P_t, P_{t-1}, P_{t-2})$, $Y_t = f(P_t, P_{t-1}, P_{t-2}, P_{t-3})$ etc. until the coefficients ceased to make sense. Another criterion he used was the standard errors of the regression coefficients. P_{t-i} would be included as long as the a_i were significantly different from 0.

In Alt's approach, no assumption is necessary about the form of the distributed lag. His technique is an attempt to determine what that form is. This may be viewed as a weakness of this method since no theory of distributed lags is being tested other than establishing whether or not a distributed lag relationship exists.

A statistical problem in using the regression approach to estimate distributed lags is that time series, such as the P_{t-i}, are often serially correlated, hence there is often correlation between independent variables. Although correlation between independent variables does not invalidate an equation for prediction purposes, it does present difficulty in obtaining accurate estimates of the parameters.

Fisher's Approach

Irving Fisher recognized the distributed lag concept and placed some restrictions on the form that such a distribution would have.[4] The form he postulated as the most common was a type of probability curve skewed toward the right, i.e. the rate of response eventually

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[3]F. L. Alt, "Distributed Lags," Econometrica, Vol. 10, (1942), pp. 113-128.

[4]Irving Fisher, "Note on a Short Cut Method for Calculating Distributed Lags," Bulletin de L'Institut International de Statistique, Vol. 29, (La Haye: 1937).

tapers off with time after rising to an early peak. He suggested that a logarithmically normal distribution curve would therefore be appropriate.

Because of computational difficulties, he developed a short cut in which it was assumed that the greatest response to price was in the following time period. The response declines linearly in succeeding time periods. The procedure is illustrated by the following example. Using the regression technique, the following equations are considered consecutively.

$$(3.1) \quad Y_t = (3\,P_t + 2\,P_{t-1} + P_{t-2})$$

$$Y_t = (4\,P_t + 3\,P_{t-1} + 2\,P_{t-2} + P_{t-3})$$

$$Y_t = (5\,P_t + 4\,P_{t-1} + 3\,P_{t-2} + 2\,P_{t-3} + P_{t-4})$$

The trial which produces the highest correlation coefficient is chosen.

Koyck's Approach

Fisher's method assumed a linear decrease of lagged influences. Koyck developed a technique which assumed that there was a proportional decrease of lagged influences. Both approaches mitigated the problem of correlation between independent variables present in the standard regression approach.

Koyck's technique and assumptions are as follows.[5]

Let α_i be a series of coefficients $i = 0, 1, 2 \ldots$ in the supply response equation $Y_t = \sum_{i=0}^{\infty} \alpha_i \; P_{t-i}$. Assume that the α_i from $i \geq k$ can be approximated by a converging geometric series.

$$(3.2) \quad \alpha_{k+m} = \lambda\, \alpha_{k+m-1}$$

where $m \geq 0$ and $0 \leq \lambda < 1$

Then

[5]L. M. Koyck, *op. cit.*, p. 20.

$$(3.3)\quad Y_t = a_0 P_t + a_1 P_{t-1} + \dots + a_{k-1} P_{t-k+1}$$
$$+ a_k P_{t-k} + a_k \lambda P_{t-k-1} + a_k \lambda^2 P_{t-k-2} + \dots$$

For simplicity, assume P_t rises from a constant level,

$P_t = 0$ for $t \leq 0$, to a new level $P_t = 1$ for $t > 0$.

Letting $\sum_{i=0}^{k-1} a_i = \beta$

$$(3.4)\quad Y_{k+n} = \beta + a_k \lambda^2 + \dots + a_k \lambda^{n-1}$$

$$(3.5)\quad = \beta + \frac{a_k}{1-\lambda} - \frac{a_k}{1-\lambda} \lambda^n$$

The new equilibrium value of Y is then

$$(3.6)\quad \overline{Y} = \lim_{n \to \infty} Y_{k+n} = \beta + \frac{a_k}{1-\lambda}$$

The change in Y_{k+n} per unit of time is

$$(3.7)\quad \Delta Y_{k+n} = a_k \lambda^n$$

If we consider a simpler case where the entire adjustment path of Y can be approximated by an exponential curve, i.e. k = 0, then

$$(3.8)\quad Y_t = \sum_{i=0}^{\infty} a_i P_{t-i} \qquad \text{becomes}$$

$$(3.9)\quad Y_t = \sum_{j=0}^{\infty} a_0 \lambda^j P_{t-j} \qquad 0 \leq \lambda < 1$$

Then ΔY can be obtained by the following method.

$$(3.10)\quad Y_{t+1} = a_0 P_{t+1} + a_0 \lambda P_t + a_0 \lambda^2 P_{t-1} + \dots$$

$$(3.11)\quad \lambda Y_t = a_0 \lambda P_t + a_0 \lambda^2 P_{t-1} + \dots$$

$$(3.12)\quad Y_{t+1} - \lambda Y_t = a_0 P_{t+1}$$

Adding λY_t to and subtracting Y_t from both sides of (3.12)

(3.13) $$Y_{t+1} - Y_t = a_0 P_{t+1} - (1 - \lambda) Y_t$$

Then

(3.14) $$\Delta Y_t = a_0 P_{t+1} - \gamma Y_t \quad \text{where} \quad \gamma = 1 - \lambda$$

In this form only two coefficients (a_0 and γ) need to be estimated rather than the many that may be involved using traditional techniques.

At equilibrium $\Delta Y_t = 0$ and

(3.15) $$\overline{Y}_t = \frac{a_0}{\gamma} P_t$$

The coefficient for the long run reaction a is

(3.16) $$a = \frac{a_0}{\gamma}$$

It can be shown that the speed of the adjustment to the new equilibrium is indicated by γ. By substitution

(3.17) $$\Delta Y_t = \gamma (\overline{Y}_{t+1} - Y_t), \quad 0 < \gamma \leq 1.$$

An increase in the value of γ (up to 1) means that the rate of adjustment of Y_t to the equilibrium increases. A γ equal to 1 would mean that the entire adjustment would be made in 1 period.

Koyck's technique, then, was essentially to estimate the first few coefficients (up to k) of the increasing phase of the distributed lag function by traditional regression methods. He assumed the declining phase to be a converging geometric progression. With this restriction, the estimation of the coefficients k + m can be simplified.

At this point, the reader may have sensed the empirical problem which is developing. Essentially, two problems are involved. One is to obtain estimates of expected prices and the other is to obtain estimates of the distributed lags of adjustment in the response to expected prices. In models using time series, there is a difficult, if not impossible, task in isolating lags in adjustment from a measurement of expectations.

Nerlove's Approach

Marc Nerlove, drawing upon the concepts of Hicks and Koyck, has given considerable attention to these problems. Nerlove's approach as developed in his book, The Dynamics of Supply: Estimation of Farmer's Response to Price, is as follows:[6]

"The price which farmers expect at any time period can be considered as equivalent to the prices they expected in the period before but adjusted for the difference between the actual price and the price expected in the period before. That is

$$(3.18) \quad P^*_t = P^*_{t-1} + \beta\,[P_{t-1} - P^*_{t-1}] \qquad 0 < \beta \leq 1$$

where P^* is the expected price, P the actual price and β a constant. The β is the "coefficient of expectation" or, if the P^* and the P_t were in logarithms, the elasticity of expectation as defined by Hicks. A β value of 0 means that actual prices have no effect on expected prices. A β value of 1 means that expected prices change directly with changes in actual prices. The hypothesis is that "in each period people revise their notion of 'normal' price in proportion to the difference between the then current price and their previous idea of 'normal' price."[7]

Rewriting the equation above

$$(3.19) \quad P^*_t = \beta P_{t-1} + (1 - \beta)\, P^*_{t-1}$$

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[6]Marc Nerlove, The Dynamics of Supply: Estimation of Farmer's Response to Price (Baltimore: The John Hopkins Press: 1958), p.53.

[7]Ibid.

This is a first order difference equation which has the general solution

$$(3.20) \quad P^*_t = H(1-\beta)^t + \sum_{\lambda=0}^{t} \beta (1-\beta)^{t-\lambda} P_{\lambda-1}$$

Where H is a constant established in the initial conditions. Assume that equilibrium conditions existed at and prior to time t = 0 and that all prices are expressed as deviations from the equilibrium price at t = 0. The H term is then 0 and the equation becomes

$$(3.21) \quad P^*_t = \sum_{\lambda=0}^{t} \beta (1-\beta)^{t-\lambda} P_{\lambda-1}$$

This formulation of expectations implies that the expected price is a function of past prices with more recent prices being more important determinants.

Given the price expected, the next step is to determine what the long run equilibrium output would be. This is assumed to be $Y^*_t = a_0 + a_1 P^*_t$ or to simplify the computations,

$$(3.22) \quad Y^*_t = a P^*_t \qquad a > 0$$

Under usual circumstances, the equilibrium output would be a direct function of expected price.

The problem then is to determine the adjustment path of production over time to a change in the equilibrium level of output which is sought. Nerlove, as did Koyck, assumed this adjustment path to approximate a geometric or exponential curve over time.[8] Nerlove advanced as plausible the proposition that output in each period is adjusted in proportion to the difference between the output desired in long run equilibrium and actual output. That is,

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[8] _Ibid._, pp. 62-63.

$$(3.23) \qquad Y_t - Y_{t-1} = \gamma [Y^*_t - Y_{t-1}]. \qquad 0 < \gamma \leqq 1$$

where Y_t is actual output in t, Y^*_t is the long run equilibrium output desired in t and γ is the constant representing the rate of adjustment. This rate is presumably related to the time necessary for firms to acquire or depreciate inputs fixed in the short run but variable as time increases. The γ represents the elasticity or coefficient of adjustment depending on whether the output is expressed in logarithmic or absolute terms.

The form is similar to the price expectation relationship and the solution to the first order difference equation can be similarly derived to give:

$$(3.24) \qquad Y_t = \sum_{\lambda = 0}^{t} \gamma (1 - \gamma)^{t - \lambda} Y^*_\lambda$$

with output expressed at time t as a deviation from output at t = 0. Output is assumed to be at equilibrium at $t \leq 0$.

Since neither expected price nor long run equilibrium output is observable, the equation involving these variables must be transformed to equations with only observed variables. Then the problem of identification develops, that is, the solution of the separate effects of expectation and distributed lags in adjustment.

Substituting equation (3.23) into equation (3.24)

$$(3.25) \qquad Y_t = \sum_{u = 0}^{t} \gamma \; (1 - \gamma)^{t - \lambda} \; a P^*_t$$

Substituting the right hand side of equation (3.21) for P^*_t above.

$$(3.26) \quad Y_t = \sum_{u = 0}^{t} (1 - \gamma)^{t - u} \sum_{\lambda = 0}^{u} (1 - \beta)^{u - \lambda} P_{\lambda - 1}$$

$$= \alpha \beta \gamma \{ P_{t-1} + [(1-\beta) + (1-\gamma)] P_{t-2} + [(1-\beta)^2 + (1-\beta)(1-\gamma) + (1-\gamma)^2] P_{t-3} + [(1-\beta)^3 + (1-\beta)^2(1-\gamma) + (1-\beta)(1-\gamma)^2 + (1-\gamma)^3] + \ldots \}$$

The fact that β and γ enter symmetrically into (3.26) makes identification of these terms impossible. Both β and γ can be found by a set of simultaneous equations using estimates of the coefficients of the regression but there is no way to determine which of β and γ is the elasticity of expectations and which is the adjustment coefficient. Inability to distinguish the two is a serious restriction in analyzing situations where one or the other of these parameters would change.

Nerlove suggests a way for extracting additional information about these coefficients. If the equation (3.22) is lagged one year and substituted into (3.19) the result is

(3.27) $$P^*_t = \beta P_{t-1} + (1-\beta) \frac{Y_{t-1}}{\alpha}$$

Substituting (3.27) into (3.22)

(3.28) $$Y_t^* = \alpha \beta P_{t-1} + (1-\beta) Y^*_{t-1}$$

Substituting (3.28) into (3.23)

(3.29) $$Y_t - Y_{t-1} = \gamma [\alpha \beta P_{t-1} + (1-\beta) Y^*_{t-1} - Y_{t-1}]$$

Lagging (3.23) by one year

(3.30) $$Y_{t-1} - Y_{t-2} = \gamma Y_{t-1}^* - \gamma Y_{t-2}$$

(3.31) $$\gamma Y_{t-1}^* = Y_{t-1} - (1-\gamma) Y_{t-2}$$

Substituting (3.31) into (3.29)

(3.32) $$Y_t = Y_{t-1} + \gamma \alpha \beta P_{t-1} + (1-\beta) Y_{t-1} - (1-\beta)(1-\gamma) Y_{t-2} - \gamma Y_{t-1}$$

(3.33) $$Y_t = \alpha \beta \gamma P_{t-1} + (2-\beta-\gamma) Y_{t-1} - (1-\beta)(1-\gamma) Y_{t-2}$$

Again γ and β enter the regression coefficients symmetrically and cannot be identified. If, however, we can determine whether the coefficient of Y_{t-2} is 0, then we can distinguish between two cases; (1) neither β nor γ is one (the coefficient of Y_{t-2} is not 0) and (2) either β or γ or both, is one (the coefficient of Y_{t-2} is 0).

In other words, this imparts information about whether there are lags in both expected price to actual price and current output to long run equilibrium output or whether one or the other, but not both, occur.

In any case, α can be determined, and this enables the computation of the long run supply elasticity.

Another situation Nerlove considered was the case where more than one price with different elasticities of expectations entered the supply relationship. The adjustment coefficient was assumed to be equal to one.[9] Two methods were presented. One was by a single equation technique developed by Theil using Nerlove's approach.[10]

From a production response equation

$$(3.34) \quad Y_t = \alpha_0 + \alpha_1 P_{1t}^{*} + \alpha_2 P_{2t}^{*}$$

Where

$$(3.35) \quad P_{it}^{*} = \sum_{\lambda=0}^{t} \beta_i (1-\beta_i)^{t-\lambda} P_{\lambda-1} \qquad i = 1, 2$$

$$(3.36) \quad Y_t = \alpha_0\beta_1\beta_2 + \alpha_1\beta_1 P_{1,t-1} + \alpha_2\beta_2 P_{2,t-1} - \alpha_1\beta_1(1-\beta_2)P_{1,t-2} - \alpha_2\beta_2(1-\beta_1) P_{2,t-2} + [1-\beta_1+1-\beta_2] \; Y_{t-1} - (1-\beta_1)(1-\beta_2) Y_{t-2}$$

The expectation coefficient β_1 and β_2 can be estimated although more than one estimate is possible.

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[9] Ibid., pp. 193-196.

[10] H. Theil, Forecasts and Economic Policy, unpublished manuscript, (April 1956).

Nerlove proposed another method whereby expectations coefficients were determined jointly utilizing additional information. This additional information involves production response of other commodities whose prices are included in the equation of interest.

Other Time Series Models

The evidence has been strong that hog farmers have responsed to past prices which further indicates that past prices are important in formulating expectations. The problem becomes one of discovering the functional relationship between past prices and expectations, or between past prices and production adjustment.

Several alternative functions were investigated by Darcovich and Heady.[11] These were listed as (1) average, (2) normal, (3) random, (4) current year (5) 5 year moving average, (6) weighted 5 year moving average, (7) trend, (8) reverse trend, (9) outlook and (10) parallel price models. In (1), the mean of the entire price series was projected forward as the predicted value for every period in the future. This model was used as a standard to evaluate the other models. In (2), expectation was based on some period of a just or fair price such as 1910-1914. In model (3), a value was selected at random from past prices. In (4) the current year's price was projected forward one year. The expected price in model (5) was the moving average price of the previous 5 years. Model (6) is similar to (5) except that the most recent year was given the weight of 4 and earlier years each the weight of 1. The linear trend of the price between two consecutive years was added to the price in the second year in (7) and subtracted in (8). Annual farm outlook reports from federal and state agencies were used in (9). In model (10), the expected price was based on a price which

[11]William Darcovich and Earl O. Heady, Application of Expectation Models to Livestock and Crop Prices and Practices, Research Bulletin 438, Agricultural Experiment Station, Iowa State College, Ames, Iowa, (February 1956).

existed in a parallel period. An example is the price decline expected after World War II based on the parallel period of the early 1920's.

These models were evaluated in two hypothetical situations; one in which a price series was assumed to have an autocorrelation coefficient of one and the second in which a random price series was assumed. A limitation of this evaluation was that the inbetween cases of autocorrelation, most likely in hog and corn prices, were not examined.

An empirical evaluation was made on all the models using actual prices on several major farm products during 1917 to 1950. Three criteria were used, "absolute mean erros," "percentage of extreme error" and "coefficients of the range."

The outlook, current year, parallel and weighted moving average models generally gave the best results on both hogs and corn. The performance of the weighted moving average model, a particular case of distributed lags in expectations, is of particular interest. In every test, it was a better predictor than the unweighted average, which is another special case of distributed lags (rectangular distribution). Compared with the current price model, the weighted average was a better predictor of hog prices under the range criterion but somewhat less satisfactory by the other criteria. By each measure on corn, however, the weighted average was superior to current price.

The evaluation of these 10 expectation models says nothing about which one(s) farmers actually use the most. They were selected to be reasonable approximations of models farmers are believed to use or to be logical mechanical models that farmers could easily adopt.

Survey Approach

The time series approach alone is limited in yielding much precise information about farmers' expectations. Questions may be raised as to whether farmers actually do have expectations, and if so, what the nature of these expectations is. To test hypotheses about expectations and to obtain new insights into farmers' decision making process, numerous surveys have been made.

Elliott[12] and Ball[13] interviewed hog farmers in Iowa during 1946 to 1949. They found that farmers did have expectations which could be considered as probability distributions. Ball found farmers quite willing to quote the lowest, the highest and the most likely price they expected for both hogs and corn. Observing that the most likely price on hogs was near the midpoint of the lowest and highest prices expected, he concluded that the distribution of a farmer's expectation on hogs approximates a normal curve or at least is not inconsistent with a hypothesized normal distribution. As the lowest expected price on corn was nearer the most likely price than was the highest expected price, he concluded that the distribution of expected prices on corn was skewed to the right. This is logically due to the lower limit guaranteed by the support program.

The results of the studies by Elliott and Ball also revealed that expected prices on hogs and corn were often considerably different from the prices prevailing during the season the expectation was reported.

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[12]Robert T. Elliott, "Adjustments to Risk and Uncertainty in Hog Production," unpublished Masters thesis, Iowa State College, (1947).

[13]A. Gordon Ball, "Expectations in the Agricultural Firm," unpublished Masters thesis, Iowa State College, (1950).

Brownlee and Gainer interviewed Iowa farmers in March of 1947 about their expectations for corn and soybean prices in the following December.[14] All the farmers interviewed stated a "most probable anticipated price." They were also asked to state the probability that the price would be as much as 25 cents above or below the most probable price. Brownlee and Gainer were not able to ascertain from the answers whether a very high percentage of the farmers formulated their anticipations in terms of probabilities.

They also asked farmers to state whether they thought a price above the most probable price was more or less likely than a price below; then whether a price 25 cents above the most probable price was more likely than a price 25 cents below. There was no strong evidence of asymmetry in the distribution of expectations on corn prices, although a few more farmers thought a price 25 cents above the most probable price more likely than 25 cents below.

D. B. Williams, who surveyed Illinois farmers in December 1949, gained a strong impression that they based their expectation of the price of corn for the following December mainly on the present price.[15] He observed that weighted averages of past prices which involved heavy weighting of prices in the immediate past did give close approximation to the farmers' expected price on corn.

He also found that the standard deviation in expectations of hog prices was relatively small in the sample.

Drawing from the Interstate Managerial Survey of the North Central Farm Management Research Committee, Partenheimer studied the price

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[14] O. H. Brownlee and Walter Gainer, "Farmers' Price Anticipations and the Role of Uncertainty in Farm Planning," Journal of Farm Economics, Vol. 31 (May 1949), pp. 266-275.

[15] D. B. Williams, "Price Expectations of Illinois Farmers," Journal of Farm Economics, Vol. 33, No. 1 (1951).

expectation models used by farmers.[16] He concluded that a high proportion of farmers use so-called supply, supply-demand, and government action models in contrast to the highly mechanistic models such as advanced by Darcovich and Heady.[17] However, the interviews were made at a time when the forthcoming supply of hogs, for instance, was fairly well-known. At least, the farrowing intention reports had been released. The government support program on corn was also known at that time. Partenheimer noted that for expectations covering more than one production period, the less sophisticated, mechanistic models may be more important.

The criticism leveled against the mechanistic models of Ezekiel, Alt, Nerlove, Darcovich and Heady, and others is that farmers form their expectations by a far more complex process than by using some function of past prices. Farmers are conscious of many of the important factors affecting price such as production, consumer incomes, prices of competing products and the government support program. The particular expectation model used would depend on the commodity in question. If the government support program had been instrumental in establishing prices, then farmers would be attentive to the prospective government program. Farmers receive outlook information which no doubt influences their expectations.

The selection of an appropriate expectation model involves implicit assumptions about the level of knowledge and understanding by farmers of economic relationships. A high level of knowledge and understanding can not be adequately handled in a mechanistic type

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[16] Earl J. Partenheimer, "Some Expectation Models Used by Selected Groups of Midwestern Farmers," unpublished Ph. D. dissertation, Michigan State University, (1959).

[17] William Darcovich and Earl O. Heady, op. cit.

model which presumes that expected prices are a function of past prices alone. Nor would such a model properly account for changes in the level of knowledge and understanding over time.

This is a valid criticism of the mechanistic approach and should be given serious consideration in expectation studies. Even here, questions would have to be raised on how farmers form expectations of future production, consumer incomes, prices of competing products, a support price before it has been announced and other relevant variables. Can they adequately appraise each of these factors in forming a price expectation? There is the question, too, on how much farmers are inclined to form their expectations from outlook material. In hog production, it has been observed that a change in price usually has to be realized before a response in production is forthcoming.

From a survey of commercial hog farmers in Illinois, Ross concluded that most of them were "amazingly uninformed about economic factors which affect their hog business."[18] The study was made in September of 1958, a time for caution and careful planning by swine growers. Yet the study indicated that they paid little attention to outlook information in planning their future swine enterprise.

Even if farmers actually do recognize the important factors that determine the price of their products they may not apply these in formulating expectations, however. When asked, they may state that prices will depend on several very relevant factors. But in formulating expectations, they may not go through the complex process of attempting to forecast these variables and assess their relative importance in establishing price. This is a difficult task even for experienced economists. The enormity of this undertaking may force even the best informed farmers to rely on some simpler, mechanistic expectation models.

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[18]James E. Ross, "Where do Illinois Swine Growers Get Their Outlook Information?" <u>Journal of Farm Economics</u>, XLI (November 1959), pp. 830.

Evidence that such may be the case is observed in the close concurrent relationship between the prices on feeder livestock and slaughter prices. Feeder pig prices tend to parallel the slaughter hog market. Prices on feeders cattle have depended on the current slaughter market, recent profit experiences of cattle feeders and the prospective supply of range forage and feed grain.

Theoretical Approach

There is a great void in most studies of expectations in economic behavior. An underlying theoretical structure has not been developed. Although considerable work has been done in survey procedures, that is, in asking people what their expectations are, attempts to construct behaviorial models have been feeble.

The Survey Research Center of the University of Michigan has drawn from some theoretical concepts in psychology in their surveys of businessmen's and consumers' expectations. Empirical verification of the theories is only in the early stages, however.

Katona

A leading proponent of the psychological approach has been George Katona. Katona has criticized the great body of economic theory which draws only upon "mechanistic psychology"--the assumption that under given external conditions, human actions are entirely determined by those conditions.[19] Because human behavior is pliable and modifiable, and because human beings are capable of using past experiences, he is skeptical about broad generalizations that assume invariable interrelationships.

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[19]George Katona, Psychological Analysis of Economic Behavior, (First Edition, New York: McGraw-Hill Book Company, Inc., 1951), pp. 6-7.

Katona points out that economic behavior is sometimes habitual and does not involve expectations. In some cases, expectations are so weak that entrepreneurs (or consumers) do not respond and, in other cases, little doubt enters the expectation and appropriate response is noted. But in the majority of instances of uncertainty, Katona noted that expectations influenced action, especially if that action was in line with the hopes and desires of those concerned.[20]

About expectations, Katona states:

> "The study of expectations forms a part of the psychology of learning since expectations are not innate or instructive forms of behavior but rather the result of experience. Therefore, expectations are explained by the same two principles by which all learning is explained, that is, by repetition or understanding (or both). The theory of expectations based on repetition alone is: "I expect those things to happen that have happened before, and the frequency of my past experience (the number of reinforcements) determines the strength of my expectations."[21]

But Katona points out that the strongest and most influential expectations originate in understanding. New understanding results from a restructuring of the psychological field, the whole situation which involves a change in the perception of the environment. What people perceive depends on the organization of their perceptions, which differs from person to person and in the same person from time to time. Changes in the organization of perceptions are conditioned by motives, past experience, attitudes and emotions. Reaction to stimuli depends upon the particular structure of the perceptions.

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[20]George Katona, "Expectations and Decisions in Economic Behavior," The Policy Sciences: Recent Developments in Scope and Method, (Ed. Daniel Lerner and Harold Lasswell, Stanford: Stanford University Press, 1951), pp. 230-231.

[21]Ibid., p. 53.

Changes in the structuring of the psychological whole and consequently of understanding are infrequent.

Katona reasons that if understanding is the source of strongest expectations, changes in the expectations of businessmen are not constantly being revised.[22] But when there is a revision, the change is likely to be substantial. In addition, many individual businessmen are likely to revise their expectations at the same time and in the same direction.

Shackle

G. L. S. Shackle has been concerned with problems of uncertainty in situations involving choices between "non-divisible, non-seriable" experiments.[23] Here expectations cannot be based on frequency ratio probabilities since the conditions under which action is to be taken are unique. To the extent that conditions attendant to the hog industry change over time and that each year is somewhat unique, some attention should be given to this phase of the problem of specifying farmers' expectations.

Shackle reasons that entrepreneurs have some idea of the gain that would accrue to them in each of a set of mutually exclusive hypotheses if the given hypothesis were true. This he defines as the "face value" of the hypotheses and is an independent variable in his expectation model. The set of hypotheses involved could be discrete or continuous. For example, a hog farmer would have some idea of his gains under several mutually exclusive hypotheses concerning the price of hogs at the future date when he was ready to sell.

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[22]Ibid., p. 54-55.

[23]G. L. S. Shackle, Uncertainty in Economics and Other Reflections (Cambridge: University Press, 1955), Chapters I, II, III and IV.

A second "independent" variable in Shackle's model is called "potential surprise." This represents the decision-maker's degree of belief in or distrust of a hypothesis. This registers the feeling of the individual, should the particular hypothesis be true.

A third variable is a function of the two independent variables and measures the "degree of stimulus" from a combination of the "face value" of a hypothesis and the potential surprise associated with the hypothesis.

Shackle's approach probably has only limited application with respect to farmers' hog production decisions. First of all, for many farmers the decision of whether to raise hogs or how many to raise is not completely unique but is based on personal experience or the experience of others whom they have observed. The situation is not entirely unique although some conditions (new technology in raising hogs, attractiveness of other enterprises, business outlook, etc.) involved in the decision may be new within the experiences of the entrepreneurs.

Information Theory

If a probability model of expectations using past prices is appropriate for hog production, is there any theoretical basis for postulating what the parameters of the model should be? Alt, Fisher, Koyck, Nerlove and others using this model have made certain reasonable assumptions about the values of these parameters.

Noteworthy, also in this regard, are some recent explorations of expectations based on certain concepts of communication or information theory.[24] Using the terminology of this field, prices may be thought to

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[24]Listed below are some selected references on this subject:

C. E. Shannon, "A Mathematical Theory of Communication," Bell System Technical Journal, (1948).

Norbert Wiener, Cybernetics (New York: John Wiley and Sons, Inc. 1948), pp. 74-112.

serve as signals which impart certain information to producers. In formulating expectations, the signals must first be received (actual prices must be known) and decoded. The signal is composed of information and noise. The problem of the receiver is to separate out the information from the noise.

Noise is considered a random element and an interference in the transmission of the signal. A change in price may not be a message to change long-range production plans if the change originated from a random and temporary disturbance.

Production and price are much more unstable on certain farm products than others. Year to year fluctuation in onion production and prices is much greater than on milk. Onion prices are more dependent on weather, a random element. This would suggest that a given percentage change in onion prices would likely impart less information about a basic long run (more than one year) adjustment in the level of onion prices than the same percentage change in milk prices would about adjustments in the level of milk prices.

If hog prices were completely random, we would expect farmers to pay little attention to price in their production decisions. But annual hog prices are serially correlated. Cyclical patterns persist. Certain trends are in evidence.

Using information theory we would expect farmers to extract certain information from past hog prices but discount prices in any individual year because of the "noise" component.

(Continuation of footnote 24) David A. Grant, "Information Theory and Discrimination of Sequences in stimulus Events," Current Trends in Information Theory (Pittsburgh: University of Pittsburgh Press, 1953).

CHAPTER IV

HYPOTHESES

Statement

The task of this dissertation is concentrated on testing two hypotheses. The first hypothesis is that the response of hog production to price is in the form of distributed lags. The second hypothesis is that the endogenous mechanism of the hog market is cyclic and convergent.

Hypothesis I

Hog farmers, in the aggregate, base their price expectations mainly on prices at the time they make their production decision and take action. However, their expectations are conditioned by prices in previous years, with the most recent years being more dominant than earlier years. In other words, the prices farmers expect to receive for their hogs and pay for corn (or receive for corn) are functions of actual prices in the present and previous seasons. The prices in the present season are more important than those in the season before. The prices in the season before are more important than prices two years ago, etc.

Mathematically,

$$P_t^* = \sum_{i=1}^{n} E_i P_{t-i}$$

where t is the year, P_t^* is the expected price in year t, P_{t-i} is the actual price in year t-i, E_i is the weight given to year t-i, n is the number of years influencing expectations,

$$\sum_{i=o}^{n} E_i = 1, \; E_i > E_{i+1}$$

It is recognized that present and past prices are not the only influences on farmers' expectations. The general business climate is believed to effect price expectations, for example. The support program on corn probably narrowed the range of price expectation on corn in the late 1950's. It is argued in this dissertation, however, that present and past prices have been predominant factors in hog farmers' expectations during peacetime.

In addition, it is believed that there is a lag in the adjustment of production to expected prices which extends over more than one year. Because fixed costs in hog production represent a relatively small proportion of the total costs, the hog enterprise is flexible; entry into and exit from the hog industry is comparatively easy. The adjustment of production to a change in the expected price is assumed to be greater in the first year than in any succeeding year. Adjustments continue in succeeding years but at a declining rate. The distributed lag function for adjustment would be similar to that for expectations. That is,

$$Q_{t+1} = K + \sum_{i=o}^{m} A_i \; P^*_{t-i}$$

where Q_{t+1} is the supply in year t+1 (assuming a technical lag of 1 year), P^*_{t-i} is the price expected in the long run in year t-i, k is a constant, A_i is the coefficient of P^*_{t-i}, m is the number of years necessary to complete an adjustment, and

$$A_i > A_{i+1}$$

As explained in Chapter III, if lags in expectation and adjustment both involve more than one year, neither the expectation function nor the adjustment function can be identified from time series data. The observed distributed lag of production response to actual prices would be a combination of the expectation function and the adjustment function. This total response function would be

$$Q_{t+1} = K + \sum_{i=o}^{m} A_i \sum_{i=1}^{n} E_i \; P_{t-i} = K + \sum_{i=o}^{m,n} W_i \; P_{t-i}$$

where Q_{t+1} is the supply in year t+1, P_{t-i} is the actual price in year t-i, W_i is the weight given to year t-i, n is the number of years influencing expectations, and m is the number of years influencing adjustments (one may involve more years than the other). The summation is over n or m years, whichever is the larger. It is also assumed that

$$W_i > W_{i+1}$$

The hypothesis is, then, that the response of hog production to actual prices extends over more than one year and is distributed among the relevant years as is shown in the function above.

Hypothesis II

The hog market has been used as a classic example of the Cobweb Theorem of Ezekiel's.[1] One assumption underlying this theorem is that farmers' production decisions are based on the expectation that the present hog price would continue through the following production period (which Ezekiel considered as two years).

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[1]Mordecai Ezekiel, op. cit.

This assumption would seem to be a special case of a more general assumption. This general assumption is that the expected price is a positive function of present and past prices. This would include the case where the expected price was based on the present price only and, in addition, the case of distributed lags in Hypothesis I.

This generalization seems particularly important in explaining Ezekiel's Case III, the exploding model. Such a case would occur, according to Ezekiel's assumption, in a market where the supply curve was more elastic than the demand curve. It seems quite probable that the supply response curve for hogs based on expected prices could be elastic over, say, a two-year planning and production period. An inelastic demand curve for hogs at the farm is also quite probable as shown by previous studies.[2] Yet the possibility that the hog market is an "exploding" case seems quite remote.

The difficulty lies in the assumption that farmers naively expect present prices to continue in an industry characterized by highly fluctuating prices. If farmers are reluctant to change their expectations to the same extent that actual prices change, the model could be convergent even though the supply curve for the production period may be more elastic than the demand curve.

Nerlove demonstrates that as the coefficient of expectations decreases from 1 to 0, the probability of a diverging or exploding market declines.[3] That is, a wider range in the ratio between the supply and the demand elasticities is admissible under the convergent model as $\beta \rightarrow 0$. Ezekiel assumes that $\beta = 1$.

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[2]Karl A. Fox, The Analysis of Demand for Farm Products, U. S. Department of Agriculture Technical Bulletin No. 1081, (1953), p. 46.

[3]Marc Nerlove, op. cit., pp. 55-59.

Ezekiel also assumed that adjustment of production to an initial price continues over a two-year period regardless of any change in price during the first year. At the end of two years, the adjustment is complete and the market re-evaluated in making production plans for the next two years.

Under Hypothesis I, the assumption was made that considerable adjustment could be made within a year in response to an expected price. Adjustment to the initial expected price would not necessarily continue in the second year regardless of any change in expectations in the meantime, however.

The second hypothesis is that the hog market has cyclical tendencies but would eventually converge to an equilibrium in the absence of external disturbances. This is based on the Cobweb Theorem as modified above.

Methodology

Two methods of estimating distributed lags were tried in testing Hypothesis I. One was the traditional regression approach as used by Alt in which hog and corn prices were lagged one, two, and three years in successive equations. Hog production was used as the dependent variable. The signs on the coefficients and statistical properties of the equations were used as criteria in judging the validity of the distributed lag hypothesis.

The second technique was the one proposed by Nerlove. The estimates of the parameters in these equations along with the statistical properties of the equations were compared with those of Alt's procedure.

To test Hypothesis II and to ferret out the characteristics of the endogenous mechanism of the hog industry, "complete" models of the hog market were developed for the 1947-1958 period. Each model included, in addition to a supply equation, a consumer demand equation, a marketing ma rgin equation used to obtain the farm price of hogs, and equations linking sows farrowing in the spring to pork production in the fall. Four of these "complete" models were constructed using four alternative supply equations. Each model was "reduced" to a difference equation by holding the exogenous variables constant. The solution of the difference equation yielded certain information about the dynamics of the hog market, including whether or not it was cyclic and whether or not it was convergent.

Statistical Procedure

Estimates of the parameters of the relationships investigated were obtained by the single equation least squares regression technique. Under certain assumptions, this procedure is formally equivalent to the maximum likelihood estimating procedure. The random disturbance is assumed to be normally distributed with mean O and a finite variance, and independent of the "independent" variables of the equation. This involves the assumption that there are no errors in the measurement of the independent variables nor simultaneous relationships among the endogenous variables.

Maximum likelihood estimates have certain desirable properties such as being "efficient" under certain specified conditions, "consistent" in a wide variety of problems, "sufficient" if a "sufficient" estimator exists and "invariant."[4] Least squares estimates in themselves require only that the disturbances are independently distributed in order to obtain the best, unbiased linear estimates of the parameters.

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[4]Lecture notes taken in a course given by Dr. Clifford Hildreth on "Estimating Economic Relationships in Agriculture," Agricultural Economics Department, Michigan State University, East Lansing, Michigan, Spring 1957.

Several tests were conducted on the estimates, including the "t" test on the regression coefficients and the computation of the R values, the coefficients of correlation, to test the explanatory power of the equations. The Durbin-Watson and Von Neumann-Hart ratio tests were applied to the residuals to test for serial correlation. An F test was conducted on the R^2 values of successive equations under Alt's procedure to determine whether the addition of variables in the second equation explained significantly more of the variation in the dependent variable than did the first equation.

The standard error of the estimate was also computed for each equation.

CHAPTER V

SUPPLY RESPONSE

Background

Time Periods

The data used in this study extended over a 51-year period from 1908 to 1958. This period was punctuated by two major wars and a government control program on hogs.

The 1908 to 1958 period was divided into three separate periods, 1908 to 1924, 1925 to 1941 and 1947 to 1958. The World War I (1918 and 1919) and World War II (1942 to 1946) periods were omitted because the structure of farmers' expectations was thought to have changed during wartime. The 1933-34 crop year was omitted because of the government's program to reduce hog numbers in that year.

Before 1925, hog slaughter was used to indicate supply response. Since 1924, the United States Department of Agriculture has estimated the number of sows farrowing in the spring and in the fall. The number of sows farrowing is a more accurate indication of year to year supply response than hog slaughter which is modified by weather and short term influences. For this reason, the number of sows farrowing was used since 1924.

The pre-World War II and post-World War II periods were separated because the general economic climate changed and because the structure of the hog industry, both in production and marketing, underwent a transition not easily explained by a trend factor.
The 1925-1941 period was an era of a declining general price level

and depression. The 1947-1958 period, on the other hand, was characterized by inflation and rising per capita incomes. Adoption of new technology in agriculture was of revolutionary proportions during World War II and in the succeeding years. Dissemination of outlook information has increased and the government's support program on feed grains has become more important since the pre-World War II period. These changes would likely affect farmers' expectations and production response to these expectations.

Variables

The variables included in the supply response equations are defined and coded as follows:

Spring Pig Crop

F, t — Sows farrowing in the spring: Sows farrowing in the United States between December, t-1, and May, t; in thousands.

Sh, t — Slaughter of hogs from spring pig crop: Total slaughter of hogs in the United States between October, t, and April t+1; in thousands.[1]

Ph, t — Price of hogs at breeding time for spring pig crop: Average price per hundred weight of 200-220 pound barrows and gilts at Chicago between October, t, and January, t+1; in dollars.

Pc, t — Price of corn: Average price per bushel of No. 3 yellow corn at Chicago between October, t, and January, t+1; in dollars.

Sg, t — Free supply of feed grain other than corn: (a) 1908-1924:

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[1]For derivation, see APPENDIX C.

Production of oats and barley, t, (b) 1925-1958: Stocks of oats and barley on July 1, t, (and sorghum grain stocks on October 1, t, between 1947 and 1957) not owned by the C.C.C.; plus production of oats, barley and sorghum grain in t; in thousands of tons.

H:C, t = Ph, t $\div$ Pc, t   Hog: Corn Ratio

F^d, t = F, t - F, t-1

Sh^d, t = Sh, t - Sh, t-1

Sg^d, t = Sg, t - Sg, t-1

Fall Pig Crop

Ff, t   Sows farrowing in the fall: Sows farrowing in the United States between June, t, and November, t; in thousands.

Shf, t   Slaughter of hogs from fall pig crop: Total slaughter of hogs in the United States between May, t+1, and September, t+1; in thousands.

H:Cf, t   Hog: corn ratio (modified) at breeding time for fall pig crop: (Average price per hundred weight of 200-220-pound barrows and gilts at Chicago between April, t, and June, t) $\div$ (Average price per bushel of No. 3 yellow corn at Chicago between October, t-1, and January, t).

IScg, t   Indicated free supply of corn and other feed grain: (a) 1908-1924: (Indicated production of corn in the United States, as of July 1, t, + actual production of oats and barley, t) - (Actual production of corn, oats and barley, t-1); in thousands of tons. (b) 1925-1958: ("Free" stocks of corn, oats, barley and sorghum grain at beginning of crop years, t, + indicated production of corn, oats and barley on July 1, t, sorghum grain on August 1, t.) - ("Free" stocks of corn, oats, barley and sorghum grain[2] at beginning of crop years, t-1, + Actual production, t-1).

T Time in years:

(a) 1908-1924: 1907 = 1

(b) 1925-1958: 1924 = 1

Selection of Variables

United States total farrowings, slaughter data, and grain production data were employed. Corn and hog prices were based on Chicago quotations.

Chicago prices of hogs and corn were used because Chicago is centrally located in the great surplus corn and hog area. The Chicago grain and livestock markets have historically been recognized as leading markets and price quotations there have been widely publicized.

The 200 to 220-pound weight bracket was selected because it is a price series representative of all butcher hogs and would be less affected by changing average weights of hogs slaughtered from year to year than an "average" hog price. Number 3 yellow corn was selected rather than an average farm price which is affected more by the changing quality of the crop from year to year.

In the spring pig crop equations, the hog and corn price variables were October to January averages. This particular period was selected for three main reasons. (1) The bulk of the previous spring pig crop has been sold during these months. Therefore, the price of barrows and gilts during this period is representative of the returns on the

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[2]Sorghum grain stocks available only for 1947 to 1958.

previous spring pig crop. Hog farmers would presumably be particularly conscious of hog prices at that time.

(2) During October to January, sows are bred to farrow in the following February to May, the important farrowing season. As late as January, the sows bred earlier in the fall and not yet "piggy" could be shipped to market without substantial discounts, if price expectations had dropped in the meantime.

In other words, October to January is a critical period in which farmers would be conscious of the prices received for the previous spring pig crop and also in which production decisions for the following spring are made and carried through.

(3) The October to January average corn price is representative of the fall corn crop and with normal seasonal adjustments would be a good indicator of prices of corn during the remainder of the crop year. Within that crop year the spring pig crop would be at least partly fed out. The finishing period would also include much of the following October to January period for pigs farrowed in March to May. For this reason, farmers must anticipate corn production and/or corn prices in the October to January period of the following crop year.

Although hog and corn prices were postulated as the predominant variables in guiding hog production, other variables are recognized as components of the hog supply model. However, the limited number of observations precluded the inclusion of all of these variables. These variables were tried in different combinations with hog and corn prices to determine their effect on supply of hogs. Only the supply of feed grains other than corn was selected as an additional variable in the supply equations for the spring pig crop.

Theoretically, the prices on all variables which are substitutes for hogs in production or are inputs along with corn and other feed grains determine the supply curve. Fat cattle are one such substitute. Cattle feeding operations are important in the Corn Belt states, the major hog feeding area. Cattle suitable for fattening on grain compete with hogs for the feed grain supply. Profit in feeding cattle was therefore introduced into the supply equation. The coefficients on this variable were not significant and the sign in one of the periods investigated was inconsistent with theory.

To account for costs other than corn in producing hogs, the index of prices paid by farmers for production items was tried but was not found to be significant nor to add to the explanation of the dependent variable.

Because most of the corn fed to hogs is raised on the same farm as the hogs, corn supply was considered in addition to and in place of corn prices. This formulation did not improve on the use of corn prices alone, based on the coefficient of determination.

As expectations of farmers would be affected by the general business climate, an attempt was made to account for this influence. A change in stock (corporation) prices during the previous year was tried to represent this element. Inconsistent signs on the coefficients of this variable were obtained in the two periods investigated. The coefficients were also insignificant under the null hypothesis.

Several of the equations in which these variables were tried are presented in APPENDIX A.

Form of the Variables

The variables were all in arithmetic form. There was no a priori reason for putting the variables in the form of logarithms. Although such a form would simplify computation of elasticities, this was not considered a major advantage in this study.

The hog:corn price ratio has been commonly used in predicting hog supplies, This does involve the rather restrictive assumption that hog and corn prices are of equal importance to farmers in their production decisions. Because hog prices would be thought to be somewhat more important than corn prices, hog prices and corn prices were used separately as well as in ratio form to test this possible difference.

The variables F, t, Sh, t and Sg, t were used in the form of first differences and actual values as well. The first difference (or, similarly, percentage change) of hog production from year to year in response to price has been widely used in studying supply response on hogs.

An objection to putting the dependent variable in the first difference form is that the coefficient of the dependent variable in the previous year (t-1) is assumed to be 1, possibly an unjustified restriction. Consider the equation,

$$F, t = a_0 + a_1 F, t-1 + a_2 H{:}C, t-1$$

Assume an equilibrium at t = 0 with F, t = F, t-1. If $a_1 = 1$, then any increase in H:C, t-1 would generate a linear increase in F, t which would continue without bound with the passage of time. F, t would decrease similarly if H:c, t-1 was reduced.

If $0 < a_1 < 1$, any increase in H:C, t-1 would generate an increase in F, t but at a decreasing rate. F, t would approach an upper limit. Similarly, F, t would decline at a decreasing rate to a lower limit, if for some reason H:C, t-1 were to be reduced.

Theoretically, the assumption that $0 < a_1 < 1$ is more realistic. The management factor, feed supplies, availability of land, etc. would tend to put an upper limit on hog production by increasing marginal costs. The lower limit is zero production.

Because the hog-corn ratio does not remain favorable or unfavorable long enough for the extremes in production to be approached, the error in assuming $a_1 = 1$, that is, using first differences, would not necessarily be a serious one.

The primary purpose of this chapter is to test Hypothesis I, that hog farmers respond not only to prices during the breeding season but also to prices in previous years, though to a lesser extent. Two methods were used, the traditional method as demonstrated by Alt and the technique suggested by Nerlove.[3]

Alt's procedure was tried in each of the three time periods using lagged values of the hog:corn ratio as independent variables and first differences of hog slaughter from the spring pig crop (1908-1924) or first differences of sows farrowing in the spring (1925-1941 and 1947-1958) as the dependent variable. To check the possible error in assuming that hog and corn prices were of equal importance, as is the case when they are used in ratio form, hog and corn prices were also tried separately. Also, a check was made on the use of first differences by reformulating certain equations; putting the dependent variable in absolute values and using the dependent variable lagged one year as an independent variable.

Elasticities of production to observed prices were calculated from the estimates of the regression coefficients.

Three alternative Nerlove type models were then estimated for each of the three time periods. In the first model, the hog:corn ratio was used and no restrictions were placed on the values of the coefficient of expectation and the coefficient of adjustment. Hog and corn prices were tried separately in the second model, with the restriction that

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[3]Refer to page 30 for Alt's method and to pages 34-39 for Nerlove's approach.

the coefficient of expectation on hog prices was equal to the coefficient of expectation on corn prices. In the third model, hog and corn prices were also separate, but the expectation coefficients were not restricted to be equal. However, to estimate the separate expectation coefficients, the adjustment coefficient was restricted to equal one.

The parameters and elasticities of the Nerlove model were calculated from the regression equations.

The equations for both the Alt and Nerlove models were estimated by the traditional least squares, single equation regression technique. In addition to the "t" tests on the coefficients and the computation of the coefficient of determination (and adjusted coefficient of determination) and the standard error of the estimate, the Durbin-Watson statistic was calculated from the residuals of each equation. The results of all the Durbin-Watson tests either indicated no serial correlation at the 5 percent level of confidence, or the test was inconclusive. The Von Neumann-Hart ratio test was also applied to these residuals and, in all cases no serial correlation was indicated at the 5 percent level. To simplify the discussion of the statistical results in the remainder of this chapter, references to the Durbin-Watson statistic presented in the tables will be omitted.

Alt's Procedure

As presented in CHAPTER III, the procedure which Alt suggested in accounting for distributed lags in supply response was to fit successively equations with the price variable lagged one year; one and two years; one, two and three years; etc. until the coefficients ceased to make sense. The values of the coefficients over the relevant time period would indicate the distribution of the lagged response over time.

<u>1908-1924</u>

Dependent Variable in First Differences

With the dependent variable in first differences, the three equations in TABLE 4 demonstrate Alt's procedure for 1908-1924. In Equation (5.1), the hog:corn ratio at breeding time was a highly significant indicator of year to year changes in hog slaughter from the spring pig crop. The sign on the coefficient of Sg^d, t-1 was negative, contrary to the presumed relationship. However, the value of the coefficient was not significantly different from zero.

Equation (5.2) is identical to Equation (5.1) except that H:C, t-2 was added. The coefficients of H:C, t-1 and H:C, t-2 were both significant, at the 1 and 5 percent levels respectively. As in (5.1), the coefficient of Sg^d, t-1 was negative but insignificant. Equation (5.2) explains a significant proportion of the unexplained variation in the dependent variable of Equation (5.1) as indicated by $F_{(T-k_2-1,\, k_2-k_1)}$. The F statistic determines the significance of the difference between the R values of the two equations. The F statistic is described in APPENDIX B. The coefficient of H:C, t-1 in Equation (5.2) was larger and more significant than the coefficient of H:C, t-2, conforming to Hypothesis I.

The inclusion of H:C, t-3 in Equation (5.3) added very little to the explanation of Sh^d, t over Equation (5.2). In fact, $\bar{R}^2$ was actually less and S greater in (5.3). The significance of the coefficient of H:C, t-1 in (5.3) was greater than in either (5.1) or (5.2). However, the coefficient of H:C, t-2 which was significant in (5.2) became insignificant in (5.3). As in (5.1) and in (5.2) the coefficient of Sg^d, t-1 was negative and insignificant.

By inspection of the three equations in TABLE 4, there is reason to consider lags distributed over a two-year period as sufficient in

TABLE 4. Regressions of alternative hog supply equations, with dependent variable in first differences of hog slaughter, hog and corn prices as a ratio; 1908-1924.[a]

Item	Equation (5.1)	(5.2)	(5.3)
Dependent Variable	$\hat{Sh}^d, t$	$\hat{Sh}^d, t$	$\hat{Sh}^d, t$
Constant	-13984	-24018	-25430
Independent Variables	Coefficients with t values in parenthesis		
H:C, t-1	1217.0 (3.34)**	1155.1 (3.66)**	1766.7 (4.51)**
H:C, t-2		862.8 (2.26)*	20.0 (.05)
H:C, t-3			369.0 (.80)
Sg^d, t-1	-.2793 (1.43)	-.0246 (.12)	-.4574 (1.56)
R^2	.49	.65	.65
$\bar{R}^2$	.41	.56	.51
S	3713	3206	3363
d	1.75	1.75	1.82
$F_{(T-k_2-1,\, k_2-k_1)}$		5.09*	0

* Significant at 5 percent level.
** Significant at 1 percent level.

[a]The symbols in the bottom section of this and subsequent tables represent the following statistics:

R^2 = Multiple correlation coefficient.

$\bar{R}^2$ = The value of R^2 adjusted for the degrees of freedom, i.e.

$\bar{R}^2 = 1-(1-R^2)\,\frac{n-1}{n-m}$ where n is the number of observations and m is the number of variables.

S = Standard error of the estimate.

d = The Durbin-Watson statistic. This is described in APPENDIX B.

$F_{(t-k_2-1,\, k_2-k_1)}$ = F statistic to compare R values. This statistic is described in APPENDIX B.

explaining supply response. Assuming that a distributed lag over two years would complete the adjustment to the observed hog:corn ratio, Equation (5.2) would indicate that about 57 percent of the adjustment would occur in the first year and 43 percent in the second year. These percentages are obtained by adding the coefficients of H:C, t-1 and H:C, t-2 and dividing the sum into each of the coefficients.

Hog and corn prices were tried separately in Equation (5.4) as presented in TABLE 5. The coefficients of both were significant; at the 5 percent level on the coefficient of Ph, t-1 and at the 1 percent level on the coefficient of Pc, t-1. The coefficient of Sg^d, t-1, though significant at the 10 percent level, was negative, again contrary to the sign anticipated. Comparing the $\bar{R}^2$ and S of Equation (5.4) with Equation (5.1) in TABLE 4 in which the hog:corn ratio was used, there was little noticeable improvement in separating hog and corn prices.

The addition of Ph, t-2 and Pc, t-2 in Equation (5.5) explained a larger though not a significantly larger proportion of the unexplained variation in Equation (5.4). All the coefficients had the proper sign and, except for Sg^d, t-1, were significant at the 10 percent level or lower. The value and significance of the coefficients in Equation (5.5) suggest that hog and corn prices in t-2 were nearly as important as in t-1 in determining supply response in t.

Comparing the $\bar{R}^2$ and S values of Equation (5.5) with (5.2), little advantage was apparent in separating hog and corn prices from the ratio form.

Dependent Variable in Absolute Values

Equation (5.6) in TABLE 6 is identical to Equation (5.3) except that the dependent variable is in absolute values instead of first differences and the lagged values of the dependent variable is included as

TABLE 5. Regressions of alternative hog supply equations, with dependent variable in first differences of hog slaughter, hog and corn prices separate; 1908-1924.

Item	Equation (5.4)	(5.5)
Dependent Variable	$\hat{Sh}^d, t$	$\hat{Sh}^d, t$
Constant	3718	882
Independent Variables	Coefficients with t values in parenthesis	
Ph, t-1	1735.3 (2.52)*	1904.9 (2.20)#
Ph, t-2		1697.0 (2.27)*
Pc, t-1	-24472 (3.51)**	-22492 (3.70)**
Pc, t-2		-20536 (2.30)*
Sg^d, t-1	-.3950 (1.93)#	.0151 (.06)
R^2	.54	.72
$\bar{R}^2$	.41	.56
S	3692	3181
d	2.24	2.00
$F_{(T-k_2-1, k_2-k_1)}$		2.91

Significant at 10 percent level.

* Significant at 5 percent level.

** Significant at 1 percent level.

TABLE 6. Regressions of alternative hog supply equations with dependent variable in absolute numbers of hogs slaughtered; 1908-1924.

Item	Equation (5.6)	Equation (5.7)
Dependent Variable	$\hat{S}h, t$	$\hat{S}h, t$
Constant	-21498	318
Independent Variables	Coefficients with t values in parenthesis	
Sh, t-1	.9399 (3.32)**	.8674 (3.31)*
H:C, t-1	987.6 (1.83)	
H:C, t-2	935.9 (2.19)#	
H:C, t-3	-154.3 (.40)	
Ph, t-1		1434 (1.23)
Ph, t-2		1917 (2.78)*
Pc, t-1		-18110 (1.91)#
Pc, t-2		-23167 (2.81)*
Sg, t-1	.1308 (.30)	.2988 (.68)
R^2	.77*	.82*
$\bar{R}^2$	.64*	.68*
S	3494	3281
d	1.71	1.86

\# Significant at the 10 percent level.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

an independent variable. Equation (5.6) explained considerably more of the variation in the dependent variable than did Equation (5.3). The $\bar{R}^2$ was significant at the 5 percent level in (5.6) and not significant in (5.3). The S value was higher in (5.6), however. Although the coefficient of H:C, t-1 was less significant in (5.6) than in (5.3), the coefficient of H:C, t-2 was more significant and more plausible than the coefficient of this variable in (5.3).

The elasticity of supply can be calculated from the coefficients of (5.6). Letting the coefficients of H:C, t-1 and H:C, t-2 be c_1 and c_2 respectively, the elasticity of supply with respect to H:C, t-1 at the means is

$$eH{:}C, t-1 = \left(\frac{\overline{H{:}C, t-1}}{\overline{Sh}, t}\right) c_1 = \left(\frac{11.97}{39686}\right) 987.6 = .30$$

where $\overline{H{:}C}$, t-1 and $\overline{Sh}$, t are the mean values of these variables for 1908-1924.

The elasticity of supply with respect to H:C, t-2 is also .30. If adjustments in supply are assumed to have been completed in a two-year period, then the long run supply elasticity is .60, the sum of the elasticities with respect to H:C, t-1 and H:C, t-2.

Equation (5.7) in TABLE 6 is the representation of Equation (5.5) with the dependent variable in absolute values and the lagged dependent variable as an independent variable. The $\bar{R}^2$ value for Equation (5.7) was higher, but the S value was also higher than for Equation (5.5). In Equation (5.7), the coefficients of Ph, t-2 and Pc, t-2 were actually greater and more significant than the coefficients of Ph, t-1 and Pc, t-1. This contradicts part of Hypothesis I; that the more recent prices are more important than prices in previous years in supply response.

The elasticity of supply at the means with respect to Ph, t-1 is .30 and for Ph, t-2 is .42. The supply elasticity is -.33 for Pc, t-1 and -.42 for Pc, t-2. The elasticities for Ph and Pc are very close except for sign.

1925-1941

Dependent Variable in First Differences

The stepwise procedure for obtaining distributed lags is shown in TABLE 7 for 1925-1941 using the hog:corn ratio. The coefficient of H:C, t-1 was highly significant in each of the three equations, (5.8), (5.9), and (5.10). However, the coefficient of H:C, t-2 was positive but not significant in Equation (5.9) in contrast to the results in Equation (5.2) for 1908-1924. The $\overline{R}^2$ was actually lower and S higher in Equation (5.9) than in Equation (5.8).

The coefficient of H:C, t-3 in Equation (5.10) was negative and not significant. The $\overline{R}^2$ was no higher than for (5.8) and the S was only slightly lower. The conclusion is that the distributed lag extends over two years and is weighted heavily by the hog:corn ratio in t-1. Based on Equation (5.9), 97 percent of the adjustment to the observed hog:corn ratio took place in the first year and 3 percent in the second.

The coefficients of Sg^d, t-1 were positive as expected in (5.6), (5.7), and (5.8), though not significant.

Alt's procedure was applied to hog and corn prices separately in TABLE 8, using a one year lag for Equation (5.11) and one and two-year lags for Equation (5.12). In Equation (5.11) the coefficients of Ph, t-1 and Pc, t-1 were both highly significant; and the coefficient of Sg^d, t-1, though not significant, carried the proper sign.

The addition of Ph, t-2 and Pc, t-2 in Equation (5.12) did not improve the statistical fit. In fact, the $\overline{R}^2$ was lower and S higher than

TABLE 7. Regressions of alternative hog supply equations, with dependent variable in first differences of sows farrowing, hog and corn prices as a ratio; 1925-1941.

Item	Equation (5.8)	(5.9)	(5.10)
Dependent Variable	$\hat{F}^d, t$	$\hat{F}^d, t$	$\hat{F}^d, t$
Constant	-3545	-3613	-2538
Independent Variables	Coefficients with t values in parenthesis		
H:C, t-1	291.28 (6.93)**	288.44 (6.26)**	245.01 (4.77)**
H:C, t-2		8.48 (.19)	26.38 (.62)
H:C, t-3			-65.47 (1.59)
Sg^d, t-1	.0259 (1.18)	.0285 (1.07)	.0467 (1.70)
R^2	.84**	.84**	.87**
$\bar{R}^2$	.82**	.80**	.82**
S	408	424	400
d	2.32	2.30	1.99
$F_{(T-k_2-1, k_2-k_1)}$		.04	2.50

* Significant at 5 percent level.

** Significant at 1 percent level.

TABLE 8. Regressions of alternative hog supply equations, with dependent variable in first differences of sows farrowing, hog and corn prices separate; 1925-1941.

Item	Equation (5.11)	Equation (5.12)
Dependent Variable	$\hat{F}^d, t$	$\hat{F}^d, t$
Constant	187.6	261.6
Independent Variables	Coefficients with t values in parenthesis	
Ph, t-1	342.80 (4.78)**	367.03 (2.96)*
Ph, t-2		-1.551 (.02)
Pc, t-1	-4272.5 (5.86)**	-4330.4 (4.80)**
Pc, t-2		-300.4 (.31)
Sg^d, t-1	.032 (1.30)	.034 (1.03)
R^2	.81**	.81*
$\bar{R}^2$	.76**	.72*
S	465	506
d	2.35	2.24
$F_{(T-k_2-k_1, k_2-k_1)}$		.06

* Significant at 5 percent level.

** Significant at 1 percent level.

for (5.11). The coefficients of Ph, t-2 and Pc, t-2 were not significant and the sign on the coefficient of Ph, t-2 was actually negative. So, as concluded for the hog:corn ratio, price variables lagged two years were of negligible importance in explaining hog supplies in 1925-1941.

Comparing the statistical properties of Equations (5.11) and (5.12) with (5.8) and (5.9), respectively, the separation of hog and corn prices actually was less satisfactory than considering hog and corn prices in ratio form.

Dependent Variable in Absolute Values

In Equations (5.13) and (5.14) in TABLE 9, the dependent variables are in absolute values and are lagged to form independent variables. Comparing these two equations with Equations (5.10) and (5.12), respectively, in which the dependent variable is in first differences, it is observed that the $\bar{R}^2$ values are higher and S values are lower in (5.13) and (5.14), indicating a distinct improvement in the statistical fit.

As was suggested by the equations with the dependent variable in first differences, there was apparently little response to H:C, t-2 and H:C, t-3 or to Ph, t-2 and Pc, t-2.

In (5.13), the elasticity of supply at the means with respect to H:C, t-1 is .32 and only .04 for H:C, t-2. This adds to a total "long run" elasticity of .36 for the two-year period. This is considerably less than the two-year supply elasticity of .60 calculated for 1908-1924.

In (5.14), the supply elasticity for Ph, t-1 is .29 and for Ph, t-2 is .04 at the means. The supply elasticities are -.31 for Pc, t-1 and -.04 for Pc, t-2. These add to a "long run" supply elasticity of .33 for Ph and -.35 for Pc, considering a two-year adjustment period. As in 1908-1924, the elasticities on Ph and Pc are remarkably close except for sign.

TABLE 9. Regressions of alternative hog supply equations with dependent variable in absolute numbers of sows farrowing; 1925-1941.

Item	Equation (5.13)	Equation (5.14)
Dependent Variable	$\hat{F}, t$	$\hat{F}, t$
Constant	-1940	1017
Independent Variables	Coefficients with t values in parenthesis	
F, t-1	.7310 (7.57)**	.6875 (5.81)**
H:C, t-1	217.14 (4.48)**	
H:C, t-2	26.06 (.76)	
H:C, t-3	-41.47 (1.21)	
Ph, t-1		286.2 (2.67)*
Ph, t-2		42.30 (.57)
Pc, t-1		-3478 (4.10)**
Pc, t-2		-467 (.59)
Sg, t-1	.0593 (2.02)#	.0573 (1.63)
R^2	.94**	.93**
$\bar{R}^2$	.92**	.88**
S	351	421
d	2.21	2.23

\# Significant at the 10 percent level.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

1947-1958

Dependent Variable in First Differences

Equations (5.15), (5.16), and (5.17) in TABLE 10 represent the successive steps in the procedure of Alt's for obtaining the relevant lag distribution. The addition of H:C, t-2 in Equation (5.16) increased the $\bar{R}^2$ and lowered the S value as compared with Equation (5.15). Further improvement was achieved with the addition of H:C, t-3 in (5.17), as the $\bar{R}^2$ was increased even more and the S value reduced. The F statistic, however, did not indicate the increases in the R^2 values to be significant.

The coefficient of H:C, t-1 was highly significant in all three equations and its significance increased as lagged values of H:C were added. The significance of the coefficient of H:C, t-2 also was greater in (5.17) than in (5.16). The coefficient of Sg^d, t-1 had the proper sign in all three equations, though not significant.

The value and significance of the coefficients of H:C in (5.17) was the greatest for t-1, decreased in t-2 and decreased even more in t-3. This supports Hypothesis I. Assuming the adjustment to the hog:corn ratio was completed in a three-year period, 56 percent of the adjustment was in the first year, 28 percent in the second, and 16 percent in the third.

Hog and corn prices were observed separately in Equations (5.18) and (5.19), presented in TABLE 11. The coefficients of Ph, t-1 and Pc, t-1 were both significant in (5.18). In (5.19) the significance of these coefficients was even greater and the coefficients of Ph, t-2 and Pc, t-2 were significant at the 10 percent level. In both (5.18) and (5.19), the coefficient of Sg^d, t-1 was positive, though insignificant.

Equation (5.19) explained a large though not a significant proportion of the unexplained variation in F^d, t estimated by Equation (5.18).

TABLE 10. Regressions of alternative hog supply equations, with dependent variable in first differences of sows farrowing, hog and corn prices as a ratio; 1947-1958.

Item	Equation (5.15)	(5.16)	(5.17)
Dependent Variable	$\hat{F}^d, t$	$\hat{F}^d, t$	$\hat{F}^d, t$
Constant	-3044	-4937	-6702
Independent Variables	Coefficients with t values in parenthesis		
H:C, t-1	226.04 (3.34)**	256.62 (4.10)**	287.42 (4.36)**
H:C, t-2		117.21 (1.83)	143.38 (2.18)#
H:C, t-3			80.63 (1.21)
Sg^d, t-1	.034 (1.32)	.025 (1.09)	.018 (.75)
R^2	.67*	.77*	.81*
$\bar{R}^2$	.60*	.68*	.70*
S	483	430	418
d	1.48	1.95	1.77
$F_{(T-k_2-1,\, k_2-k_1)}$		3.36	1.47

\# Significant at 10 percent level.

* Significant at 5 percent level.

** Significant at 1 percent level.

TABLE 11. **Regressions of alternative hog supply equations, with dependent variable in first differences of sows farrowing, hog and corn prices separate; 1947-1958.**

Item	Equations (5.18)	(5.19)
Dependent Variable	$\hat{F}^d, t$	$\hat{F}^d, t$
Constant	-831.5	-920.6
Independent Variables	Coefficients with t values in parenthesis	
Ph, t-1	175.94 (3.40)**	192.13 (4.34)**
Ph, t-2		106.17 (2.23)#
Pc, t-1	-1777.9 (3.13)*	-2284.0 (4.40)**
Pc, t-2		-971.4 (1.97)#
Sg^d, t-1	.036 (1.38)	.020 (.88)
R^2	.71*	.85*
$\bar{R}^2$	.61*	.73*
S	479	397
d	1.51	2.35
$F_{(T-k_2-k_1,\, k_2-k_1)}$		2.85

\# Significant at the 10 percent level.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

The standard error of the estimate was also lower in (5.19). This also supports the hypothesis that prices in years prior to breeding time influence production decisions.

Some improvement in the statistical properties was gained by separating hog and corn prices. This can be seen by comparing the $\bar{R}^2$ and S values of (5.18) and (5.19) with (5.15) and (5.16), respectively.

Dependent Variable in Absolute Values

No clear-cut advantage was found in putting the dependent variable in absolute values and using lagged values of the dependent variable as an independent variable over putting the dependent variable in first differences. Using the $\bar{R}^2$ and S criteria, Equation (5.20) in TABLE 12 was somewhat superior to its counterpart in first differences, Equation (5.17) in TABLE 10. The coefficient of Sg, t-1 was negative in (5.20), however. On the other hand, Equation (5.21) was somewhat less satisfactory by these standards than its counterpart in first differences, Equation (5.19) in TABLE 11. In addition, the coefficients of Ph, t-1 and Pc, t-1 were less significant in Equation (5.21) than in (5.19).

Equation (5.20), just as (5.17), indicates positive response of production to the hog:corn ratio lagged one, two, and three years, with the coefficients larger and more significant in the more recent years. Even the coefficient of H:C, t-3 is significant at the 10 percent level.

The coefficient of Sg, t-1 was negative in (5.20) but not significant. Though positive in (5.21), it was also not significant.

The supply elasticities at the means, as calculated from the coefficients of Equation (5.20), are .41, .32, and .27 for H:C, t-1, H:C, t-2 and H:C, t-3, respectively. Assuming that the adjustment to the observed hog:corn ratios is completed within a three-year period,

TABLE 12. **Regressions of alternative hog supply equations with dependent variable in absolute numbers of sows farrowing; 1947-1958.**

Item	Equation (5.20)	Equation (5.21)
Dependent Variable	$\hat{F}, t$	$\hat{F}, t$
Constant	-3990	-1098
Independent Variables	Coefficients with t values in parenthesis	
F, t-1	.5693 (2.10)#	.9930 (3.83)*
H:C, t-1	252.7 (3.72)**	
H:C, t-2	205.6 (3.03)*	
H:C, t-3	169.5 (2.20)#	
Ph, t-1		198.6 (3.12)*
Ph, t-2		120.2 (2.22)#
Pc, t-1		-2437 (3.54)*
Pc, t-2		-1035 (1.76)
Sg, t-1	-.0165 (.70)	.0047 (.15)
R^2	.85*	.83
$\bar{R}^2$	.73*	.63
S	400	470
d	1.61	2.45

\# Significant at the 10 percent level.

* Significant at the 5 percent level.

** Significant at the 1 percent level.

the long run supply elasticity would be 1.00. This is greater than the supply elasticity of .60 calculated for 1908-1924 and .36 calculated for 1925-1941, both based on a two-year period. Assuming a distributed lag over only two years in 1947-1958, the total supply elasticity would be .73.

As calculated from (5.21), the supply elasticity for Ph, t-1 is .48 and for Ph, t-2 is .29. The supply elasticity for Pc, t-1 is -.46 and for Pc, t-2 is -.20. As in 1908-1924 and in 1925-1941, the elasticities of Ph and Pc are not much different except for the expected difference in signs.

1925-1941 Compared With 1947-1958

As mentioned in the introductory section of this chapter, the decision was made to separate the pre-World War II period from the post-World War II period. Certain differences in the supply response equations between these two periods were noted and discussed in the previous two sections of this chapter.

To compare statistically the 1947-1958 period with 1925-1941, the two periods were merged in Equation (5.22). The variables Ph' and Pc' applied to 1925-1941 and were set at 0 levels for 1947-1958. Conversely, Ph'' and Pc'' applied to 1947-1958 and were set at 0 levels for 1925-1941. The supply of other feed grains, Sg^d, was assumed to hold the same relationship in both periods.

$$(5.22)\quad \hat{F}^d{,t} = -33.89 + \underset{(3.37)^{**}}{369.02\, Ph',t-1} + \underset{(.08)}{6.354\, Ph',t-2} - \underset{(5.62)^{**}}{4265.9\, Pc',t-1}$$

$$- \underset{(.10)}{88.5\, Pc',t-2} + \underset{(3.46)^{**}}{169.39\, Ph'',t-1} + \underset{(1.69)}{90.65\, Ph'',t-2} - \underset{(3.96)^{**}}{2279.6\, Pc'',t-1}$$

$$- \underset{(1.97)\#}{1058.6\, Pc'',t-2} + \underset{(1.30)}{.026\, Sg^d,t-1}$$

$R^2 = .80$

$\overline{R}^2 = .71$

$S = 466$

Significant at 10 percent level.

** Significant at 1 percent level.

Using a t test statistic described in APPENDIX B, significant differences were apparent in the coefficients on the lagged prices of hogs and corn between 1925-1941 and 1947-1958. The results are presented in TABLE 13.

TABLE 13. Significance of differences between coefficients of variables in 1925-1941 and coefficients of corresponding variables in 1947-1958, in reference to Equation (5.22).

Variable	Coefficient		t value of
	1925-1941	1947-1958	difference
Ph, t-1	369.021	169.39	5.30**
Ph, t-2	6.35	90.65	2.78*
Pc, t-1	-42.659	-22.796	7.14**
Pc, t-2	-.885	-10.586	2.08#

Significant at 10 percent level.
* Significant at 5 percent level.
** Significant at 1 percent level.

The tests indicate that the price of hogs and the price of corn in t-1 became significantly less important in influencing farmers' hog production decisions in the 1947-1958 period than in 1925-1941. On the other hand, consideration of hog and corn prices in t-2 became significantly more important.

Nerlove's Method

Nerlove's model is actually a special case of the more general model for distributed lags in supply response set forth in Hypothesis I, with the weights declining with increasing lags.

As presented in CHAPTER III, Nerlove specified a certain family of distribution functions for lagged responses. The estimation problem is to determine the parameters of the functions under the assumed restrictions. Using F, t as the supply variable (Sh, t for 1908-1924) and the hog:corn ratio, the Nerlove model would include the following equations:

$$(5.23)\quad F^{*}, t = \alpha_0 + \alpha_1 H{:}C^{*}, t \qquad \alpha_1 > O$$

$$(5.24)\quad H{:}C^{*}, t = \beta\ H{:}C, t-1 + (1-\beta) H{:}C^{*}, t-1 \qquad O < \beta \leq 1$$

$$(5.25)\quad F, t = \gamma F^{*}, t + (1-\gamma)\ F, t-1 \qquad O < \gamma \leq 1$$

Where F*, t is the long run equilibrium number of sows farrowing in the spring as desired in year t; H:C*, t is the expected hog:corn ratio for year t; α_0 is a constant and α_1 the coefficient of the long run supply adjustment; β is the "coefficient of expectations" and γ is the "coefficient of adjustment."

By a process of substitution as demonstrated by Equations (3.27) through (3.33) in CHAPTER III, the following equation of observable variables is obtained:

$$(5.26)\quad F, t = \alpha_0\gamma + (2-\beta-\gamma)\ F, t-1 - (1-\beta)\ (1-\gamma)\ F, t-2 + \alpha_1\beta\gamma H{:}C, t-1$$

As β and γ enter the equation symmetrically, neither can be identified unless one or the other can be regarded as known a priori. Letting the coefficients of Equation (5.26) equal c_0, c_1, c_2, and c_3,

$$\alpha_0\gamma = c_0 \qquad\qquad -(1-\beta)\ (1-\gamma) = c_2$$

$(2-\beta-\gamma) = c_1$ $\qquad\qquad$ $a_1\beta\gamma = c_3$

β and γ can be estimated by forming a quadratic from c_1 and c_2.

$$\beta(\text{or } \gamma) = 1/2 \left[-(c_1 - 2) + \sqrt{(c_1-2)^2 - 4(1-c_1-c_2)}\right]$$

$$\gamma(\text{or } \beta) = 1/2 \left[-(c_1 - 2) - \sqrt{(c_1-2)^2 - 4(1-c_1-c_2)}\right]$$

However, there is no way of telling which estimate is β and which is γ.

On the other hand, the coefficient of the long run supply adjustment, a_1, can be identified.

Transposing and substituting,

$$\beta + \gamma = 2 - c_1$$

$$\beta\gamma = -1 + \gamma + \beta - c_2 = 1 - c_1 - c_2$$

$$a_1 = \frac{c_3}{\beta\gamma} = \frac{c_3}{1-c_1-c_2}$$

The long run supply elasticity with respect to the expected hog:corn ratio, $eH:C^*, t$, may then be calculated.

$$eH:C^*, t = \left(\frac{\overline{H:C}, t}{\overline{F}, t}\right) a_1$$

where $\overline{H:C}, t$ is the mean of H:C and $\overline{F}, t$ is the mean of F, t for the period studied.

Note the coefficient of F, t-2 in (5.26), which was labeled c_2. If the value of this coefficient is not significantly different from zero, then one of the following null hypotheses may be accepted as true; (1) β equals one, (2) γ equals one, (3) both β and γ equal one.

As Nerlove assumes that $0 < \beta \leq 1$ and that $0 < \gamma \leq 1$, then $0 \leq c_1 < 2$ and $-1 < c_2 \leq 0$.

Some additional complications arise in Nerlove's model when hog and corn prices are introduced as separate variables in place of the hog:corn ratio. The long run supply equation would be

(5.27) $F^*,t = a_0 + a_1 Ph^*,t + a_2\ Pc^*,t$

If the expectation coefficients for hog and corn prices are assumed to be the same,

(5.28) $a_1 Ph^*,t + a_2\ Pc^*,t = \beta[a_1\ Ph,t-1 + a_2\ Pc,t-1] + (1-\beta)[\ a_1\ Ph^*,t-1$
$+ a_2\ Pc^*,t-1]$

Lagging (5.27) by one year and substituting into (5.28)

(5.29) $a_1\ Ph^*,t + a_2\ Pc^*,t = \beta[a_1\ Ph,t-1 + a_2\ Pc,t-1]$
$+ (1-\beta)\ [F^*,t-1 - a_0\ ]$ $\qquad 0 < \beta \leq 1$

Substituting (5.29) into (5.27)

(5.30) $F^*,t = a_0 + \beta[a_1\ Ph,t-1 + a_2\ Pc,t-1] + (1-\beta)\ [F^*,t-1 - a_0\ ]$

The adjustment equation would be

(5.31) $F,t = F,t-1 + \gamma[F^*,t - F,t-1]$ $\qquad 0 < \gamma \leq 1$

Substituting (5.30) into (5.31)

(5.32) $F,t = F,t-1 + \gamma\ a_0 + \gamma\beta[a_1\ Ph,t-1 + a_2\ Pc,t-1]$
$+ \gamma\ (1-\beta)\ [F^*,t-1 - a_0\ ] - \gamma\ F,t-1$

Lagging (5.31) by one year,

(5.33) $F,t-1 = F,t-2 + \gamma F^*,t-1 - \gamma\ F,t-2$

Transposing,

(5.34) $\gamma\ F^*,t-1 = F,t-1 - (1-\gamma)F,t-2$

Substituting (5.34) into (5.32)

(5.35) $F,t = (1-\gamma)\ F,t-1 + \gamma\ a_0 + \gamma\beta a_1\ Ph,t-1 + \gamma\beta a_2\ Pc,t-1$
$+ (1-\beta)\ [F,t-1 - (1-\gamma)\ F,t-2\ ] - \gamma\ (1-\beta)a_0$

$F,t = a_0\beta\gamma + [\ (1-\gamma) + (1-\beta)\ ]\ F,t-1 - (1-\beta)\ (1-\gamma)\ F,t-2$
$+ \gamma\beta\ a_1\ Ph,t-1 + \gamma\ \beta a_2\ Pc,t-1$

This equation can then be estimated by the traditional least squares procedure. Again, the parameters β and γ cannot be identified; but the long run adjustment coefficients a_1 and a_2 can be determined. Letting

$$a_0\beta\gamma = c_0 \qquad \gamma\beta a_1 = c_3$$
$$2 - \beta - \gamma = c_1 \qquad \gamma\beta a_2 = c_4$$
$$-(1-\beta)(1-\gamma) = c_2$$

the long run adjustment coefficients can be determined as follows.

$$\beta + \gamma = 2 - c_1$$
$$-1 + \gamma + \beta - \beta\gamma = c_2$$
$$\beta\gamma = -1 + \gamma + \beta - c_2$$
$$\beta\gamma = -1 + (2 - c_1) - c_2 = 1 - c_1 - c_2$$

$$a_1 = \frac{c_3}{1 - c_1 - c_2}$$

$$a_2 = \frac{c_4}{1 - c_1 - c_2}$$

The long run supply elasticities then are obtained.

$$ePh^*, t = \left(\frac{\overline{Ph}, t}{\overline{F}, t}\right) a_1$$

$$ePc^*, t = \left(\frac{\overline{Pc}, t}{\overline{F}, t}\right) a_2$$

where $\overline{Ph}, t$, $\overline{Pc}, t$ and $\overline{F}, t$ are the respective mean values of these variables for the period studied.

There is no a priori basis for regarding the coefficient of expectations as the same for hog and corn prices. This is particularly questionable in the post-World War II period when government programs have tended to reduce the year to year variation in corn prices. There is reason to believe that the coefficient of expectations on corn prices would have increased between 1925-1941 and 1947-1958, whereas there is little reason to believe that the coefficient of expectation on hog prices would have changed in the same way.

A third model was therefore estimated. In this model, the expectation coefficients on hog and corn prices were allowed to differ. But to identify the expectation coefficients, β_1 and β_2, the coefficient of adjustment was considered to equal one. The model is as follows:

(5.36) $F^*,t = a_0 + a_1 \; Ph^*,t \; + \; a_2 \; Pc^*,t$

(5.37) $Ph^*,t = \beta_1 \; Ph,t-1 \; + \; (1-\beta_1) \; Ph^*,t-1 \qquad 0<\beta_1 \leq 1$

(5.38) $Pc^*,t = \beta_2 \; Pc,t-1 \; + \; (1-\beta_2) \; Pc^*,t-1 \qquad 0<\beta_2 \leq 1$

(5.39) $F,t = \gamma \; F^*,t \; + (1-\gamma) \; F,t-1 \; = \; F^*,t \qquad \gamma = 1$

By Thiel's procedure outlined by Nerlove, this model can be reduced to an equation with observable variables.[4]

(5.40) $F,t = a_0\beta_1\beta_2 + (2-\beta_1-\beta_2) \; F,t-1 \; - (1-\beta_1)(1-\beta_2) \; F,t-2$
$+ \; a_1\beta_1 \; Ph,t-1 - a_1\beta_1 (1-\beta_2) \; Ph,t-2 + a_2\beta_2 \; Pc,t-1$
$- \; a_2\beta_2 (1-\beta_1) \; Pc,t-2$

The coefficients β_1 and β_2 enter asymmetrically so both can be estimated. However, two separate sets of estimates are possible. Letting

$a_0 \beta_1\beta_2 = c_0$ $\qquad -a_1\beta_1 (1-\beta_2) = c_4$

$(2-\beta_1 - \beta_2) = c_1$ $\qquad a_{.} \beta_2 = c_5$

$-(1-\beta_1)(1-\beta_2) = c_2$ $\qquad -a_2 \beta_2 (1-\beta_1) = c_6$

$a_1\beta_1 = c_3$

The coefficients of expectations can be estimated either as follows

$$\frac{c_6}{c_5} = \frac{-a_2 \beta_2 (1-\beta_1)}{a_2\beta_2} = -(1-\beta_1) = \beta_1 - 1$$

$$\beta_1 = \frac{c_6}{c_5} + 1$$

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[4]Marc Nerlove, op. cit., pp. 193-194.

$$\frac{c_4}{c_3} = \frac{-\alpha_1\beta_1(1-\beta_2)}{\alpha_1\beta_1} = -(1-\beta_2) = \beta_2 - 1$$

$$\beta_2 = \frac{c_4}{c_3} + 1$$

or by solving a quadratic using coefficients c_1 and c_2

$$\beta_1 \text{ (or } \beta_2) = \tfrac{1}{2} \left[-(c_1-2) + \sqrt{(c_1-2)^2 - 4(1-c_1-c_2)} \right]$$

$$\beta_2 \text{ (or } \beta_1) = \tfrac{1}{2} \left[-(c_1-2) - \sqrt{(c_1-2)^2 - 4(1-c_1-c_2)} \right]$$

The estimates of β_1 and β_2 cannot be identified in the quadratic solution. In addition, these estimates may or may not correspond to the estimates obtained using c_3, c_4, c_5, and c_6.

As in the model where the expectation coefficients were assumed equal, the long run adjustment coefficients, α_1 and α_2, and the respective long run supply elasticities can be estimated.

$$\alpha_1 = \frac{c_3}{\beta_1} \qquad \alpha_2 = \frac{c_5}{\beta_2}$$

Since β_1 and β_2 have two sets of estimates and cannot be identified in the quadratic solution, α_1 and α_2 and the corresponding elasticities each have two additional alternative estimates which cannot be identified.

The three models outlined in this section were tried in obtaining estimates under Nerlove's method; the first model using the hog:corn ratio and assuming $\beta \neq 1, \gamma \neq 1$; the second model using hog and corn prices separately and assuming $\beta_1 = \beta_2 \neq 1$ and $\gamma \neq 1$; and the third model using hog and corn prices separately and assuming $\beta_1 \neq \beta_2$ and $\gamma = 1$. The second model includes the supply of other feed grains, a variable not included in the first and third models. The statistical results and estimates are presented for each of the three periods studied.

1908-1924

Equations (5.40), (5.41) and (5.42) in TABLE 14 represent the three Nerlove type models described in the previous section for 1908-1924. Statistically, the third model, (5.42), was superior to the other two, having the highest $\bar{R}^2$ and lowest standard error of the estimate. The positive sign on the coefficient of Sh, t-2 in Equation (5.42) was contrary to that postulated in Nerlove's model. The coefficient was not significantly different from zero, however.

In fact, the coefficient of Sh, t-2 was not significant in Equation (5.40) or (5.41). This gives support to one of the null hypotheses that $\gamma = 1$, $\beta = 1$ or both γ and $\beta = 1$.

Comparing Equation (5.40) with its counterpart under Alt's procedure, Equation (5.6) in TABLE 6, and $\bar{R}^2$ value was lower and S higher in (5.40) than in (5.6). The two equations are not strictly comparable, however, because Sg, t-1 is not included in (5.40). Equation (5.7) in TABLE 6 derived by Alt's procedure would correspond to Equation (5.41). Based on the statistical properties of the two equations, Equation (5.7) is more satisfactory. The sign on the coefficient of Sg, t-1 in (5.7) was positive as expected and, conversely, negative in (5.41), though not significant in either equation. Although Equation (5.7) and (5.42) are not strictly comparable, the statistical properties of the two are nearly identical.

The conclusion is that, statistically, equations derived to represent lagged supply response were at least as satisfactory, if not more satisfactory, by Alt's procedure than by Nerlove's, for 1908-1924.

TABLE 15 presents estimates of the parameters and elasticities calculated from Equations (5.40), (5.41) and (5.42). Reasonable estimates for β, γ and the long run supply elasticity were obtained in Equation (5.40). Although the values of β and γ cannot be distinguished, both are greater than zero and equal to or less than one. The long run

TABLE 14. Regressions of hog slaughter response equations using Nerlove's method, under alternative assumptions; 1908-1924.

	Equation		
	(5.40)	(5.41)	(5.42)
Assumptions	$\beta \neq 1$ $\gamma \neq 1$	$\beta_1 = \beta_2 \neq 1$ $\gamma \neq 1$	$\beta_1 \neq \beta_2$ $\gamma = 1$
Dependent Variable	$\widehat{Sh}$, t	$\widehat{Sh}$, t	$\widehat{Sh}$, t
Constant	-6912	6666	-1943
Independent Variables	Coefficients with t values in parenthesis		
Sh, t-1	1.1659 (4.26)**	1.2134 (3.50)**	.8806 (3.67)**
Sh, t-2	-.3260 (1.24)	-.1893 (.44)	.2585 (.75)
H:C, t-1	1127 (2.48)*		
Ph, t-1		2260 (1.82)	1757 (1.81)
Ph, t-2			1886 (2.90)*
Pc, t-1		-24396 (1.87)	-23845 (3.23)*
Pc, t-2			-23064 (2.91)*
Sg, t-1		-.3876 (.75)	
R^2	.64*	.62	.82*
$\bar{R}^2$	.54*	.41	.69*
S	3928	4459	3262
d	2.39	2.46	1.74

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TABLE 15. Estimates of the parameters and elasticities of hog slaughter response using Nerlove's method; 1908-1924.

Item	Equation (5.40)	(5.41)	(5.42)
	$\beta \neq 1$ $\gamma \neq 1$	$\beta_1 = \beta_2 \neq 1$ $\gamma \neq 1$	$\beta_1 \neq \beta_2$ $\gamma = 1$
β (or γ)	.53	.40	
γ (or β)	.30	1.24	
β_1			1.97[a]
β_2			2.07[a]
Elasticity of supply with respect to			
H:C*, t	2.12		
Ph*, t		-19.58	.19[b]
Pc*, t		1.83	-.21[c]

[a]Alternative estimates are 1.23 and -.11 based on quadratic solution.
[b]Alternative estimates are .30 and -3.25 based on quadratic solution.
[c]Alternative estimates are -.35 and 3.81 based on quadratic solution.

elasticity coefficient of 2.12 means that if there is, say, a 10 percent change in the expected hog:corn ratio, supply will eventually change in the same direction by 21.2 percent. This is greater than the long run supply elasticity with respect to the observed hog:corn ratio of .60 as calculated from (5.6). A greater elasticity with respect to the expected hog:corn ratio than to the observed is consistent with the theory of entrepreneural behavior in uncertainty. Producer response should be more sensitive to expected prices than to observed prices.

It should be pointed out that, in comparing the long run elasticities of supply between the Alt and Nerlove models, the elasticities estimated in the Alt model would, a priori, be biased downward. This is because only two or, at the most, three lagged prices are included in the Alt model. Of course, if hog prices exhibit cyclical tendencies (as expected) and if relevant lagged prices are omitted from the Alt model, then the disturbance would not be independent of the independent variables. This would bias the coefficients downward on lagged prices negatively correlated with the disturbance and upward on lagged prices positively so correlated. In other words, the direction of the total bias is not easily ascertained.

The parameters and elasticity estimates from Equation (5.41) do not correspond with the results from Equation (5.40). Either β or γ is estimated to be 1.24, contrary to the hypothesized value. The signs on the elasticity estimates are inconsistent with theory.

The estimates of β_1 and β_2 calculated from Equation (5.42) do not conform to the Nerlove model. Even the alternative estimates given in the footnote are not admissable. The long term elasticity estimates seem quite low, compared to the elasticity estimate for H:C*, t of Equation (5.40) and to the elasticity of supply with respect to observed prices calculated from Equation (5.6). Even the plausible alternative estimates of .30 for Ph*, t and -.35 for Pc*,t seem small. The estimates of β_1 and β_2 and the elasticities may be wrong because the true value of γ is less than one.

1925-1941

The alternative Nerlove type supply equations and their statistical properties are presented in TABLE 16 for the 1925-1941 period. Each of the three equations explained 92 percent of the variation in sows farrowing in the spring. Equation (5.43) was somewhat superior based on $\overline{R}^2$ and S. The signs on all the coefficients were as expected except for the positive sign on the coefficients of F, t-2 in Equation (5.43) and

TABLE 16. Regressions of farrowing response equations using Nerlove's method, under alternative assumptions; 1925-1941.

	Equation (5.43)	Equation (5.44)	Equation (5.45)
Assumptions	$\beta \neq 1$ $\gamma \neq 1$	$\beta_1 = \beta_2 \neq 1$ $\gamma \neq 1$	$\beta_1 \neq \beta_2$ $\gamma = 1$
Dependent Variable	$\hat{F}, t$	$\hat{F}, t$	$\hat{F}, t$
Constant	-2342	1134	2149
Independent Variables	Coefficients with t values in parenthesis		
F, t-1	.8362 (7.75)**	.7325 (5.77)**	.6006 (2.18)#
F, t-2	.0275 (.27)	-.0132 (.12)	.1460 (.65)
H:C, t-1	286.90 (7.02)**		
Ph, t-1		299.7 (3.87)**	323.5 (2.72)*
Ph, t-2			126.6 (.81)
Pc, t-1		-3741 (4.05)**	-4600 (5.18)**
Pc, t-2			-804 (.61)
Sg, t-1		.0469 (1.35)	
R^2	.92**	.92**	.92**
$\bar{R}^2$	.90**	.88**	.85**
S	399	432	483
d	2.65	2.62	2.81

Significant at the 10 percent level.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

(5.45). The coefficients of F, t-2 in all three equations were not significantly different from zero. In Equations (5.43) and (5.44), this lends credulence to one of the null hypotheses, $\beta = 1$, $\gamma = 1$ or both β and $\gamma = 1$.

Nerlove's model can be compared with Alt's procedure by comparing Equations (5.43) and (5.44) in TABLE 16 with Equations (5.13) and (5.14), respectively, in TABLE 9. The two techniques gave about the same statistical results. The S value for (5.13) was lower than for (5.43) but this may be partly because Sg, t-1 was included in (5.13) and not in (5.43).

The estimate of β and γ by Equation (5.43) in TABLE 17 shows either β or γ to be near one and the other to be .13. This indicates that both β and γ are not near one. The difference between the estimates of β and γ were greater than in 1908-1924. The long run elasticity of supply with respect to H:C*, t was 3.13, somewhat greater than in 1908-1924. This elasticity estimate is considerably larger than the long run elasticity of .36 with respect to observed hog:corn ratios, as calculated from Equation (5.13).

In Equation (5.44), the estimates of β and γ also were near the extremes of the admissible range. Of course, the -.03 is just outside this range.

Even positive values of β or γ near 0 do not seem very plausible. For example, taking Nerlove's basic model given by (5.24) and (5.25), the sum of weights for N past years relating H:C, t-i to H:C*, t, where i = 1.2...N, is

$$1 - (1-\beta)^{N+1}$$

A similar formula applies to the sum of weights relating F*, t-i to F, t ,

$$1 - (1-\gamma)^{N+1}$$

TABLE 17. Estimates of the parameters and elasticities of farrowing response using Nerlove's method; 1925-1941.

Item	Equations (5.43)	(5.44)	(5.45)
	$\beta \neq 1$ $\gamma \neq 1$	$\beta_1 = \beta_2 \neq 1$ $\gamma \neq 1$	$\beta_1 \neq \beta_2$ $\gamma = 1$
β (or γ)	1.03	.82	
γ (or β)	.13	-.03	
β_1			6.72[a]
β_2			1.39[a]
Elasticity of supply with respect to			
H:C*, t	3.13		
Ph*, t		1.10	.05[b]
Pc*, t		-1.18	-.29[c]

[a] Alternative estimates are 1.19 and .21 based on quadratic solution.

[b] Alternative estimates are .28 and 1.55 based on quadratic solution.

[c] Alternative estimates are -.34 and -1.90 based on quadratic solution.

For a given value of β and an arbitrarily small number e, we can solve for N, by

$$1 - \left| 1 - (1-\beta)^{N+1} \right| \leq e$$

The same applies to γ.

If we would agree to include enough years to accumulate all but 10 percent of the weights, and if the value of β or γ was as low as .13 as calculated from Equation (5.43), then the number of past years needed could be calculated from the following equation.

$$1 - \left| 1 - (1-.13)^{N+1} \right| = .10$$

Reducing and converting to logs, N is found to equal 15 years. Even if 20 percent error were allowed, a period of 11 past years would be necessary.

A priori, it would seem that 10 to 15 years would be much longer than necessary for farmers to either form an opinion about expected prices or to adjust to these expectations.

The long run supply elasticities estimated from Equation (5.44) were near unity for both hog and corn prices. These were considerably less than determined for the hog:corn ratio in Equation (5.43).

As in 1908-1924, the estimates of β_1 and β_2 in the third model for 1925-1941 were high. These are given in TABLE 17 by Equation (5.45). The long run elasticity estimates were low. The alternative elasticity estimates of 1.55 for Ph*, t and -1.90 for Pc*, t based on the solution of the quadratic do seem plausible.

Again, as in 1908-1924, some question may be raised about the error in restricting γ to equal one.

<u>1947-1958</u>

Equations (5.46), (5.47) and (5.48) in TABLE 18 represent the three alternative Nerlove models for 1947-1958. Based on $\overline{R}^2$ and S, the second model, Equation (5.47) was statistically superior. However, the negative sign on the coefficient of Sg, t-1 was contrary to theory, though the value of the coefficient was not significant.

The negative coefficients of F, t-2 in Equation (5.46) and (5.47) were significantly different from zero at the 10 and 5 percent levels respectively. This would tend to reject the null hypotheses that $\beta = 1$, $\gamma = 1$ or that β and $\gamma = 1$. In 1908-1924 and in 1925-1941, these hypotheses were not rejected. Some possible interpretations are that (1) Farmers are basing expectations more on earlier prices and less

TABLE 18. Regressions of farrowing response equations using Nerlove's method, under alternative assumptions; 1947-1958.

	Equation (5.46)	Equation (5.47)	Equation (5.48)
Assumptions	$\beta \neq 1$, $\gamma \neq 1$	$\beta_1 = \beta_2 \neq 1$, $\gamma \neq 1$	$\beta_1 \neq \beta_2$, $\gamma = 1$
Dependent Variable	$\hat{F}, t$	$\hat{F}, t$	$\hat{F}, t$
Constant	-2026	2225	193.4
Independent Variables	Coefficients with t values in parenthesis		
F, t-1	1.2655 (4.83)**	1.3466 (5.54)**	1.2339 (2.89)*
F, t-2	-.4739 (2.12)#	-.6108 (2.62)*	-.3953 (.71)
H:C, t-1	284.0 (3.68)**		
Ph, t-1		226.01 (4.07)**	217.4 (3.29)*
Ph, t-2			45.2 (.38)
Pc, t-1		-2456 (4.10)**	-2392 (3.66)*
Pc, t-2			-249.2 (.20)
Sg, t-1		-.0190 (.63)	
R^2	.75*	.84*	.85
$\bar{R}^2$	.66*	.72*	.66
S	453	413	449
d	2.00	2.37	2.40

Significant at the 10 percent level.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

on the more recent prices in forming expectations or (2) Farmers are not adjusting as quickly as before to changing expectations or (3) A combination of (1) and (2) has occurred in 1947-1958.

Comparing the Nerlove equation in TABLE 18 with the Alt equations in TABLE 12, there is no clear-cut preference for one technique over the other. Based on $\overline{R}^2$ and S values, Equation (5.20) is more satisfactory than (5.46). On the other hand, Equations (5.47) and (5.48) were superior to Equation (5.21). Again, Equation (5.20) is not strictly comparable to (5.46) because Sg, t-1 was excluded in Equation (5.46). The same is true in comparing (5.21) with (5.48).

Estimates of the properties of the Nerlove models for 1947-1958 are presented in TABLE 19. Estimates of β and γ in Equation (5.46) were imaginary numbers. However, the estimate of the long run supply elasticity was plausible. The elasticity of 2.19 was less than in 1925-1941 but about the same as in 1908-1924. This estimate of 2.19 is over twice the long run supply elasticity with respect to observed hog: corn ratios calculated from (5.20).

Estimates of β and γ in Equation (5.47) were also imaginary. The long run supply elasticity for Ph*, t is about the same as for H:C*, t as estimated by Equation (5.46). The elasticity for Pc*, t is negative and slightly smaller.

As in the previous two periods, estimates of β_1 and β_2 in the third model were greater than one, as shown by the estimates from Equation (5.48) in TABLE 19. The estimates of the long run supply elasticities for Ph*, t and Pc*, t were less than obtained from Equation (5.47). The alternative estimates were all imaginary. The restriction on γ to equal one may have biased the estimates of the other parameters, as may have been the case in the earlier periods.

TABLE 19. **Estimates of the parameters and elasticities of farrowing response using Nerlove's method; 1947-1958.**

Item	Equations (5.46) $\beta \neq 1$, $\gamma \neq 1$	(5.47) $\beta_1 = \beta_2 \neq 1$, $\gamma \neq 1$	(5.48) $\beta_1 \neq \beta_2$, $\gamma = 1$
β (or γ)	a	a	
γ (or β)	a	a	
β_1			1.10[b]
β_2			1.21[b]
Elasticity of supply with respect to			
H:C*, t	2.19		
Ph*, t		2.07	.48[b]
Pc*, t		-1.75	-.37[b]

[a]Both β and γ are imaginary numbers.
[b]Alternative estimates are imaginary numbers based on quadratic solution.

Summary and Conclusions

The estimates from the regression equations presented in this chapter gave substantial support to Hypothesis I. The results suggest that a study of the supply function for hogs should include prices of hogs and corn, separately or as a ratio, lagged by one, two and possibly three years. In 1908-1924 and in 1947-1958, the evidence was strong that prices in t-2 as well as in t-1 influenced farmers' production decisions for t. The effect of prices in t-2 was not significant in 1924-1925, although in most of the equations tried, the direction of the influence was consistent with that hypothesized. The hog:corn ratio in t-3 was significant at the 10 percent level in one equation for 1947-1958.

The distribution of the lagged response tended to approximate the distribution set forth by Hypothesis I. The supply response was greater from the hog:corn ratio and the separate prices lagged 1 year than lagged 2 years except in 1908-1924 when the response was about the same from both lags.

Some difficulty was experienced in obtaining reasonable estimates of the parameters of Nerlove's model which were within the restrictions of the model. The most plausible estimates were obtained in the first of the three alternative models considered. In this model, the hog:corn ratio was used and both the coefficient of expectations and the coefficient of adjustment were assumed to be not equal to one.

The necessity of specifying the value of either the coefficient of expectations or the coefficient of adjustment in order to identify one or the other emphasizes the need for more adequate theories of expectation; and also the need for more study of the cost structure of agricultural firms and the relationship between the cost structure and the adjustment lag.

Based on the statistical properties of the equations, little difference was observed between Nerlove's model and Alt's equations with the dependent variable in absolute values and lagged to form an independent variable.

Generally, there was little advantage in separating hog and corn prices into two variables rather than entering them in ratio form. The usage of the hog:corn ratio, quite common in past studies of the hog supply function, is apparently justified.

The reformulation of the dependent variable from first differences to absolute values with values lagged one year as an independent variable did not improve the estimates in every case, based on $\bar{R}^2$, S and "t" values on the regression coefficient. In only one case, however, was this reformulation clearly inferior. This was Equation (5.21) for 1947-1958. In addition, the use of absolute values is preferred because of the theoretical considerations mentioned earlier in this Chapter.

The hog supply response pattern was different in 1947-1958 as compared with 1925-1941. Nearly all of the supply response in 1925-1941 was to the prices in t-1. In 1947-1958, the response from prices in t-1 was modified more by prices in t-2. The "long run" elasticity of supply at the means with respect to observed prices was greater in 1947-1958 than in 1924-1941. In 1947-1958, the elasticity of supply with respect to the observed hog:corn ratio was 1.00 over a three year period as compared to an elasticity of .36 over a two year period in 1925-1941.

The long run elasticity of supply with respect to the expected hog: corn ratio was 2.12 in 1908-1924, 3.13 in 1925-1941 and 2.19 in 1947-1958. In each period, the elasticity with respect to the expected hog: corn ratio was greater than with respect to the observed hog:corn ratio.

Regression Estimates for Fall Pig Crop

Most sows farrowing in the fall have been on farms using the two litter system. The same sows farrowing in the spring are normally bred for fall farrowing. Since the corn crop is a known quantity in the fall, decisions on major changes in production were believed to be made at that time and reflected in the spring pig crop.

For these reasons, the number of sows farrowing in the fall was considered a function of the sows farrowing in the spring along with certain modifying variables. TABLE 20 shows the equations for the three time periods. As given earlier in this chapter,

F, t	Sows farrowing in the spring
Sh, t	Slaughter of hogs from spring pig crop
Ff, t	Sows farrowing in the fall
Shf, t	Slaughter of hogs from fall pig crop
H:Cf, t	Hog:Corn ratio effective at breeding time for fall pig crop
IScg, t	Indicated free supply of corn and other feed grain
T	Time in years

TABLE 20. Regressions estimating hogs slaughtered from fall farrowings (1908-1924) and sows farrowing in the fall, (1925-1941) and (1947-1958).

Item	Equations (5.49)	(5.50	(5.51)
Period	1908-1924	1925-1941	1947-1958
Dependent Variable	$\hat{Shf}, t$	$\hat{Ff}, t$	$\hat{Ff}, t$
Constant	16807	-964	3185
Independent Variables	Coefficients with t values in parenthesis		
Sh, t	-.0213 (.14)		
F, t		.4916 (5.47)**	.6582 (5.08)**
H:Cf, t	1.587 (.97)	41.39 (1.32)	37.74 (1.09)
IScg, t	.0148 (.26)	.0106 (1.44)	.0118 (1.34)
T	437.8 (2.62)*	91.97 (5.11)**	89.27 (3.17)*
R^2	.59*	.80**	.79*
$\bar{R}^2$	.43**	.73**	.67*
S	2210	252	265

* Significant at 5 percent level.
** Significant at 1 percent level.

In calculating H:Cf, t, hog prices in April, t to June, t and corn prices in October, t-1 to January, t were used. Since the fall pig crop would be fed mostly from the new crop, the expectations would likely be based on the corn price during the previous harvest. It was believed that farmers would be more aware of corn prices in October to January than in April to June; and that they would be particularly aware of hog prices in April to June, months in which much of the previous fall crop is marketed and in which most of the sows to farrow in the fall are bred.

Because the fall pig crop is fed out mostly on the feed crops in year t, the indicated supplies were considered a possible influence. A shift to more multiple farrowing systems in recent years was reason for including the time variable.

The results presented in TABLE 20 show a highly significant relationship between spring and fall farrowings in the 1925-1941 and 1947-1958 periods although no apparent relationship in 1908-1924. The shift to fall farrowings is apparent in each period. Though not significant, the coefficients of H:Cf, t and IScg, t have the proper sign in each period.

CHAPTER VI

THE DEMAND FUNCTION

One of the conditions specified by Ezekiel as necessary in the application of the Cobweb Theorem was that the price is set by the supply available.[1] The assumption is that current supply is largely predetermined and not affected by current price.

In the supply equations for the spring pig crop, the October to January period was considered as the critical time in which the bulk of the previous spring's pig crop is sold and also the time when sows are bred for the following spring's pig crop. Within this four month period, the supply of hogs is largely predetermined by the number of pigs saved from the farrowings of the previous spring.

Of course, farmers can regulate the market weight and timing of the marketings over short periods in response to the changing hog: corn price ratio and the hog price outlook. But, this flexibility is limited by the discounts on heavier hogs and the declining efficiency of gains as weight increases.

For these reasons, the supply of hogs within a three to four month period will be considered predetermined.

The problem then becomes one of establishing the relationship between the supply of hogs and the price of hogs. The price of hogs depends on not only the supply of hogs, but also many other factors, mainly the prices of competing meat, consumer incomes, marketing margins, time, the seasons, and the fats and oils economy (lard).

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[1]Mordecai Ezekiel, _op. cit._, p. 438.

Two separate relationships were investigated; (1) Consumer demand relating supplies of pork and other factors to the retail price of pork and (2) Marketing margins relating the retail price of pork and certain relevant factors to the farm price of hogs. The demand and marketing margin study was limited to 1947-1958.

Consumer Demand

Four consumer demand equations were estimated successively and will be referred to as Model I, Model II, Model III and Model IV. Model I and Model II were based on quarterly data for 1948-1958. Models III and IV were based on quarterly data for 1947-1958.

The basic economic model from which the four consumer demand equations were derived actually includes the demand for consumption and demand for storage. This may be represented by two equations,

(6.1) $Cpk = a_0 + a_1\, Ppk + a_2\, Pm + a_3\, Y$

(6.2) $STpk = b_0 + b_1\, Ppk$

where, for a given quarter,

Cpk = consumption of pork

Ppk = price of pork

Pm = price of other meats

Y = other variables entering the demand equation

STpk = net changes in storage stocks during the quarter

Letting Spk be the total supply of pork for the quarter,

(6.3) $Spk = Cpk + Stpk$

Adding (6.1) to (6.2)

(6.4) $Spk = (a_0 + b_0) + (a_1 + b_1)\, Ppk + a_2\, Pm + a_3 Y$

Since Spk is considered predetermined, Equation (6.4) would be transposed to apply the least squares estimation technique.

$$(6.5)\ Ppk = -\left(\frac{a_0 + b_0}{a_1 + b_1}\right) -\left(\frac{a_2}{a_1 + b_1}\right) Pm -\left(\frac{a_3}{a_1 + b_1}\right) Y + \left(\frac{1}{a_1 + b_1}\right) Spk$$

As there is reason to believe that Ppk and Pm are interdependent, Pm was replaced by a variable representing the supply of other meats, which is considered to be independent of Ppk.

The demand equation for other meats was considered to be

$$(6.6)\ Cm = c_0 + c_1\ Pm + c_2\ Ppk + c_3\ Y$$

where

Cm = consumption of other meats

Neglecting storage demand,

$$(6.7)\ Cm = Sm$$

Where Sm is the supply of other meats. Substituting Sm for Cm in (6.6) and putting Pm on the left hand side,

$$(6.8)\ Pm = -\frac{c_0}{c_1} - \frac{c_2}{c_1} Ppk - \frac{c_3}{c_1} Y + \frac{1}{c_1} Sm$$

Substituting the right hand side of (6.8) for Pm in (6.5)

$$(6.9)\ Ppk = [\ (a_1 + b_1)\ c_1 - a_2\ c_2\ ]^{-1}\ [-c_1\ (a_0 + b_0) + a_2\ c_0$$

$$+ (a_2\ c_3 - a_3\ c_1)\ Y - a_2\ Sm + c_1\ Spk]$$

Having fulfilled conditions for applying the least squares estimating procedure, the constant and a coefficient for each variable can be obtained for (6.9). The least squares coefficient for Spk would be, structurally, $[(a_1 + b_1)\ c_1 - a_2\ c_2]^{-1}\ c_1$. Using this coefficient to estimate the demand elasticity, the computation would be

$$\left(\frac{(a_1\ b_1)\ c_1 - a_2\ c_2}{c_1}\right) \left(\frac{\overline{Ppk}}{\overline{Spk}}\right)$$

where $\overline{Ppk}$ and $\overline{Spk}$ are the means of these variables in the period studied.

By inspection of the components of $\left(\frac{(a_1b_1)\ c_1 - a_2c_2}{c_1}\right)$, it is apparent that the elasticity calculated is a composite of the elasticity of demand for pork consumption plus pork storage; the elasticity of demand for other meats; and the cross elasticities between pork and competing meats. If the product of the coefficients representing the cross elasticity relationships (a_2c_2) is small, then the elasticity calculated above is near to the elasticity of demand for consumption plus storage.

The difficulty in estimating elasticities of demand is not regarded as serious limitation since the main interest is in determining the composite effect of supplies on prices.

A complete listing of the variables used in the four models is given below. The sources of the data are given in APPENDIX C.

RPpk/CP	Quarterly average retail price of pork; deflated by the Consumers Price Index; in cents per pound.
DI/CP	Disposable personal income per capita for the current quarter at the annual rate; deflated by the Consumers Price Index; in dollars.
DI'/CP	Disposable personal income per capita for current quarter and the three previous quarters; deflated by the Consumers Price Index; in dollars.
Srm	Per capita supply of red meat other than pork; by quarters; in pounds.
Spm	Per capita supply of poultry meat; by quarters; in pounds.
Som	Srm + Spm
T	Time, in quarters from 1 to 44 (First quarter of 1948 = 1).
Spk_1	Per capita supply of pork in January to March; in pounds.

Spk_2	Per capita supply of pork in April to June; in pounds.
Spk_3	Per capita supply of pork in July to September; in pounds.
Spk_4	Per capita supply of pork in October to December; in pounds.
Q_1	Dummy variable denoting the first quarter (January-March). It has the value 1 in the first quarter and 0 in the other three.
Q_2	Dummy variable denoting the second quarter (April-June). It has the value 1 in the second quarter and 0 in the other three.
Q_3	Dummy variable denoting the third quarter (July-September). It has the value 1 in the third quarter, and 0 in the other three.
Q_4	Dummy variable denoting the fourth quarter (October-December). It has the value 1 in the fourth quarter and 0 in the other three.

Model I

The investigation of the demand function began by considering consumer income, supply of red meat other than pork, supply of poultry meat, supply of pork and the season as the relevant determinants of the retail price of pork.

The supply of pork for each season was a separate variable, assuming its actual value for the relevant seasons and zero for all other seasons. This enabled the estimation of separate coefficients for each season with respect to the supply of pork. Coefficients for Q_1, Q_2 and Q_3 were estimated in addition to the constant for the equation assumed to apply to the fourth quarter. The value of Q_1, Q_2 and Q_3 each was one in its respective season and zero in the other seasons. The constants for these first three quarters, then, are below or above the constant of the fourth quarter by the value of the coefficient on Q_1, Q_2 or Q_3. The estimation of separate constants and coefficients on the pork supply variable allowed for shifts in the level and slope of the demand curve in different seasons. In this way the effect of temperature, the demand for storage and other seasonal influences could be taken into account in the aggregate.

The coefficients on disposable income, supply of other red meat, and the supply of poultry meat were assumed to be the same for each season.

The supplies of other red meat and poultry meat were included as separate variables to account for possible differences in their cross elasticities with pork.

Data from the 44 quarters from 1948 through 1958 were used in obtaining the following equation estimated by least squares:

$$(6.10)\quad \widehat{RPpk/CP} = \underset{}{146.9809} - \underset{(3.91)^{**}}{.052986\, DI/CP} - \underset{(.41)}{.125056\, Srm} - \underset{(.03)}{.024378\, Spm}$$

$$- \underset{(3.88)^{**}}{1.357845\, Spk_1} - \underset{(3.55)^{**}}{1.654050\, Spk_2} - \underset{(2.87)^{**}}{2.186141\, Spk_3} - \underset{(2.09)^{*}}{.869681\, Spk_4}$$

$$+ \underset{(.78)}{8.4826\, Q_1} + \underset{(.93)}{10.2536\, Q_2} + \underset{(1.42)}{18.5196\, Q_3}$$

$R^2 = .79$
$\bar{R}^2 = .72$
$S = 2.51$
$D = .68$

* Significant at the 5 percent level.
** Significant at the 1 percent level.

Price flexibility at the means with respect to

Spk_1	-.57	DI/CP	-1.38
Spk_2	-.54	Srm	-.05
Spk_3	-.61	Spm	-.003
Spk_4	-.39		

In equation (6.10) the coefficients on the supply of pork variables were all significant and negative as expected. The signs on Srm and Spm were also negative as anticipated but not significant. The negative sign on the coefficient of DI/CP was highly significant. This is contrary to the theorized positive income elasticity on pork.

The differences between the coefficients of Spk for the four seasons were rather substantial. The coefficients of Q_1, Q_2, and Q_3 were not significant, however.

The price flexibilities were computed for each quarter with respect to Spk. The inverses of these price flexibility figures are equal to the elasticities of total demand for pork allowing for a certain downward bias from the cross elasticities as pointed out earlier in this chapter. These flexibility estimates indicate an elastic demand for pork at the retail level.

The price flexibility on pork was much lower (elasticity of demand much higher) in the fourth quarter of the year than in the other three. This may be due to the additional demand for storage. Pork supplies have generally reached the seasonal peak in the fourth quarter. Net additions to storage are usually larger during this period than in any other quarter. Also, lower temperatures may increase the elasticity of consumer demand at that time of year. Nevertheless, the price flexibility coefficient for the fourth quarter was lower than expected.

The Durbin-Watson statistic is quite low, indicating positive serial correlation. This was believed to be due to certain short term exogenous influences in the pork market which tend to prevail over more than one quarter. The expectations of a post war recession in the late 1940's and the anticipation in the early stages of the Korean War are examples of such influences.

Model II

A second equation was tried which differed in the following respects from Model I.

Per capita disposable income covered the three preceding quarters in addition to the current quarter. The rationale for this lag was the presumption that consumers do not complete their adjustment in expenditures on pork to a change in income within the quarter in which income changes. No attempt was made to estimate the distribution of the lag. It was assumed that a span of one year was sufficient to account for most of the adjustment.

The variables Srm and Spm were added together to form one variable Som rather than being considered separately as in Model I. Neither Srm nor Spm was indicated to be significant by Model I but their combined influence was thought to be important enough to be included.

A variable representing time (T) was introduced to account for a possible declining demand for pork. Working found a downward trend in the demand for pork during 1922 to 1941. He listed three factors of primary importance in causing changes in demand for pork during that period, "(1) changes in real incomes of consumers; (2) a downward trend in the demand for pork; and (3) changes in supplies of non-pork meats."[2] These are listed in order of importance.

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[2]Elmer J. Working, Demand for Meat, (Chicago: University of Chicago Press, The Institute of Meat Packing, 1954), p. 68.

In addition to the widespread recognition that consumers have been discriminating against over-fat pork, Luby has cited several other reasons why this downward trend has continued during the post war period.[3] Luby mentioned that new merchandizing techniques have favored beef over pork, and that "urbanization of rural people's eating habits, better transportation to city retail markets, increased used of freezers in rural homes, and less home slaughter of hogs on farms" have increased beef consumption relative to pork in rural areas. He attributes a decline in the demand for bacon to a trend toward lighter breakfasts, and in ham to the increased use of hot lunch programs in institutions.

If there has been a significant decline in the demand for pork, such a trend might help explain the negative coefficient on DI/CP in Model I. Disposable income is positively correlated with time. If the effect of the downward trend in demand is more important than the upward trend in income on the retail price of pork, then a negative coefficient on income would be plausible.

Model II is represented by Equation (6.11). As in Model I, the "wrong" sign was obtained on the coefficient of disposable income, although in Model II the value of the coefficient was not significantly different from zero. The signs on the coefficient of Som and T were negative, as expected, though the values were not significant.

Although Model II did not explain more of the variation in RPpk/CP than did Model I, the coefficients of the pork supply variables by quarters were more significant. The larger negative values obtained on the coefficients of the supply of pork are reflected in the price flexibility estimates. The price flexibility as calculated from Equation (6.11) was higher in each quarter than calculated from Equation (6.10).

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[3]Patrick J. Luby, "Declining Demand for Pork--Reconsideration of Causes and Suggested Prescription for Remedy." Journal of Farm Economics, Vol. XL, No. 5 (Dec. 1958), pp. 1832-1838.

Again, the price flexibility was calculated to be the lowest in the fourth quarter and highest in the third quarter.

The problem of positive serial correlation in the residuals is again present as indicated by the low value of the Durbin-Watson statistic.

$$(6.11)\ \widehat{RPpk/CP} = \underset{}{127.9030} - \underset{(.96)}{.021954}\ DI'/CP - \underset{(1.31)}{.391961}\ Som - \underset{(1.15)}{.160075}T$$

$$- \underset{(4.54)^{**}}{1.666898}\ Spk_1 - \underset{(4.12)^{**}}{2.068621}\ Spk_2 - \underset{(3.44)^{**}}{2.755085}\ Spk_3 - \underset{(3.16)^{**}}{1.335833}\ Spk_4$$

$$+ \underset{(.30)}{3.192310}\ Q_1 + \underset{(.51)}{5.283032}\ Q_2 + \underset{(1.23)}{15.957899}\ Q_3$$

$R^2 = .77$ $\qquad$ $S = 2.62$

$\bar{R}^2 = .70$ $\qquad$ $d = .62$

Price flexibility at the means with respect to

Spk_1	-.70	DI'/CP	-.57
Spk_2	-.68	Som	-.22
Spk_3	-.77		
Spk_4	-.59		

Model III

The problem of positive serial correlation in the residuals was considered serious enough to modify the estimating procedure. Least squares estimates become less efficient as serial correlation in the residuals increases either positively or negatively.

A technique for mitigating the undesirable effects of serial correlation in the residuals has been formulated by Dr. Clifford Hildreth and investigated by John Lu.[4] Consider the general form of the least

[4]John Lu, "Application of First Order Autoregressive Model to Some Economic Relations," Unpublished Master's thesis, Michigan State University, (East Lansing, 1957). (A Michigan State University Exp. Sta. Bulletin is being prepared on this procedure.)

squares regression equation,

(6.12) $Y = \mathbf{Z}\ \pi + U$

where Y is a column vector of J observations of the dependent variable, **Z** is a JxK matrix of J observations on each of K independent variables, π is a column vector of K regression coefficients to be estimated, and U is a column vector of J unexplained residuals or disturbances.

The assumption is made that U is generated by a first order autoregressive scheme,

(6.13) $U = \rho\ U_{t-1} + V \qquad |\rho| < 1$

where ρ is a constant called the autocorrelation coefficient, U_{t-1} is a vector of the elements of U lagged one year, and V is a vector of independent random disturbances.

Substituting (6.12) into (6.13)

(6.14) $Y = Z\ \pi + \rho\ U_{t-1} + V$

From (6.12) it can be seen that

(6.15) $U_{t-1} = Y_{t-1} - Z_{t-1}\ \pi$

where Y_{t-1} is a vector of elements of Y lagged one year and Z_{t-1} is a matrix of elements of **Z** lagged one year.

Substituting (6.15) into (6.14),

(6.16) $(Y - \rho Y_{t-1}) = (Z - \rho Z_{t-1})\ \pi + V$

If ρ were known, Equation (6.16) could be fitted by the ordinary least squares estimation technique. It can be readily seen that if $\rho = 0$, Equation (6.16) would be equivalent to Equation (6.12). If ρ were assumed equal to one, Equation (6.16) would be equivalent to the widely used first difference model.

The problem is that ρ is not known. To select an appropriate value for ρ, several values are tried in (6.16); between -1 and 0 if negative serial correlation is suspected, between 0 and + 1 if positive serial correlation is suspected. Values below -1 and above +1 are deemed highly improbable. The value of ρ which minimizes V'V, the sum of the squares of residuals, in (6.16) is then accepted as the appropriate value under the assumption that the residuals are generated by a first order autoregressive process.

Positive serial correlation was indicated by the Durbin-Watson test for Models I and II. In Model III, the same variables were included as in Model II except that T was dropped. In addition, it was assumed that the residuals were generated by a first order autoregressive scheme and for this reason the estimating procedure outlined above was used. The value of ρ was set at intervals of one-tenth from 0 to 1.0. The sum of squares of residuals was calculated from each equation. The equation giving the smallest sum of squares of the residuals was selected. This was the equation for which the autocorrelation coefficient was assumed to be .4. Thereby, the appropriate value of ρ was estimated to be .4.

The constants were estimated for each quarter directly rather than assuming the fourth quarter to be the base quarter as was done in Models I and II. The estimates of the coefficients of Q_1, Q_2, Q_3 and Q_4 are the constants for the respective quarters.

The equation obtained by this procedure and the price flexibilities with respect to the supply of pork by quarters are as follows:

$$(6.17)\ \widehat{RPpk}/CP = -.023604\ DI'/CP -.581800\ Som -1.725508\ Spk_1$$
$$-2.077206\ Spk_2 -2.796519\ Spk_3 -1.326604\ Spk_4 +136.57\ Q_1$$
$$+137.34\ Q_2 +148.80\ Q_3 +132.25\ Q_4$$

Price flexibility at the means with respect to

Spk_1	-.72	DI'/CP	-.61
Spk_2	-.68	Som	-.33
Spk_3	-.78		
Spk_4	-.59		

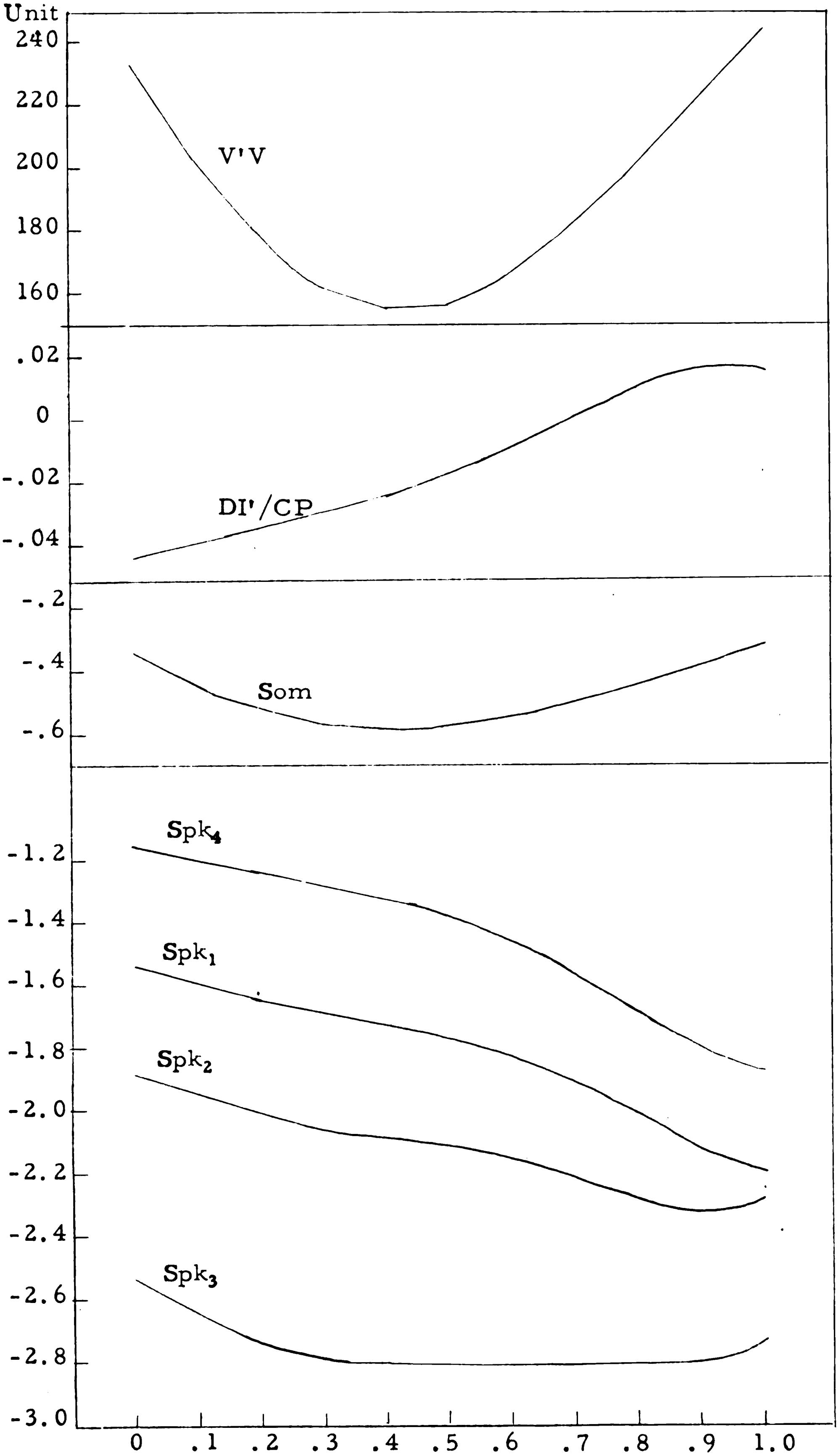
The values of the sum of squares of residuals and the regression coefficients are graphed in Figure 7 for the various levels of ρ tried. The minimum of the sums of squares of residuals was 155.85 where the value of ρ was .4. This is the value of ρ assumed in Equation (6.17). The sum of squares of residuals at $\rho = .4$ was substantially below the value at $\rho = 0$, the traditional linear regression model, and also well below the value at $\rho = 1$, the first difference model.

By comparing the values of regression coefficients at $\rho = 0$ and $\rho = 1$ with the values at $\rho = .4$ in Figure 7, substantial differences may be noted.

The coefficient on disposable income in (6.17) is again negative as in Model I and Model II. It may be noted in Figure 7 that the coefficient becomes positive at ρ values above .7. The coefficient is positive in the first difference equation.

All of the other coefficients in (6.17) carried the expected sign. The effect of Som on the retail price of pork was more pronounced in (6.17) than in Model II. This is probably because the variable T was excluded from (6.17). There has been an upward trend in the supply of other meat. Since a negative (but not significant) relationship between T and RPpk/CP was indicated in Equation (6.11), part of this time factor was explained by Som in (6.17) in the absence of the time variable.

FIGURE 7. Sum of squares of residuals (V'V) and estimates of regression coefficients for Model III at values of the autocorrelation coefficients ranging from 0 to 1.



The coefficients of the quarterly pork supply variables were about the same as in Model II, but considerably more negative than in Model I. This is reflected in the price flexibilities.

Model IV

Model IV is identical to Model II with the additional assumption that the residuals are generated by a first order autoregressive process. The estimation procedure was the same as for Model III, except that the neighborhood of the minimum was investigated in more detail. In Model IV, levels of autocorrelation ranging from 0 to .9 were tried at intervals of one-tenth. The V'V calculated from the resulting equations were plotted. It was clear that the minimum was near a value of .5 for ρ. The ρ values of .47, .48, and .49 were then tried. The value of ρ which minimized the sum of squares of residuals was found to be .49. The equation representing this level of autocorrelation is:

$$(6.18)\quad \widehat{RPpk}/CP = .0056956\ DI'/CP - .563996\ Som - .240471\ T$$
$$-1.915357\ Spk_1 - 2.348226\ Spk_2 - 2.992810\ Spk_3 - 1.646263\ Spk_4$$
$$+105.31\ Q_1 + 106.88\ Q_2 + 116.70\ Q_3 + 104.45\ Q_4$$

Price flexibility at the means with respect to

Spk_1	-.80	DI'/CP	+.15
Spk_2	-.77	Som	-.32
Spk_3	-.84		
Spk_4	-.73		

Price elasticity at the means with respect to

$RPpk_1$	-1.25
$RPpk_2$	-1.30
$RPpk_3$	-1.19
$RPpk_4$	-1.37

All of the coefficients in (6.18) carried the expected sign. In contrast to the previous three models, the coefficient on disposable income was positive. The importance of income was small, however, having a price flexibility coefficient of .15.

As shown in FIGURE 8, the estimates in Equation (6.18) are substantially different than in the traditional least squares equation where $\rho = 0$, or in the other extreme equation at $\rho = .9$. The minimum sum of squares of residuals is 144.09 as compared to 226.77 at $\rho = 0$, and 252.89 at $\rho = .9$. This minimum is somewhat lower than the minimum of 155.85 in Model III.

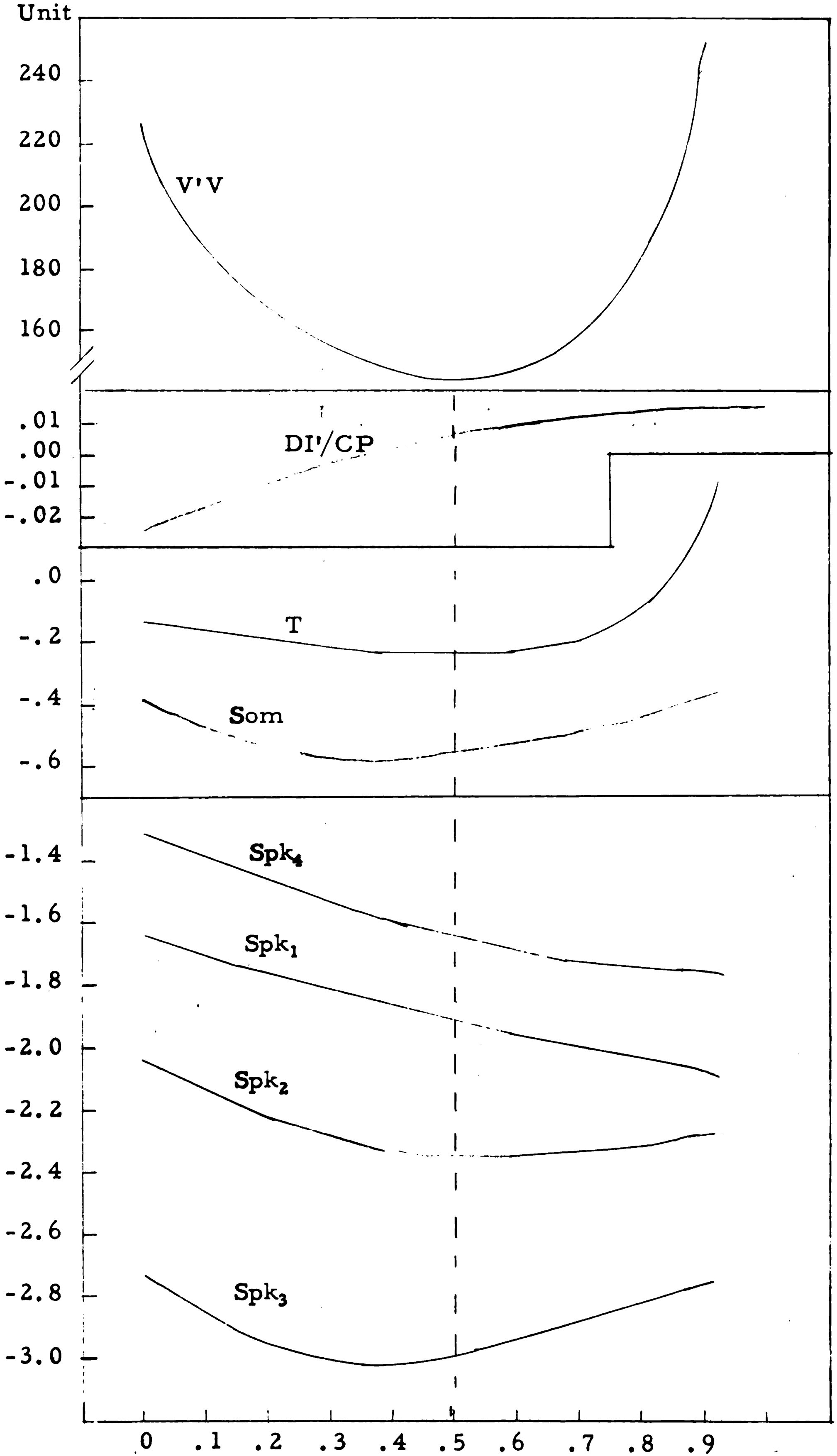
In addition to the change in sign on DI'/CP in Equation (6.18) as compared with Equation (6.11), the coefficients of Som, T, Spk_1, Spk_2, and Spk_3 and Spk_4 all were substantially larger negative numbers in Equation (6.18). The changes in the coefficients on the quarterly pork supply variables were reflected in the price flexibilities.

The elasticities of demand as the inverses of the price flexibilities were about the same for each quarter, the greatest difference being between the summer and fall quarters. The demand was indicated to be slightly elastic in each quarter. These estimates are somewhat higher than the estimates obtained for consumer demand elasticity in previous studies. Certain prominent studies based on annual data have found the elasticity of consumer demand for pork to be near unity, ranging from -.76 to -1.135.[5]

The demand elasticities as determined in this study would not necessarily correspond to the elasticities of consumer demand. This is because the elasticity of storage demand which is a component of the demand function in this study is not necessarily the same as for

[5]See the summary table presented by Thomas D. Wallace and George G. Judge, Econometric Analysis of the Beef and Pork Sectors of the Economy. Oklahoma State University Experiment Station Technical Bulletin T-75 (August, 1958), pp. 47.

FIGURE 8. Sum of squares of residuals (V'V) and estimates of the regression coefficients for Model IV at values of the autocorrelation coefficient ranging from 0 to .9.



consumer demand. If the elasticity of demand for storage is somewhat higher than for consumption, the estimates of the total elasticity of demand from Equation (6.18) seem quite plausible in comparison with the estimates from previous studies.

Using annual data for 1922-1941, Karl Fox found a price flexibility on pork of -.85 relative to production, slightly higher than the price flexibilities determined from Equation (6.18).[6]

The performance of Equation (6.18) is indicated in TABLE 21. The estimates are compared with the actual retail prices. In only 6 of the 43 quarters estimated were the errors greater than 5 per cent. None of the errors exceeded 10 per cent of the actual retail prices. The Durbin-Watson statistic for Equation (6.18) is 1.70 indicating a much lower level of serial correlation than the .62 for Model II.

Demand for Hogs

The demand for pork at the retail level is translated to the farm level through the marketing chain. Each link in this chain may be considered to have a supply curve and a demand curve for the particular processing operation or service performed. No effort was made to isolate these various segments, but they were taken into account in the aggregate.

Since the objective was to derive the price of hogs, the marketing margin was not estimated directly. The retail price of pork and wholesale price of lard were used as independent variables along with certain variables relating to the marketing margin.

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[6]Karl Fox, op. cit., p. 43.

TABLE 21. Quarterly retail price of pork deflated by the Consumers' Price Index; estimated by Equation (6.18) as compared with the actual; 1948-1958.

Year	Quarter	Estimate[a] $/cwt.	Actual $/cwt.	Percent Difference
1948	1		58.6	
	2	57.3	58.7	-2.4
	3	65.8	63.8	+3.1
	4	54.3	58.8	-7.7
1949	1	56.7	54.4	+4.2
	2	57.7	55.4	+4.2
	3	59.7	57.9	+3.1
	4	52.3	51.7	+1.2
1950	1	52.1	49.5	+5.3
	2	53.2	52.6	+1.1
	3	57.1	59.1	-3.4
	4	52.5	52.8	- .6
1951	1	51.6	53.7	-3.9
	2	51.7	53.4	-3.2
	3	54.1	54.4	- .6
	4	50.9	51.6	-1.4
1952	1	46.5	48.8	-4.7
	2	49.4	49.5	- .2
	3	52.5	53.7	-2.2
	4	50.0	50.4	- .8
1953	1	50.7	50.4	+ .6
	2	54.0	56.3	-4.1
	3	58.6	60.4	-3.0
	4	54.5	54.8	- .5
1954	1	56.1	59.1	-5.1
	2	58.2	59.9	-2.8
	3	57.5	55.7	+3.2
	4	50.5	51.1	-1.2
1955	1	50.2	48.5	+3.5
	2	51.1	48.6	+5.1
	3	51.3	50.0	+2.6
	4	45.3	44.6	+1.6
1956	1	43.7	41.4	+5.6
	2	46.9	44.8	+4.7
	3	49.0	47.2	+3.8
	4	46.4	45.8	+1.3

[a]Estimate from Equation (6.18) plus .49 times the residual in the previous quarter.

Continued

TABLE 21 - Continued

Year	Quarter	Estimate[a] $/cwt.	Actual $/cwt.	Percent Difference
1957	1	49.0	47.9	+2.3
	2	50.6	49.6	+2.0
	3	52.4	54.1	-3.1
	4	52.4	48.8	+7.4
1958	1	53.1	51.4	+3.3
	2	52.3	53.1	-1.5
	3	52.4	54.5	-3.9
	4	52.0	50.3	+3.4

[a]Estimate from Equation (6.18) plus .49 times the residual in the previous quarter.

The variables selected as the most important in explaining the marketing margin were the price of lard, wage rates in the meat packing and food retailing industries and the commerical slaughter of hogs.

Lard is an important end product in hog slaughter, representing about 20 per cent of the weight of the products from a medium weight butcher hog. The price of lard was, therefore, included in the hog demand equations. The price of lard was considered as exogenous since lard prices are highly dependent upon the fats and oils economy. The error from this assumption depends on the extent to which hog slaughter and thereby lard production affects lard prices. Some error is undoubtedly introduced but the magnitude is thought to be small.

Since a large portion of the costs in assembling, processing, and distributing pork is for labor, wage rates were included to represent these costs. The unit costs for the other major items such as transportation, building and equipment, taxes, etc. have also trended upward with labor costs and in part were taken into account by the wage rate variable.

Because unit costs in marketing pork also depend on volume, the commercial slaughter of hogs was included in the marketing margin equation. It was reasoned that the marketing margin would be positively related to slaughter. Consider the marginal costs of marketing pork to be the summation of the marginal cost curves of the various links in the marketing chain. If pork marketing is competitive, the marketing margin would tend to be equal to the marginal cost of marketing pork which is an increasing function of slaughter at the rational levels of production above the minimum of the average variable cost curve.

Prices were deflated by the Wholesale Price Index to account for the changing general price level at wholesale.

Variables included in the hog demand equations are coded as follows:

Ph/WP_i	Price of 200-220 pound barrows and gilts at Chicago in quarter i (i = 1, 2, 3, 4), deflated by the Wholesale Price Index; in dollars per hundred weight.
$RPpk/WP_i$	Retail price of pork in quarter i, deflated by the Wholesale Price Index; in cents per pound.
Pl/WP_i	Wholesale price of lard in one pound cartons at Chicago in quarter i, deflated by the Wholesale Price Index; in dollars per hundred weight.
W/WP_i	Wage rates in the meat packing industry and retail stores, average hourly earnings in quarter i and the 3 previous quarters, deflated by the Wholesale Price Index; in dollars per hour.
CSh_i	Commercial slaughter of hogs in quarter i; in thousands.

The equations for the four quarters and their statistical properties are presented in TABLE 22. As would be expected, the price of hogs is closely associated with the price of pork at retail. The coefficients of RPpk/WP were highly significant in each quarter. The wholesale price of lard also contributed positively to the explanation of hog prices in addition to the explanation attributed to retail pork prices. The coefficient of Pl/WP was not significant in the first quarter, however.

The effect of rising wage rates tended to increase the marketing margin depressing hog prices and/or increasing retail prices. The coefficient of W/WP was significant in all but the second quarter.

TABLE 22. Regression equations representing the demand for hogs by quarters, 1947-1958.

Item	(6.19) 1	(6.20) 2	(6.21) 3	(6.22) 4
	Equation and Quarter			
Dependent Variable	$\hat{Ph}/WP_1$	$\hat{Ph}/WP_2$	$\hat{Ph}/WP_3$	$\hat{Ph}/WP_4$
Constant	5.00	-16.94	-.66	3.36
Independent Variables	Coefficients with t values in parenthesis			
$RPpk/WP_i$	.5687	.5914	.4814	.4465
	(8.60)**	(6.96)**	(5.03)**	(5.53)**
Pl/WP_i	.1694	.1998	.2636	.2059
	(1.29)	(2.87)	(2.00)#	(3.28)*
W/WP_i	-4.6061	-2.0769	-5.7381	-3.3643
	(4.77)**	(1.75)	(2.56)*	(3.03)*
CSh_i	-.0006524	.0002785	-.0001491	-.0003719
	(4.49)**	(1.10)	(.38)	(2.14)#
R^2	.99**	.98**	.98**	.99**
$\bar{R}^2$	.99**	.96**	.97**	.98**
S	.53	.65	.79	.51
d	1.56	1.57	1.48	1.79

#Significant at the 10 percent level.
*Significant at the 5 percent level.
**Significant at the 1 percent level.

The marketing margin was directly related to the commercial slaughter of hogs in the first, third and fourth quarters, but inversely related in the second. The inverse relationship in the second quarter was contrary to that anticipated. It may be observed that the coefficients of CSh in the second quarter and in the third quarter as well were not significantly different from zero. Supplies of hogs have been seasonally low during these two quarters. Conceivably, the level of slaughter during these quarters has been in the relatively flat portion of the average and marginal cost curves of the marketing firms. Changes in quarterly slaughter at this level would have only negligible effects on margins.

Equations (6.19), (6.20), (6.21) and (6.22) all explained a highly significant portion of the variation in the price of hogs. High R^2 values would be expected, of course, with the retail price of pork as an independent variable.

The estimates by quarters for the 1947 to 1958 period are given in TABLE 23 and compared to the actual hog prices. The error exceeded 5 per cent of the actual price of hogs in 7 of the 48 quarters examined. The estimate was particularly low in the first quarter of 1956.

"Complete" Demand Function for Hogs

By substituting one of the consumer and storage demand functions for RPpk in (6.19), (6.20), (6.21) and (6.22), a "complete" demand function for hogs can be obtained for each quarter. Such functions were constructed by substituting Equation (6.18) into (6.19), (6.20), (6.21) and (6.22). By multiplying both sides of the resulting equations by the Wholesale Price Index, the undeflated price of hogs for each quarter is obtained.

TABLE 23. Quarterly price of 200-220 pound barrows and gilts at Chicago deflated by the Wholesale Price Index; estimated by Equations (6.19), (6.20), (6.21) and (6.22) as compared with the actual; 1947-1958.

Year	Quarter	Estimate $/cwt.	Actual $/cwt.	Percent Difference
1947	1	28.70	27.81	+3.2
	2	25.26	26.06	-3.1
	3	28.19	28.68	-1.7
	4	26.54	26.61	- .3
1948	1	26.06	24.43	+6.7
	2	23.43	22.85	+2.5
	3	27.38	28.05	-2.4
	4	22.73	22.74	0
1949	1	21.73	20.93	+3.8
	2	20.87	20.17	+3.5
	3	22.86	22.12	+3.3
	4	18.00	17.18	+4.8
1950	1	17.71	17.20	+3.0
	2	19.13	18.94	+1.0
	3	22.54	22.37	+ .8
	4	17.30	17.46	- .9
1951	1	18.70	19.16	-2.4
	2	19.14	18.97	+ .9
	3	19.75	19.58	+ .9
	4	16.73	17.01	-1.4
1952	1	14.13	15.92	-11.2
	2	17.41	17.78	-2.1
	3	18.89	19.41	-2.7
	4	15.69	16.24	-3.4
1953	1	16.89	18.25	-7.5
	2	21.21	21.99	-3.6
	3	23.32	22.90	+1.8
	4	20.38	20.41	- .2
1954	1	25.35	23.67	+7.1
	2	24.33	24.19	+ .6
	3	21.14	20.07	+5.3
	4	17.57	17.18	+2.3
1955	1	16.09	15.59	+3.2
	2	16.53	16.88	-2.1
	3	15.90	15.26	+4.2
	4	12.23	11.61	+5.3

Continued

TABLE 23 - Continued

Year	Quarter	Estimate $/cwt.	Actual $/cwt.	Percent Difference
1956	1	8.78	11.41	-23.0
	2	14.02	14.39	-2.6
	3	14.06	14.62	-3.8
	4	13.52	13.91	-2.8
1957	1	15.00	15.19	-1.3
	2	16.88	16.29	+3.6
	3	17.43	17.57	- .8
	4	15.09	15.31	-1.4
1958	1	17.63	17.21	+2.4
	2	19.18	18.88	+1.6
	3	17.50	18.35	-4.6
	4	15.80	15.93	- .8

$$(6.23)\ Ph_1 = 5.001WP_1 + .56873\ CP_1\ [\widehat{RPpk_1/CP_1}] + .169400\ Pl_1 - 4.606099\ W_1 - .000652383\ CSh_1 \cdot WP_1$$

$$(6.24)\ Ph_2 = -16.944\ WP_2 + .591475\ CP_2\ [\widehat{RPpk_2/CP_2}] + .199822\ Pl_2 - 2.076889\ W_2 + .000278511\ CSh_2 \cdot WP_2$$

$$(6.25)\ Ph_3 = -.664\ WP_3 + .481377\ CP_3\ [\widehat{RPpk_3/CP_3}] + .263577\ Pl_3 - 5.738064\ W_3 - .00149103\ CSh_3 \cdot WP_3$$

$$(6.26)\ Ph_4 = +3.364\ WP_4 + .446530\ CP_4\ [\widehat{RPpk_4/CP_4}] + .205899\ Pl_4 - 3.364306\ W_4 - .000371949\ CSh_4 \cdot WP_4$$

These equations can be expanded by substituting the right hand side of Equation (6.18) for $\widehat{RPpk_i/CP_i}$. This would make the price of barrows and gilts for each quarter a function of the Wholesale Price Index, the Consumer's Price Index, disposable income per capita, the per capita supply of pork, the per capita supply of meat other than pork, time, the price of lard, wage rates in the meat packing industry and retail stores and the commercial slaughter of hogs. The estimates as compared with the actual price of hogs are presented in TABLE 24.

The errors are somewhat larger than in TABLE 23. This is to be expected since the estimated retail price of pork was used in the equations of TABLE 24 rather than the actual prices as used in the equations of TABLE 23. The errors were greater than 5 per cent in 23 of the 43 quarters estimated. Errors of 10 per cent or more were observed in 7 quarters.

The fourth quarter is of especial interest in this study. It may be noted that there were no errors greater than 10 per cent and there were 4 errors greater than 5 per cent. The absolute value of the errors for the fourth quarter averaged 4.5 per cent.

TABLE 24. Quarterly price of 200-220 pound barrows and gilts at Chicago; estimated by Equation (6.23), (6.24), (6.25) and (6.26) as compared with the actual; 1948-1958.

Year	Quarter	Estimate $/cwt.	Actual $/cwt.	Percent Difference
1948	1			
	2	23.55	23.74	- .8
	3	29.99	28.05	+6.9
	4	21.70	23.79	-8.8
1949	1	23.46	21.26	+10.3
	2	22.03	19.97	+10.3
	3	23.29	22.12	+7.2
	4	17.88	16.80	+6.4
1950	1	18.87	16.89	+11.7
	2	19.39	18.83	+3.0
	3	22.68	22.37	-3.5
	4	18.80	19.15	-1.8
1951	1	20.35	22.23	-8.5
	2	21.09	21.97	-4.0
	3	22.31	19.58	+ .1
	4	18.63	19.32	-3.6
1952	1	14.43	17.93	-19.5
	2	19.36	19.83	-2.4
	3	20.46	19.41	-5.8
	4	17.13	17.95	-4.6
1953	1	18.72	20.04	-6.6
	2	21.70	24.10	-10.0
	3	24.85	22.90	-2.0
	4	22.25	22.45	- .9
1954	1	26.06	26.18	- .5
	2	25.78	26.75	-3.6
	3	24.33	20.07	+9.9
	4	18.99	18.85	+ .7
1955	1	18.85	17.18	+9.7
	2	19.93	18.60	+7.2
	3	18.40	15.26	+8.6
	4	13.93	12.93	+7.7
1956	1	11.35	12.82	-11.5
	2	17.42	16.42	+6.1
	3	17.14	14.62	+2.2
	4	15.98	16.12	- .9

Continued

TABLE 24 - Continued

Year	Quarter	Estimate $/cwt.	Actual $/cwt.	Percent Difference
1957	1	18.31	17.76	+3.1
	2	20.46	19.09	+7.2
	3	19.63	17.57	-5.5
	4	19.83	18.08	+9.7
1958	1	22.18	20.52	+8.1
	2	22.32	22.52	- .9
	3	19.60	18.35	-10.3
	4	19.75	18.97	+4.1

Setting the Consumer Price Index and the Wholesale Price Index at their respective means, the complete demand function for hogs can be reduced as shown in TABLE 25.

The supply of hogs affects the price of hogs in two ways, (1) through changing the supply of pork and thereby retail prices and (2) through changing the marketing margin. The price flexibility with respect to Spk_i as given in TABLE 25, measures the effect of pork supplies on the farm price of hogs that may be ascribed to changing retail prices on pork. The price flexibility with respect to CSh_i, on the other hand, measures the effect of hog slaughter on hog prices which may be ascribed to changing marketing margins.

The two price flexibility coefficients were added in TABLE 25 to obtain the total price flexibility coefficient for each quarter with respect to the supply of hogs. As may be noted, about one-third of the effects of changing supplies on the farm price of hogs in the fall and winter quarters was due to changing marketing margins. Changing margins due to changing supplies were of minor importance during the spring and summer quarters.

The total price flexibility coefficients were noticeably higher for the fall and winter quarters than for the spring and summer. The elasticities of demand for hogs by quarters, which are inverses of the flexibilities, show the demand to be inelastic particularly in the fall and winter when supplies have been seasonally large.

TABLE 25. Complete demand function for hogs by quarters, derived by substituting (6.18) into (6.19), (6.20), (6.21) and (6.22), 1947-1958.

Item	Equation and Quarter (6.23) 1	(6.24) 2	(6.25) 3	(6.26) 4
Dependent Variable	Ph_1	Ph_2	Ph_3	Ph_4
Constant	75.27	52.14	62.68	56.53
Independent Variables	Coefficients			
DI'_i	.003239	.003369	.002742	.002543
Som_i	-.3570	-.3736	-.3065	-.2851
T_i	-.1522	-.1593	-.1307	-.1216
Spk_i	-1.2124	-1.5556	-1.6265	-.8321
Pl_i	.1694	.1998	.2636	.2059
W_i	-4.6061	-2.0769	-5.7381	-3.3643
CSh_i	-.0007183	.0003066	-.0001652	-.0004125
Price flexibility at the means with respect to				
Spk_i	-1.37	-1.36	-1.22	-1.07
CSh_i	-.72	.24	-.11	-.49
Supply of hogs[a]	-2.09	-1.12	-1.33	-1.56
Elasticity of demand at the means with respect to				
Ph_i	-.48	-.89	-.75	-.64

[a]If the total supply of hogs is directly proportional to Spk_i and to CSh_i, then the price flexibility for the total supply of hogs is the summation of the price flexibilities with respect to Spk_i and CSh_i.

CHAPTER VII

SUPPLY-DEMAND MODELS

The specifications for the Cobweb model, as modified in CHAPTER IV, are that producer price expectation is some positive function of present and past prices, that production is completely determined by producers' response to expected prices, that conditions of perfect competition prevail, and that price is determined by the supply available. The argument has been presented in some detail in previous chapters that the hog market fulfills these specifications in most respects. The purpose of this chapter is to determine: (1) whether or not the estimates of the supply and demand relationships actually generate a cobweb, or cyclic, pattern of hog production and price, and if so, (2) whether the cycles are of convergent, constant, or increasing amplitude. By Hypothesis II, it is believed that the endogenous mechanism of the hog market is cyclic but convergent.

The supply equations of CHAPTER V relate the number of sows farrowing in the spring to the price of hogs and the price of corn in previous breeding seasons, and, in some cases, also to the supply of other feed grains in the previous year. The "complete" demand equation developed in CHAPTER VI, Equation (6.26), relates the price of hogs to the supply of pork, commercial slaughter of hogs, and certain exogenous variables. To complete the model, it is necessary to determine the relationships between the number of sows farrowing in the spring and (1) the supply of pork and (2) the commercial slaughter of hogs in the following fourth quarter.

Farrowings-Supply of Pork Relationship

An equation relating sows farrowing in the spring to the supply of pork in the following fourth quarter was derived from two equations; one which measured the upward trend in pigs saved per litter and the other which related pigs saved in the spring to the supply of pork in the fall. The first equation is:

$$(7.1)\quad Spg/F,t = 6.126 + \underset{(10.28)^{**}}{.08469T'}$$

$R^2 = .92^{**}$ $\quad S = .0986$

where

Spg, t = Number of pigs saved from December, t-1 to May, t; in thousands

F, t = Number of sows farrowing from December, t-1 to May, t; in thousands

T' = Time in years; 1947 = 1.

**Significant at the 1 percent level.

A strong upward trend in pigs saved per litter is evident from Equation (7.1).

The second equation, which relates the supply of pork in the fourth quarter to the pigs saved in the spring, is

$$(7.2)\quad Spk',t.4 = 537.957 + \underset{(4.52)^{**}}{.0566452Spg,t}$$

$R^2 = .67^{**}$ $\quad S = 247.95$

where

Spk', t.4 = Supply of pork in the fourth quarter of year t; in millions of pounds.

**Significant at the 1 percent level.

Multiplying both sides of (7.1) by F, t and substituting the right hand side of the result for Spg, t in (7.2), (7.3) $Spk', t.4 = 537.957 + [.347020 + .00479702T'] \; F, t$

By dividing Equation (7.3) by population (N), the per capita supply of pork for the fourth quarter (Spk, t.4) is obtained which is the form used in the demand equations.

(7.4) $Spk, t.4 = 1/N \; Spk', t.4 = 1/N \; [537.957 + (.347020 + .00479702T') \; F, t]$

Farrowing-Commercial Hog Slaughter Relationship

The equation relating the number of sows farrowing in the spring to the commercial slaughter of hogs in the fourth quarter was derived as follows by the least squares procedure:

(7.5) $$CSh, t.4 = 2129.46 + \underset{(4.27)^{**}}{.349979} \; Spg, t$$

$$S = 1018.40 \qquad R^2 = .65^{**}$$

Multiplying both sides of (7.1) by F, t and substituting the right-hand side of the result for Spg, t in (7.5),

(7.6) $CSh, t.4 = 2129.46 + .349979 \; (6.126 + .08469T') \; F, t$

Farrowing-Price of Hogs Relationship

To relate the number of sows farrowing in the spring to the price of hogs in the following fall, Equations (7.4) and (7.6) can be substituted in Equation (6.26) for Spk, t.4 and CSh, t.4, respectively.

(7.7) $$\hat{Ph}_4 = 3.364WP_4 + .44653CP_4 \Big\{104.45 + .0056956DI'/CP_4 - .563996 \; Som - .240471T - 1.646263 \; 1/N \; [537.957 + (.34702 + .00479702T') \; F, t]\Big\} + .205899Pl - 3.364306W_4 - .000371949WP_4 \; [2129.46 + (2.144 + .02964T') \; F, t]$$

Equation (7.7), then, gives the undeflated price of hogs in the fourth quarter as a function of spring farrowings and certain other variables assumed to be exogenous in this model. The performance of this equation for the 1948 to 1958 period is presented in TABLE 26.

TABLE 26. Prices of 200-220-pound barrows and gilts in the fourth quarter; estimated by Equation (7.7) as compared with the actual; 1948-1958.

Year	Estimate $/cwt.	Actual $/cwt.	Percent Difference
1948	23.12	23.79	-2.8
1949	18.05	16.80	+7.4
1950	17.56	19.15	-8.3
1951	17.52	19.32	-9.3
1952	18.58	17.95	+3.5
1953	22.10	22.45	-1.6
1954	19.05	18.85	+1.1
1955	15.85	12.93	+22.6
1956	17.34	16.12	+7.6
1957	18.81	18.08	+4.0
1958	17.99	18.97	-5.2

The magnitude of the errors shown in TABLE 26 illustrates the difficulty of accurately predicting hog prices even when the spring farrowings and the exogenous variables are known. The only serious error, however, was the overestimate of hog prices in the fall of 1955.

Difference Equation Models

To investigate the endogenous mechanism of the hog market, we want to eliminate the effect of changes in the exogenous variables. This can be accomplished by holding them at some constant value.

If all the assumed exogenous variables in Equation (7.7) were arbitrarily set at their mean values for the 1947-1958 period, the following equation is obtained:

(7.8) $Ph_4 = 43.143 - .0029174F, t$

This is a simple linear relationship between spring farrowings and the price of hogs in the fall, and is representative of the 1947 to 1958 period. It is devoid of the effect of <u>changes</u> in the general price level, incomes, pigs saved per litter, population, supply of meat other than pork, the price of lard, wage rates in the meat packing industry, and time. These exogenous variables were, of course, used in the equations from which the constant and coefficient of F, t in Equation (7.8) were calculated.

The right-hand side of Equation (7.8) can then be substituted for the price of hogs in the supply equations developed in CHAPTER V. It should be noted that the price of hogs determined in the demand relationship is an average for October to December while the average used in the supply equations was for October to January. The differences between the two averages are small, however. The reason the October to December average was used in the demand relationship was because U. S. average retail prices and U. S. total pork and other meat production data were available only on a quarterly basis.

Just as the exogenous variables in Equation (7.7) were set at their respective means, the price of corn and the supply of other feed grain in the supply equations can also be set at their respective means. There may be some question as to whether the price of corn can be considered independent of the price of hogs. But because the government support program has been a dominant influence on corn prices in the 1947 to 1958 period, particularly the latter part of this period, there is justification for treating corn prices as an exogenous variable.

By substituting the right-hand side of (7.8) for the price of hogs in the supply equations of CHAPTER V and setting the price of corn and supply of other feed grains at their means, difference equations can be constructed with spring farrowings in year t as a function of spring farrowings in previous years. Each of these alternative models would enable us to determine a time path for spring farrowings assuming that all exogenous influences were held constant at their mean values.

These difference equations can be solved and thereby spring farrowings can be established as a function of time. The properties of this solution reveal whether the model is cyclic; and, if so, whether the cycles are damped. The approximate length of the cycle can also be determined. The procedure for solving the difference equations and interpreting the results is outlined by Baumol.[1]

Four supply equations, (5.19), (5.21), (5.46), and (5.47), were selected from CHAPTER V. The right-hand side of Equation (7.8) was substituted into each to form four alternative models of the hog market.

The supply equation, (5.19), as determined in CHAPTER V is as follows:

$$(5.19)\quad \hat{F}^{d}{,t} = -\ 920.649 + 192.134\ Ph{,t-1} + 106.171\ Ph{,t-2} - 2283.98\ Pc{,t-1} - 971.42\ Pc{,t-2} + .0203837\ Sg^{d}{,t-1}$$

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[1]William J. Baumol, Economic Dynamics (New York: The Macmillan Company, 1951), pp. 141-217.

By substituting the right-hand side of (7.8) for Ph in (5.19) and by setting Pc, t-1, Pc, t-2, and Sg^d, t-1 at their respective mean values, the following equation is obtained.

$$(7.9)\ \hat{F}, t = 6971 + .43947\ F, t-1 - .30974\ F, t-2$$

The solution of this second order difference equation is

$$(7.10)\ \hat{F}, t = 8010 + .5565^{t}\ [538 \cos (t66^{\circ}45') - 577 \sin (t66^{\circ}45')]$$

Farrowings in 1946 and 1947 were used as the initial values in the solution. The variable t, is time in years and is equal to zero in 1946.

It is obvious from inspection that Equation (7.10) is cyclic. The cycles are damped ($.5565 < 1$) and between 5 and 6 years in length ($360^{\circ} \div 66^{\circ}45' = 5.4$).

The second supply equation selected to be tried in a complete supply-demand model is Equation (5.21).

$$(5.21)\ \hat{F}, t = - 1098.10 + .99295\ F, t-1 + 198.593\ Ph, t-1 + 120.183\ Ph, t-2 - 2436.67\ Pc, t-1 - 1035.48\ Pc, t-2 + .00469455\ Sg, t-1$$

By substituting the right-hand side of (7.8) for Ph and setting Pc, t-1, Pc, t-2 and Sg, t-1 at their respective means, the following equation is derived:

$$(7.11)\ \hat{F}, t = 7508 + .41357\ F, t-1 - .35062\ F, t-2$$

Using farrowings in 1946 and 1947 as the initial values, the solution is

$$(7.12)\ \hat{F}, t = 8012 + .5921^{t}\ [536 \cos (t69^{\circ}26') - 523 \sin (t69^{\circ}26')]$$

Equation (7.12) is also cyclic with damped fluctuations ($.5921 < 1$). The length of the cycle is between 5 and 6 years ($360^{\circ} \div 69^{\circ}26' = 5.2$).

Another supply equation selected for study was (5.46).

(5.46) $\hat{F}_{,t} = -2025.67 + 1.26551\ F_{,t-1} - .473910\ F_{,t-2} + 284.030\ H{:}C_{,t-1}$

By substituting the right-hand side of (7.8) for $P_{,h}$ in the hog: corn ratio of Equation (5.46) and setting $P_{,c}$ at its mean in the hog:corn ratio, the following equation was constructed:

(7.13) $\hat{F}_{,t} = 5956 + .72577\ F_{,t-1} - .47391\ F_{,t-2}$

The solution of this second order difference equation is

(7.14) $\hat{F}_{,t} = 7961 + .6884^{t}\ [587 \cos (t58^{\circ}10') - 583\ (t58^{\circ}10')]$

using farrowings in 1946 and 1947 as the initial values.

Equation (7.14) is cyclic and the fluctuations are damped ($.6884 < 1$). The length of the cycle is just over 6 years ($360^{\circ} \div 58^{\circ}10' = 6.2$).

The fourth supply equation to be tried was (5.47).

(5.47) $\hat{F}_{,t} = 2225.33 + 1.34658F_{,t-1} - .610801F_{,t-2} + 226.013Ph_{,t-1}$
$-2455.60Pc_{,t-1} - .0190059Sg_{,t-1}$

By substituting the right-hand side of (7.8) for Ph and setting $Pc_{,t-1}$ and $Sg_{,t-1}$ at their respective means, Equation (5.47) becomes

(7.15) $\hat{F}_{,t} = 7456 + .68721\ F_{,t-1} - .61080\ F_{,t-2}$

Using farrowings in 1946 and 1947 as the initial values, the solution of this second order difference equation yields

(7.16) $\hat{F}_{,t} = 8073 + .7815^{t}\ [\ 475 \cos (t63^{\circ}55') - 574 \sin (t63^{\circ}55')]$

As in (7.10) and (7.12) and (7.14), Equation (7.16) is cyclic with damped fluctuations ($.7815 < 1$). The length of the cycle is between 5 and 6 years ($360^{\circ} \div 63^{\circ}55' = 5.6$).

Conclusions and Implications

The results obtained in the four complete supply-demand models constructed were similar and supported Hypothesis II; that the hog market is cyclic and convergent. Convergency is indicated even though the elasticity of supply is greater than the elasticity of demand in the region of the intersection of the two curves.

In the discussion of Equation (5.21) in CHAPTER V, the supply elasticity with respect to $P_{h,t-1}$ and to $P_{h,t-2}$ was said to be .48 and .29 respectively. This makes a total response of .77 to the price of hogs for the two past years. Assuming that the actual price for the two past years completely determines farmers' price expectations, then the elasticity of supply for a two-year period would be considered to be .77 at the means. The elasticity of demand at the means for the fourth quarter was estimated to be -.64 by Equation (6.26). By definition, this would represent Ezekiel's case of divergent price and supply fluctuations; yet convergency is indicated because farmers evidently do not expect prices at breeding time to continue. Their plans are modified by prices in previous years.

The differences between supply and demand elasticities are even more marked in the complete supply-demand models derived from the Nerlove-type supply equations, (5.46) and (5.47) TABLE 19 in CHAPTER V indicated a long run supply elasticity of around 2.00 with respect to the hog:corn ratio in (5.46) and to the price of hogs in (5.47). These elasticities are considerably greater (absolutely) than the -.64 demand elasticity obtained for the fourth quarter (or any of the other quarters).

Although convergency is indicated by the solution to the difference equations, such has not been observed in the 50-year period included in this study. The hog market would be expected to converge to an equilibrium only if all exogenous influences were held constant as was fabricated for the difference equation analysis. However, the hog market is sensitive to many outside influences which keep hog prices and production in continual oscillation. The major exogenous factors have been wars, droughts and depressions.

Efforts have been made to stabilize the hog market through feed grain storage programs which stabilize feed supplies. In the latter part of the 1947-1958 period, the size of the Commodity Credit Corporation's feed grain holdings was sufficient to maintain feed grain supplies except during years of extreme drought.

Information of the type obtained in this study, with proper interpretation, could be a valuable guide in government policies directed toward stabilizing the hog market. Forward pricing schemes, pork buying operations, feed grain support programs, outlook programs, and other such programs directed toward stabilizing hog prices would require a careful analysis of farmers' responses to price and of the price flexibility of hog supplies. If these relationships could be accurately ascertained, then a counter-cyclical hog program could conceivably reduce the variation in hog prices and supplies to an acceptable range within some specified length of time. Of course, a forward pricing scheme would have to make allowance for additional response to a guaranteed price.

Hog producers and the many market agencies which handle hogs and hog products as well as firms which supply farmers with inputs, can profit by knowing the dynamic properties of the hog market. Buying or selling sows and feeder pigs, expanding a hog enterprise, and shiftingto or away from hogs are examples of decisions farmers must make which require some assumptions about the dynamics of the hog market. Meat packers must plan their killing operations well ahead of time and establish storage policies. Feed companies must anticipate farmers' requirements. All must make forecasts of hog production and prices which extend beyond the forthcoming year.

Unfortunately, the number of observations on the post-World War II period was relatively small. Consequently, the estimates of supply response and price flexibilities in this study were not as precise as would be desirable for policy decisions, and decisions of producers and market agencies.

There have been numerous studies concerned with forecasting hog production and prices for a year in advance. As more data becomes available and more is learned about expectations and decision making, researchers should endeavor to further isolate and analyze the factors which generate and perpetuate the oscillations in the hog market. There is a need for not only improving predictions for the year ahead but for several years ahead. Many decisions by those concerned with the hog industry involve commitments which extend beyond one year.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The instability characteristic of hog production and prices has long been a problem for farmers, farm supply firms, market agencies and even consumers. The instability has tended to be cyclical, a phenomenon explained most simply by Ezekiel's Cobweb Theorem. The hog market, for the most part, fulfills the three conditions specified as necessary for the Cobweb Theorem to apply:

(1) Production is completely determined by producers' response to price, under conditions of perfect competition.

(2) The time needed for production requires at least one full period before production can be changed, once the plans are made.

(3) The price is set by the supply available.

Ezekiel states that the production or price cycle may be convergent if the slope of the supply curve is greater than the slope of the demand curve; divergent if the supply slope is less; and of constant amplitude if the two slopes are the same.

Ezekiel presumes in his Cobweb Theorem that producers expect present prices to continue and make their plans accordingly. However, it seems unrealistic to believe that farmers naively expect present prices to continue in a market characterized by widely fluctuating prices. The possibility of a divergent cycle also seems remote.

The presumption that producers expect present prices to continue is not vital to the Cobweb Theorem and is only a special case of a more general assumption. That assumption is that the expected price is some positive function of past prices.

A change in actual price may not be accompanied by a corresponding change in expected price. One or more production periods may pass before the expected price is equivalent to the actual price, provided the new price level is maintained. The supply response to a change in actual price would therefore not necessarily be complete within one production period. The supply response would be in the form of a distributed lag over several production periods. Actual prices over several past years would be necessary to determine expected prices and thereby the supply curve.

It is difficult if not impossible to identify price expectations from time series data. The observed lag in supply response to actual price is composed not only of a lag between actual and expected prices but may also involve an economic and a technical lag. There is no way to isolate the separate lags unless one or the other is assumed arbitrarily.

The composite distributed lag between actual price and supply response can be estimated, however. One technique, developed by Alt, is a stepwise procedure in which supply equations are estimated with price lagged one year; one and two years; one, two and three years; etc., until the coefficients of price cease to make sense. Another method suggested by Nerlove involves the estimation of the parameter of a particular type of lag distribution in which the greatest response is assumed to be in the first year and proportionally less in succeeding years.

Two hypotheses were tested. Hypothesis I was that the response of hog production to actual prices extends over more than one year and that the response in the first year was greater than in the second, the response in the second year greater than in the third, etc. Hypothesis II is that the hog market has cyclical tendencies but would eventually converge to an equilibrium in the absence of external disturbances.

Three separate periods were examined in estimating supply response, 1908 to 1924, 1925 to 1941 and 1947 to 1958. Spring farrowings were used as the dependent variable in the latter two periods and hog slaughter from the spring pig crop as the dependent variable in the 1908 to 1924 period. The price of hogs and the price of corn in the fall and early winter were the main independent variables. Supply of feed grain other than corn, cattle prices, index of prices paid, supply of corn and stock (corporation) prices were also tried in various combinations but were not found to be significant.

Both Alt's and Nerlove's techniques were applied. Hog and corn prices were introduced into the supply equations both as a ratio and as separate variables. The dependent variable was used in first difference form and alternatively the dependent variable was in absolute values with lagged values as an independent variable. The single equation, least squares estimating technique was used.

The estimates obtained by both Alt's and Nerlove's procedures gave substantial support to Hypothesis I. Some disappointment was experienced using Nerlove's method, which places a restriction on the form of the distributed lag.

Little advantage was found in entering hog and corn prices as separate variables over including them in ratio form. Some preference was indicated for putting the dependent variable in absolute values with lagged values as an independent variable rather than using first differences.

A significant difference was observed in the supply response pattern between the 1925-1941 period and the 1947-1958 period. In 1925-1941, the response was almost entirely determined by prices in the fall preceding farrowing. Prices in both the fall preceding farrowing and the fall of the year before were significant in the supply response equations for 1947-1958.

Long run supply elasticities were estimated in the Nerlove equations; 2.12 in 1908-1924, 3.13 in 1925-1941 and 2.19 in 1947-1958.

Regression equations were also estimated for the fall pig crop. Spring farrowing, the hog:corn ratio, the indicated supply of feed grain and time were used as independent variables. Only spring farrowings and time were found to be significant.

Four alternative demand equations for pork were estimated based on quarterly data for the 1947-1958 period. In the first demand equation, the retail price of pork was the dependent variable. Disposable per capita income, the per capita supply of red meat other than pork, the per capita supply of poultry meat, the per capita supply of pork for each of the four quarters, and dummy variables representing the quarters were the independent variables. The per capita supply of pork in each quarter was a separate variable equal to its actual value in the appropriate quarter and zero in all other. A significant negative coefficient was obtained on income but the supply of red meat other than pork and the supply of poultry meat were not significant factors. The coefficients on the supply of pork were all highly significant.

In the second demand equation, time was introduced and the supply of red meat other than pork was combined into one variable with the supply of poultry meat. The coefficient on income was again negative but insignificant. The coefficients on the supply of other meat and time were not significantly negative. The coefficients on the supply of pork were all highly significant.

Positive serial correlation of the residuals was indicated in the first two alternative demand equations. To mitigate the error from this source, a technique formulated by Dr. Clifford Hildreth was followed. The assumption was made that the residuals were generated by a first order autoregressive scheme. Several levels of autocorrelation between zero and one were assumed. The sum of squares of residuals was calculated from each of the equations representing the assumed levels of autocorrelation. The equation for which the sum of squares of residuals was the minimum was selected.

Two additional demand equations were investigated by this technique. One was identical to the second demand equation and in the other the time variable was dropped. In both equations, the minimum of the sum of squares of residuals was determined to be near a level of autocorrelation of .4 to .5. The coefficient on disposable income was still negative in the equation in which time was omitted but was positive in the equation in which time was included. The latter demand equation was selected for the construction of a complete supply-demand model of the hog market. Price flexibilities of the demand for pork at the means were estimated by this equation to be -.80, -.77, -.84 and -.73 for quarters one through four, respectively.

An equation representing the marketing margin for pork was estimated for each of the four quarters. The price of hogs was the dependent variable with the retail price of pork; the price of lard; wage rates in meat packing plants and retail stores; and the commercial slaughter of hogs as independent variables. These variables explained 98 percent or more of the variation in the quarterly price of hogs.

The demand for pork equation and the marketing margin equation were combined to form a "complete" demand function for hogs. The price flexibilities of the demand for hogs were calculated to be -2.09, -1.12, -1.33 and -1.56 for the four quarters, respectively.

To test Hypothesis II, that the hog market is cyclical and convergent, four supply equations were selected to be combined alternatively with an equation which determined the relationship between spring farrowings and hog prices in the following fall. The variables assumed to be exogenous were set at their mean values. The supply-demand models were then reduced to second order difference equations involving only spring farrowings and lagged values of spring farrowings.

The solution of the difference equations yielded certain information about the dynamic properties of the hog market. The properties of the four alternative models investigated were similar. All were cyclical and convergent, substantiating Hypothesis II. A cycle of 5 to 6 years was indicated.

This analysis illustrates that the hog market is convergent even though the elasticity of supply (based on a two or three year production adjustment period) is greater than the elasticity of demand, Ezekiel's "explosive" case.

The main purpose of this study was to determine whether the distributed lag approach to supply response was appropriate; and if so, whether this would help explain a rather uncomfortable assumption in the Cobweb Theorem. To do this, price flexibilities of demand for hogs had to be estimated as well as supply elasticities.

In the course of obtaining the price flexibilities of demand, a unique estimating procedure was followed which took into consideration the serial correlation in the residuals. This approach gave quite satisfactory results and, although somewhat tedious, holds promise as an estimating procedure in cases where significant serial correlation of the residuals is indicated.

Because of the relatively small number of observations obtainable in the post-war period, the supply-demand models in CHAPTER VII are of only limited value for prediction purposes. As more data become available, more reliable estimates can be obtained on the dynamic properties of the hog market. A recognized weakness of this and other studies on supply response is the lack of a theoretical structure of expectation formulation. More information is also needed on the cost structure of agricultural firms in order to gain more precise specifications on the adjustment lag. Information of the type obtained in this study, however, would be helpful in formulating government programs to help stabilize the hog industry, and in assisting producers, farm supply firms and market agencies in planning their operations for several years ahead as well as for the forthcoming year.

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APPENDICES

APPENDIX A

Additional Equations

Several equations other than those presented in the text of this dissertation were considered in this study. Listed in APPENDIX A are some of these equations along with their statistical properties. Variables other than those described in the text are listed below:

Variables

$\overline{S}g^{d}$, t	Sg, t divided by Sc, t and expressed as a first difference.
Mst, t	Margin between average price of choice steers at Chicago in June t to October t and average price of feeder steers at Kansas City in August t-1 to December t-1, dollars per hundredweight.
PPI, t	Index of Prices Paid by Farmers (1910-14 = 100), December t.
D, t	Index of stock prices: Combined index of prices of 500 stocks; percent change from previous year.
(Ph/PRI), t	Average price of 200-220-pound barrows and gilts at Chicago deflated by the Index of Prices Received by Farmers (1910-14 = 11), October t to January t+1, dollars per hundredweight.
Sc, t/LPU, t-1	Free supply of corn in crop year t to t+1 divided by the number of grain-consuming livestock production units in October t-1 to September t, tons per unit.

(Pc/PRI), t — Average price of No. 3 yellow corn at Chicago deflated by the Index of Prices Received by Farmers (1910-14-100), October t to January t+1, dollars per bushel.

Equations

1925-41

(A. 1)

$$F^d, t = 287 + \underset{(2.79)}{336.6}\ Ph, t-1 + \underset{(.23)}{21.0}\ Ph, t-2$$

$$-\underset{(6.67)}{5188.6}Pc, t-1 + \underset{(.65)}{630.6}Pc, t-2 + \underset{(1.77)}{37.34}\overline{S}g^d, t-1$$

$$-\underset{(.19)}{14.41}Mst, t-1 \qquad R^2 = .85 \qquad \overline{R}^2 = .74$$

$$S = 480$$

(A. 2)

$$F^d, t = 1273 + \underset{(3.08)}{375.0}\ Ph, t-1 + \underset{(.38)}{36.1}\ Ph, t-2$$

$$-\underset{(3.86)}{3809.3}\ Pc, t-1 + \underset{(.02)}{17.2}\ Pc, t-2 + \underset{(1.05)}{.03339}\ Sg^d, t-1$$

$$-\underset{(1.19)}{14.58}\ PPI, t-1 \qquad R^2 = .84 \qquad \overline{R}^2 = .73$$

$$S = 496$$

(A. 3)

$$F^d, t = -3362 + \underset{(5.74)}{283.6}\ H{:}C, t-1 + \underset{(.18)}{8.18}\ H{:}C, t-2$$

$$+ \underset{(3.14)}{.02752}\ Sg, t-1 - \underset{(.39)}{1.819}\ D, t-1$$

$$R^2 = .84 \qquad \overline{R}^2 = .79 \qquad S = 440$$

(A. 4)

$$F^d, t = -6793 + \underset{(3.34)}{501.51}\ (Ph/PRI), t-1 + \underset{(.05)}{6.36}\ (Ph/PRI), t-2$$

$$+ \underset{(3.38)}{6865}\ (Sc, t-1/LPU, t-2) - \underset{(.29)}{626}\ (Sc, t-1/LPU, t-2)$$

$$R^2 = .72 \qquad \overline{R}^2 = .62 \qquad S = 585$$

(A.5) $F^d, t = -1196 + 593.8\ (Ph/PRI), t\text{-}1\ -4962\ (Pc/PRI), t\text{-}1$

$\qquad (6.32) \qquad\qquad (6.13)$

$R^2 = .84 \qquad \bar{R}^2 = .82 \qquad S = 408$

<u>1947-58</u>

(A.6) $F^d, t = -678 + 183.2\ Ph, t\text{-}1 + 104.7\ Ph, t\text{-}2$

$\qquad (3.98) \qquad\qquad (1.96)$

$-2542.2\ Pc, t\text{-}1\ -912.3\ Pc, t\text{-}2 + 7.747\ \overline{Sg}^d, t\text{-}1$

$(5.39) \qquad\qquad (1.42) \qquad\qquad (.37)$

$+41.45\ Mst, t\text{-}1 \qquad R^2 = .87 \qquad \bar{R}^2 = .85$

$(1.08) \qquad\qquad S = 401$

(A.7) $F^d, t = -645 + 188.2\ Ph, t\text{-}1 + 102.8\ Ph, t\text{-}2$

$\qquad (3.05) \qquad\qquad (1.65)$

$-2248.8\ Pc, t\text{-}1 \quad -939.7\ Pc, t\text{-}2 + .02190\ Sg^d, t\text{-}1$

$(3.35) \qquad\qquad (1.49) \qquad\qquad (.74)$

$-.8877\ PPI, t\text{-}1 \qquad R^2 = .85 \qquad \bar{R}^2 = .68$

$(.10)$

$S = 434$

(A.8) $F^d, t = -8594 + 332.8\ H{:}C, t\text{-}1 + 167.4\ HC, t\text{-}2$

$\qquad (4.34) \qquad\qquad (2.46)$

$+.008297\ Sg^d, t\text{-}1 \ + \ 1.848\ D, t\text{-}1$

$(.34) \qquad\qquad (1.52)$

$R^2 = .83 \qquad \bar{R}^2 = .73 \qquad S = 399$

(A.9) $F^d, t = -11129 + 342.4\ (Ph/PRI), t\text{-}1$

$\qquad (2.57)$

$+109.4\ (Ph/PRI), t\text{-}2 + 9577\ (Sc, t\text{-}1/LPU, t\text{-}2)$

$(.82) \qquad\qquad (3.17)$

$+4336\ (Sc, t\text{-}1/LPU, t\text{-}2)$

(1.45)

$R^2 = .75 \qquad \bar{R}^2 = .61 \qquad S = 475$

(A.10) $F^d, t = -991 + 518.5\ (Ph/PRI), t\text{-}1\ -5084\ (Pc/PRI), t\text{-}1$

$\qquad (3.45) \qquad\qquad (2.82)$

$R^2 = .65 \qquad \bar{R}^2 = .56 \qquad S = 508$

APPENDIX B

Statistical Formulas

F. Test in Alt's Procedure[1]

The following test was made on the R^2 values of successive equations using Alt's procedure in Chapter V:

$$F(k_2-k_1,\ T-k_2-1) = \frac{T-k_2-1}{k_2-k_1} \cdot \frac{R_2^2 - R_1^2}{1 - R_2^2}$$

where k_2 is the number of independent variables in the second equation, k_1 is the number of independent variables in the first equation, T is the total number of observations and R_1^2 and R_2^2 the respective coefficients of determinations (unadjusted) of the first and second equation. The degrees of freedom are k_2-k_1 and $T-k_2-1$.

T Test on Equation (5.12)

The test used to determine the significance of difference in coefficients of the supply relationship between 1925-1941 and 1947-1958 was:

$$t = \frac{b_i - b_j}{S\sqrt{s^{ii}\ s^{jj} - 2s^{ij}}}$$

where b_i is a coefficient in 1947-1958, b_j is a coefficient in 1925-1941, s^{ij} is an element in of the inverse matrix $(s_{ij})^{-1}$ which corresponds to b_i and b_j. This test is described by Snedecor.[2] The results of the tests are presented in TABLE 13.

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[1]See: R. L. Anderson and T. A. Bancroft, Statistical Theory in Research (New York: McGraw-Hill Book Co., Inc., 1952), pp. 171-172.

[2]George W. Snedecor, Statistical Methods, (Ames: The Iowa State College Press, 1956), p. 442.

Durbin-Watson Test on Residuals

To test for serial correlation in the residuals, the Durbin-Watson statistic was used.[3] This statistic is:

$$d^1 = \frac{\sum_{t=2}^{N} (d_t - d_{t-1})^2}{\sum_{t=1}^{N} d_t^2}$$

where d_t is the residual of an observation from its estimate.

[3] J. Durbin and G. S. Watson, "Testing for Serial Correlation in Least Squares Regression," Biometrika, XXXVIII, No. 1 and 2, (1951), pp. 159-177.

APPENDIX C

Sources of Data

The number of sows farrowing and pigs saved were obtained from U. S. Department of Agriculture's Agricultural Statistics 1952, p. 405; Pig Crops by States, 1930-54 (Statistical Bulletin No. 187, July 1956); and Pig Crop Reports, June and December issues of 1955 to 1958.

Data on hog slaughter and production of pork and other red meat were obtained from U. S. Department of Agriculture's Livestock and Meat Statistics, 1957 (Statistical Bulletin No. 230, July 1958); Commercial Livestock Slaughter and Meat Production, December 1958; and The Livestock and Meat Situation, August 17, 1956. Monthly commercial poultry meat production figures were furnished by the Agricultural Estimates Division of the Agricultural Marketing Service, U. S. Department of Agriculture.

Prices on barrows and gilts and lard were taken from Prices of Hogs and Hog Products, 1905-56 (Statistical Bulletin No. 205, March 1957) and 1957-1958 issues of Livestock, Meat, Wool Market News, Weekly Summary and Statistics, both publications of the U. S. Department of Agriculture.

Corn prices for 1905 to 1919 were obtained from the U. S. Department of Agriculture's Feed Statistics, (Fd 5-7 Sup., Jan. 1941) pp. 31-32. Corn prices from 1920 to 1958 and feed grain production and supply data for 1905 to 1958 were obtained from Grain and Feed Statistics Through 1956 (Statistical Bulletin No. 159, May 1957), Grain and Feed Statistics Through 1957 (Supplement to Statistical

Bulletin No. 159, March 1958) and The Feed Situation (July, 1958), all publications of the U. S. Department of Agriculture. Indicated production on feed grains was taken from the U. S. Department of Agriculture's Crops and Markets.

The U. S. Department of Agriculture's Farm-Retail Spreads for Food Products (Misc. Publication No. 741, Nov. 1957), pp. 105, and the January 1958 to January 1959 issues of The Marketing and Transportation Situation were the sources for retail prices of pork. Disposable personal income by quarters was obtained from the July 1958 and February 1959 issues of the Survey of Current Business, U. S. Department of Commerce. The Handbook of Basic Economic Statistics (Washington: Economic Statistics Bureau, Vol. VII, No. 1 and Vol. XIII, No. 1) was the source for monthly U. S. population figures. Average annual wage rates in the meat packing industries and retail stores were furnished by the Market Organization and Costs Branch, Marketing Research Division of the Agricultural Marketing Service, U. S. Department of Agriculture.

The Consumer Price Index and Wholesale Price Index were obtained from issues of the Monthly Labor Review of the U. S. Department of Labor.

Derivation of Data

In the 1908 to 1924 period, non federally inspected, retail and farm hog slaughter data were not available on a monthly basis. To construct total hog slaughter between October t and April t + 1 and also between May t + 1 and September t + 1, federally inspected slaughter for those months were multiplied by a factor representing the ratio between annual total slaughter and annual federally inspected slaughter.

Since October to April federally inspected slaughter was divided between two years, the adjustment factor was computed by a weighted average of the ratios of the annual total to annual federally inspected slaughter for the two years involved. The weights were determined by the proportion of federally inspected slaughter in October to December of year t to the slaughter in January to April of t + 1.

Quarterly pork supplies and supplies of other red meat were the sum of cold storage stocks at the beginning of the quarter and total (commercial and farm) production during the quarter. Poultry meat supplies were the sum of cold storage stocks at the beginning of the quarter and commercial production of chicken and turkey meats during the quarter, ready to cook basis.

Population figures were U. S. total. Quarterly estimates were simple averages of the population estimates for the second and third months of each quarter.

Data

The following tables contain data used in this study.

TABLE C-1. Data for spring pig crop equations, 1908-1924.

Year	H:C Ph/Pc	Ph $/cwt	Pc $/bu.	Sg 1000 T	Sh 1000 Head
1905	11.52				
1906	14.95	6.43	.430		33514
1907	9.00	5.29	.588	16432	36262
1908	8.97	5.90	.658	17368	39445
1909	13.54	8.15	.602	20376	30721
1910	17.18	8.11	.472	21117	31624
1911	9.58	6.32	.660	17650	37839
1912	15.21	7.94	.522	26379	33826
1913	12.07	8.15	.675	20438	35006
1914	10.90	7.50	.688	21326	39877
1915	10.63	7.21	.678	27932	43917
1916	10.42	10.00	.960	22043	43915
1917	8.82	17.15	1.945	27453	39100
1918	12.83	18.02	1.405	28259	46665
1919	10.03	14.67	1.462	20852	40002
1920	15.01	11.56	.770	27214	38395
1921	16.23	7.61	.469	19909	37254
1922	12.18	8.61	.707	22036	46537
1923	8.66	7.22	.834	23451	50894
1924					46936

TABLE C-2. Data for spring pig crop equations, 1925-1941 and 1947-1958.

Year	H:C	Ph	Pc	Sg	F
	Ph/Pc	$ / cwt.	$ / bu.	1000 T	1000 Head
1922	12.18				
1923	8.66	7.22	.834		
1924	8.58	9.99	1.165	29581	9799
1925	14.48	11.58	.800	30721	8334
1926	16.60	12.30	.741	28880	9048
1927	10.89	9.34	.858	28465	9754
1928	10.24	9.13	.892	33233	9301
1929	10.72	9.51	.887	29543	8854
1930	11.92	8.58	.720	31642	8278
1931	11.86	4.59	.387	28113	8971
1932	13.99	3.40	.243	31777	8811
1933	8.85	4.00	.452	21447	9123
1934	7.37	6.37	.864	14913	6825
1935	14.97	9.88	.660	29600	5467
1936	9.27	9.98	1.077	23112	6954
1937	15.26	8.96	.587	28092	6177
1938	15.90	7.68	.483	29611	6795
1939	11.52	6.13	.532	27858	8692
1940	10.55	6.70	.635	33394	8247
1941					7760
1944	12.82				
1945	12.61	14.81	1.174		8302
1946	16.00	22.74	1.421	39025	8077
1947	10.69	27.13	2.537	34104	8548
1948	16.26	23.18	1.426	39412	7833
1949	13.64	16.70	1.224	35785	8820
1950	12.10	19.75	1.632	40018	9179
1951	10.26	19.10	1.862	37953	9484
1952	11.39	18.22	1.599	33666	8311
1953	15.48	23.32	1.506	32782	7045
1954	12.26	18.60	1.517	43004	7669
1955	10.49	12.74	1.214	46227	8359
1956	12.50	16.66	1.333	39594	7665
1957	16.04	18.48	1.152	52078	7277
1958					7428

TABLE C-3. Data for fall pig crop equations, 1908-1924.

Year	Sh (1000 Head)	H:Cf	IScg (1000 T)	Shf (1000 Head)
1908	39445	978	7354	19638
1909	30721	1109	17016	18859
1910	31624	1611	9752	22101
1911	37839	1326	-6317	19503
1912	33826	1168	18147	21812
1913	35006	1688	-5292	19369
1914	39877	1255	18935	20313
1915	43917	1105	14733	21484
1916	43915	1432	-4854	18716
1917	39100	1644	24976	20663
1918	46665	885	7743	22453
1919	40002	1462	3058	22623
1920	38395	1031	9175	23317
1921	37254	1105	-5838	25412
1922	46537	2262	-5510	28100
1923	50894	1083	412	26980
1924	46936	879	-11943	22478

TABLE C-4. Data for fall pig crop equations, 1925-1941 and 1947-1958.

Year	F	H:Cf	IScg	Ff
	1000 Head		1000 T	1000 Head
1924	9799	8.79	-10866	4344
1925	8334	10.71	17724	3939
1926	9048	16.99	- 268	4330
1927	9754	13.36	- 8337	4609
1928	9301	11.32	772	4429
1929	8854	12.44	- 2797	4264
1930	8278	11.26	7442	4074
1931	8971	9.89	22187	4797
1932	8811	9.92	13644	5180
1933	9123	18.06	-26932	5208
1934	6825	8.92	-20837	2935
1935	5467	10.92	23734	3857
1936	6954	15.54	- 7352	3957
1937	6177	10.10	27000	3845
1938	6795	14.72	375	4517
1939	8692	14.45	- 7088	5352
1940	8247	10.49	-10454	4763
1941	7760	14.57	931	5535
1947	8548	17.33	-23115	4866
1948	7833	9.36	20334	5070
1949	8820	14.00	- 5198	5568
1950	9179	15.38	- 9331	5927
1951	9484	13.46	555	5955
1952	8311	10.65	482	5067
1953	7045	15.07	- 3497	4479
1954	7669	17.76	4964	5014
1955	8359	12.26	7205	5586
1956	7665	13.52	-14894	5194
1957	7277	14.32	- 7847	5176
1958	7428	19.55	- 4916	5926

TABLE C-5. Data for consumer demand equation, 1948-1958.

Year	Quarter	DI/CP $	Som lb.	Spk_i lb.	RPpk/CP $/cwt.
1948	1	1226	25.36	23.03	58.6
	2	1236	23.79	19.21	58.7
	3	1243	25.00	15.05	63.8
	4	1255	27.60	24.78	58.8
1949	1	1264	24.30	22.49	54.5
	2	1262	24.13	17.58	55.4
	3	1255	26.67	15.47	57.9
	4	1248	27.34	24.60	51.7
1950	1	1264	24.58	22.66	49.5
	2	1280	24.38	18.33	52.6
	3	1304	26.47	16.13	59.1
	4	1330	28.58	24.88	52.8
1951	1	1326	23.76	23.51	53.7
	2	1329	22.39	20.43	53.4
	3	1329	24.88	18.02	54.4
	4	1326	28.09	25.64	51.6
1952	1	1329	24.95	25.52	48.8
	2	1330	25.08	20.48	49.5
	3	1331	27.81	17.50	53.7
	4	1338	30.74	24.83	50.4
1953	1	1354	28.76	21.77	50.4
	2	1370	30.20	16.44	56.3
	3	1379	32.60	14.43	60.4
	4	1382	35.05	20.50	54.8
1954	1	1378	31.22	17.95	59.1
	2	1372	30.54	14.87	59.9
	3	1371	32.65	14.66	55.7
	4	1376	35.40	21.29	51.5
1955	1	1384	29.96	20.59	48.5
	2	1403	30.39	16.49	48.6
	3	1426	32.81	15.35	50.0
	4	1448	35.03	23.41	44.6

Continued

TABLE C-5 - Continued

Year	Quarter	DI/CP $	Som lb.	Spk_i lb.	RPpk/CP $/cwt.
1956	1	1466	32.57	22.25	41.4
	2	1478	32.54	17.15	44.8
	3	1482	34.66	15.49	47.2
	4	1484	38.22	20.96	45.8
1957	1	1486	33.89	18.54	47.9
	2	1488	32.45	15.43	49.6
	3	1489	34.31	14.38	54.1
	4	1484	35.50	18.94	48.8
1958	1	1472	30.24	16.76	51.4
	2	1458	30.18	14.54	53.1
	3	1451	33.05	14.42	54.5
	4	1448	34.76	19.00	50.3

TABLE C-6. Data for the marketing margin equations, 1947-1958.

Year	Quarter	$RPpk/WP_i$ $/cwt.	Pl/WP_i $/cwt.	W/WP_i $/hr.	CSh_i 1000 Head	Ph/WP_i $/cwt.
1947	1	61.0	32.38	1.18	16930	27.81
	2	60.8	24.35	1.19	13829	26.06
	3	66.2	20.82	1.18	11579	28.68
	4	63.6	28.67	1.14	19591	26.61
1948	1	57.2	25.56	1.13	16250	24.43
	2	57.7	23.56	1.16	14160	22.85
	3	63.0	22.98	1.18	10511	28.05
	4	58.2	21.32	1.20	18747	22.74
1949	1	54.6	15.81	1.27	17087	20.93
	2	57.1	14.45	1.31	13904	20.17
	3	60.0	15.89	1.33	12862	22.12
	4	53.6	14.68	1.35	20908	17.18
1950	1	50.7	13.20	1.35	18610	17.20
	2	53.6	13.95	1.34	15695	18.94
	3	58.3	17.17	1.28	13664	22.37
	4	51.0	16.47	1.25	21575	17.46
1951	1	50.8	18.96	1.20	19729	19.16
	2	51.0	17.63	1.23	17772	18.97
	3	53.1	17.31	1.29	15461	19.58
	4	51.2	16.98	1.31	23090	17.01
1952	1	48.8	14.23	1.35	22719	15.92
	2	50.2	13.36	1.38	17440	17.78
	3	54.8	12.95	1.40	14777	19.41
	4	52.1	11.32	1.43	22753	16.24
1953	1	52.2	11.17	1.47	19808	18.25
	2	58.6	12.83	1.49	14447	21.99
	3	62.7	16.77	1.50	13463	22.90
	4	57.4	18.02	1.54	19196	20.41
1954	1	61.5	18.99	1.55	16409	23.67
	2	62.2	20.24	1.56	13202	24.19
	3	58.1	19.29	1.58	14615	20.07
	4	53.3	16.75	1.60	20601	17.18

Continued

TABLE C-6 - Continued

Year	Quarter	$RPpk/WP_i$	Pl/WP_i	W/WP_i	CSh_i	Ph/WP_i
		$ /cwt.	$/cwt.	$/hr.	1000 Head	$ /cwt.
1955	1	50.3	14.37	1.60	19286	15.59
	2	50.4	14.06	1.62	15155	16.88
	3	51.5	13.18	1.63	15778	15.26
	4	46.1	13.25	1.64	23998	11.61
1956	1	42.2	12.75	1.65	22654	11.41
	2	45.4	13.73	1.66	17302	14.39
	3	48.1	13.73	1.67	16555	14.62
	4	46.6	15.30	1.67	22002	13.91
1957	1	48.6	15.73	1.68	19256	15.19
	2	50.7	13.67	1.70	16636	16.29
	3	55.4	14.38	1.73	16340	17.57
	4	50.1	13.53	1.74	20363	15.31
1958	1	52.9	13.31	1.74	17928	17.21
	2	55.0	13.75	1.77	16231	18.88
	3	56.7	14.21	1.81	16675	18.35
	4	52.3	13.12	1.82	20161	15.93

TABLE C-7. Data for the farrowing-pork supply equations, 1947-1958.

Year	Spg, t 1000 Head	Spg/F, t Number	Spk', t.4 Mil. lbs.
1947	52199	6.11	3783
1948	50468	6.44	3658
1949	56969	6.46	3698
1950	57958	6.31	3802
1951	61298	6.46	3985
1952	55135	6.64	3925
1953	47940	6.80	3296
1954	52852	6.89	3483
1955	57690	6.90	3895
1956	53186	6.94	3498
1957	51812	7.12	3266
1958	52336	7.05	3328[a]

[a]Farm slaughter estimated.