DEMAND ANALYSIS FOR COMBINES, PICK-UP BALERS AND FORAGE HARVESTERS

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Eldon A. Reiling

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THESIS

DEMAND ANALYSIS FOR
COMBINES, PICK-UP BALERS
AND FORAGE HARVESTERS

By

Eldon A. Reiling

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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MASTER OF SCIENCE

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Approved Lester V. Manderscheid

ABSTRACT

DEMAND ANALYSIS FOR COMBINES, PICK-UP BALERS AND FORAGE HARVESTERS

by Eldon Reiling

Producers of farm machinery (and other durable goods) are confronted with the task of planning production for a future period. This study illustrates a method of predicting shipments in a future period; that is, single-equation regression models were developed to predict the manufacturers' shipments of combines (self-propelled and pull-type), pick-up balers and forage harvesters in the next calendar year.

Secondary data for the period 1947 through 1959 were used. These data were drawn largely from publications of the U.S. Departments of Agriculture, Commerce and Labor.

The independent variables used in predicting shipments of self-propelled combines were wholesale price index (W.P.I.) of self-propelled combines, total net income of farm operators the previous year and acres of crops per farm. An adjusted coefficient of multiple correlation ($\bar{R}^2$) of .904 was yielded by the model.

The W.P.I. of pull-type combines divided by the prices received for all crops, total net income of farm operators lagged one year, and W.P.I. of pull-type combines were used as independent variables in the prediction model for shipments of pull-type combines. The model yielded an $\bar{R}^2$ of .628.

The model for pick-up balers using receipts from dairy and beef in the prior year, the W.P.I. of balers divided by the W.P.I. of forage harvesters, W.P.I. of balers, and the number of balers and harvesters scrapped during the previous period as independent variables yielded an $\bar{R}^2$ of .624.

The model predicting shipments of forage harvesters yielded an $\bar{R}^2$ of .454 using receipts from dairy and beef the previous year, relative price of harvesters to balers, W.P.I. of forage harvesters, and the number of balers and harvesters scrapped the previous year.

Because a standard of current industry practice was not found, the results of the regression models were compared with a model which assumed that shipments of the current year would be equal to the shipments of the preceding year. The standard deviation and mean deviation using the regression model were smaller than for this alternative model in all cases.

Future revisions of the models might devote further attention to problems such as the specialization of the machines, the use of income as a variable, inventory levels of machines and the used machinery market. These problems were investigated but appear to warrant further attention.

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CHAPTER I

INTRODUCTION

All economic planning - whether by business, by government, or by consumers - involves making assumptions regarding the future. Prediction is an aspect of life which can not be avoided. This is true of the business firm budgeting its operations for the coming year; it is equally true of the consumer as he tries to plan his activities of the future period.

Forecasting can be viewed from many different aspects; it can be long-run or short-run or can engulf a large segment of the economy as contrasted with a restricted industry. The assumptions and techniques vary with the kind of planning needed. This study is restricted to the task of predicting manufacturers' shipments of self-propelled combines, pull-type combines, field forage harvesters and pick-up balers.

Prediction and explanation are not always the same or found together. It is possible to predict without explaining; however, if explanation is possible then prediction follows. It is possible to predict without explaining because there may exist phenomena that are correlated with the item in question, and these correlations make it possible to infer predictions. Where it is possible to explain events predictions differ not in logic, but only in the temporal point of the observer. If the result has occurred, the search is for the events and laws leading up to the result. This is explanation. But with prediction, the events and laws are available and from these the results must be deduced.

A methodological problem arises in a demand study where the demand for a particular item is in question. Two different approaches may be taken. One method is to develop a model which will yield predictions of future demand for the entire industry of which the specific item is a part. Then, assuming knowledge of the interrelations among the specific items is known, the demand for any specific item can be deduced. The second method is to arrive at some estimates of demand for each specific item and aggregate these individual demands to arrive at the industry demand.

The knowledge of the relations between specific machines is not sufficient at this time to use the first method. Therefore, this study will concentrate on the latter approach by making forecasts for individual machines. From these estimates and others of this nature, such as the tractor and machinery study by Cromarty[1], it may be possible to develop an overall picture of the farm equipment industry with an understanding of the interrelations among the various segments.

The Problem Setting

Business firms are currently making these estimates of shipments using a great variety of devices ranging from naive expectation models[2] to more refined procedures involving econometric models where mathematics, statistics and economic theory are used. A large mass of literature has been published about the technique, methodology and organization involved in the estimation of future sales. Few of the writings really attempt to answer the question of how and on what grounds the prediction is made; instead they concentrate on the organi-

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[1]William A. Cromarty, The Demand for Farm Machinery and Tractors, Technical Bulletin 275 (Michigan State University Agricultural Experiment Station, East Lansing, Michigan, 1959).

[2]Naive models refer to models utilizing only a very small portion of the relevant information which might be appropriate.

zational aspects of estimation procedures.

D. Gale Johnson lists several naive expectation models used by farmers estimating future prices.[3] They are equally applicable to industry and to production as well. They are:

(1) Project the current price into the future.

(2) Project the trend in prices over some past period.

(3) Project prices as normal, that is, "normal prices" in the future will be the same as the average for some past period.

(4) Believe that future prices will be more nearly "normal" than present prices but that there will still be a fairly high correlation with present prices. (May heavily weight more recent years.)

(5) Select some particular time or period of time in the past as determining anticipations and disregard the time before and after (important with historical events, for example, war, drought, and so forth).

It is difficult to say just how much these naive models are used by manufacturers. It can be said with some certainty that they are used, but they are, in all probability, not used singly but in conjunction with other information.

Personal judgment pervades all possible techniques of estimation, but there is a forecasting technique which employs personal judgment

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[3]D. Gale Johnson, Forward Prices in Agriculture (Chicago: University of Chicago Press, 1947), pp. 74-76.

alone. This involves a survey of the executives, the sales force, and outsiders such as consultants or suppliers. According to C. M. Crawford, "These individuals may be asked to make a direct estimate of total company sales or any segment thereof. More commonly, the judgment is directed first at the level of industry. In this way, a product-by-product analysis is made by the person involved; and he may even be asked to make the next step of estimating company share. Furthermore, the judgment may relate to general business conditions or to expected behavior in certain segments of the economy. Finally, the firm's specialists are frequently qualified to express opinions regarding certain aspects of the effectiveness of various planned activities."[4] A weakness of this method is that goals or objectives of the top executives are often known which tends to bias the survey toward that figure. Also, persons involved in the survey frequently lack sufficient data and knowledge of the overall picture to make accurate decisions of this type.

Where the survey technique is employed in a committee, the individual in charge of presenting

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[4] C. M. Crawford, Sales Forecasting, Methods of Selected Firms (Urbana: University of Illinois, 1955), p. 21.

background information such as general economic activity, current sales, and so forth, may bias the judgment of the group by the material presented or omitted. There is also the problem of conjectural interdependence, where each individual is trying to take into consideration what the other person will do, and at the same time, consider the other person's reaction to his own acts. The group decision has certain advantages, however. The most important is the pooling of specialized knowledge. The specialized facts are not so important as the judgment which can be applied to these facts in determining consequences of various alternatives. Another advantage of this method is that the surveyor need not be a statistician nor any other kind of specialist. The technique is a normal human procedure. Crawford generalizes that this technique along with one or more other techniques is used by almost all firms which forecast sales.

Surveys of purchaser intentions is a second technique used to make predictions of sales of a future period. Prospective purchasers are interviewed to determine if they intend to buy a given product in a given future period of time. The logic of the idea is good; the buyer seems to be the appropriate individual to ask, but there are certain assumptions which must be met. The respondent is assumed to answer honestly without omissions. The validation of this assumption depends partially on the type of question asked; for example, is the question personal or does it reflect on the respondent's status in any way? If there is any knowledge of the distribution of the bias, it may be possible to compensate for it. Respondents are also assumed to be able to predict the future and know how they will react under the different possible conditions. From this assumption it follows that respondents have plans of purchasing products in the future and these plans are specific with respect to price, quality and time. The respondents will also have the ability to pay at the future date. These assumptions are quite restricting. Crawford[5] concluded that in spite of many attempts to apply the survey technique, adoption has not been widespread. Wright and Vincent[6] conducted a research project in Michigan where they studied the relationship of

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[5] Ibid., p. 29.

[6] K. T. Wright and W. H. Vincent, "Intended and Actual Tractor Purchases by Farmers in Michigan, 1959", Quarterly Bulletin of Michigan Agricultural Experiment Station, Vol. 44, (East Lansing, Michigan State University, 1961), pp. 334-360.

intended and actual tractor purchases by Michigan farmers in 1959. A general conclusion was that about half of those farmers who indicated there was "some chance" of a purchase actually purchased tractors. Of the 72 percent of the farmers indicating there was "no chance" of a purchase, 14 percent did purchase a tractor. If sufficient data of this type are collected in the future, it may be possible to use this method more extensively. Additional experience may enable researchers to adjust the divergence between intentions and practices to yield more useful predictions.

Analytical techniques, as a third approach to the problem, have gained in use in recent years, but are still not widely accepted. Analytical techniques involve the use of specified variables applied in some particular manner. At the lower end of this methodological continuum, an index or collection of indexes may be used to make forecasts. At the upper end of this continuum falls the field of econometrics. One of the principle contributions of econometrics has been the encouragement of model building. The function of model building and analysis is not to replace intuition and judgment, but rather to support them with the tools for handling complexity and uncertainty with which the human intuitions can not cope unaided. It must be kept in mind that no model can be constructed to describe reality, if for no other reason than the computational problem.

The Problem

The task of this thesis is not to explain the demand function for agricultural machinery. Much more must be known before this can be done.

The problem is that of examining shipments of new self-propelled combines, pull-type combines, pick-up balers and forage harvesters to determine the variables associated with changes in the rate of shipment of these machines.

Scope and Objectives

Investments which farmers have made in new combines, forage harvesters and pick-up balers over the period 1947 through 1959 are investigated in this study.

The primary objective is to develop single-equation regression models which will be useful as prediction equations for manufacturers' shipments of the respective machines. A secondary objective is to explain the demand for these machines. The achievement of the first objective is necessary for the second, but is not sufficient.

Apparent Industry Practice

A search of the literature for a standard of current industry practice was disappointing. From the literature discussing the models used and the information utilized by the models no conclusion can be drawn as to just how the decision to produce a particular number of machines next year is reached. Granting that no manufacturer uses only naive models to determine this period's production, it may still be useful to compare the results of using the single equation regression models used in this thesis relative to the results yielded by a particular naive model. The particular naive model used as a basis of comparison in the balance of the thesis is the number of units shipped last year will equal this year's shipments.

Taking self-propelled combines as an example: the standard deviation of the estimates of self-propelled combine shipments using the naive model was 5802 units as compared to the single equation regression estimates of 1965 units. The error using the regression model is, in this case, roughly one third the error of the naive model. The mean deviation of the realized shipments from the estimated shipments using the naive model was 3242 units as compared to 1300 units using the regression model.

This lends some support to the use of the pedestrian single-equation least squares regression model as a tool for use in demand analysis. Results of the model compare favorably with the naive model and yet require a minimum of time and calculating equipment. Before examining the equations used in this study and the rationale of the individual variables, a review of past published research of the demand for farm machines will give a background for this study.

CHAPTER II

REVIEW OF PREVIOUS DEMAND STUDIES OF FARM EQUIPMENT

Introduction

The economics of the farm equipment industry has received only limited attention in the past. Included in the farm equipment industry, as used here, are the manufacturers (who are normally also the wholesalers) and the retailers. Of the few studies done in recent years on the market characteristics in the farm equipment industry, the work done at Michigan State University by Cromarty is probably the most significant. Cromarty did a detailed study of the factors affecting demand for wheel-type tractors including units used in the construction industry, but excluding garden tractors. Closely related to this work was his study of the market characteristics affecting demand for all other farm machinery as a group. Z. Griliches of the University of Chicago did a similar study on the domestic tractor market. Each of these studies will be discussed in the following pages.

Cromarty's Study of the Demand for Farm Machinery

Cromarty[1] first used a simple one-equation system fitted by "least squares" procedure. The variable to be explained was the physical volume of manufacturers' shipments of farm machinery for farm use in the United States. The time period covered in the sample observations was for the calendar years 1923-1954 inclusive, a total of 32 observations. His equation for estimating the quantity of machinery purchased by farmers was:

$$\text{1-1} \quad Y_1 = 2{,}397{,}952 - \underset{(450.0)}{702.5Y_6} + \underset{(255.4)}{235.8Z_2} - \underset{(257.0)}{1206.3Z_3} + \underset{(46.3)}{28.8Z_4} + \underset{(4.1)}{15.6Z_5} + \underset{(22.4)}{38.6Z_6} + \underset{(2549.6)}{1232.9Z_7} - \underset{(126.5)}{433.0Z_9}$$

(where the standard error is given in parentheses below each parameter estimate)

The coefficient of multiple determination adjusted for the number of degrees of freedom equaled .95.

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[1] Cromarty, *op. cit.*
William A. Cromarty, *The Market for Farm Trucks*, Technical Bulletin No. 271 (Michigan State University Agricultural Experiment Station, East Lansing, Michigan, 1959).

Y_1 = the value of manufacturers' sales of farm machinery and equipment for use on farms, in dollars, deflated by the wholesale price index for farm machinery including tractors. The wholesale price index is on the basis of (1947-49 = 1000). The deflating procedure reduces manufacturers' shipments in value terms to shipments in quantity terms. The value figures are based on factory prices and refer only to sales by manufacturers to dealers and do not cover sales by dealers to consumers. It thus assumes constant inventory levels at the dealer level.

Y_6 = the wholesale price index for farm machinery including tractors, deflated by the wholesale price index for all commodities, (1947-49 = 1000).

Z_2 = the index of prices received by farmers for crops and livestock (1910-14 = 100) deflated by the wholesale price index for all commodities, (1947-49 = 100). Resulting index multiplied by 1000.

Z_3 = the index of prices paid by farmers for items used in production excluding wages and the components of farm machinery and motor vehicles (1910-14 = 100) deflated by the wholesale price index for all commodities, (1947-49 = 100). Resulting index multiplied by 1000.

Z_4 = the value of farm machinery on farms at the beginning of each year, in millions of dollars.

Z_5 = the asset position of farmers at the beginning of the year, in millions of dollars, deflated by the wholesale price index for all commodities, (1947-49 = 100). This variable represents proprietor's equity weighted further by liquid assets and current liabilities.

Z_6 = realized net farm income for the previous year, in millions of dollars, deflated by the wholesale price index for all commodities, (1947-49 = 100).

Z_7 = the average acreage of cropland per farm, in tenths of acres.

Z_9 = an index of farm labor costs (1910-14 = 100) deflated by the wholesale price index for all commodities, (1947-49 = 100).

A reformulation of equation 1-1 was made in which Z_4, the stock of machinery on farms, was omitted. The results for the remaining variables were comparable to 1-1 but were associated with smaller standard errors.

1-2
$$Y_1 = 1{,}536{,}702 - \underset{(436.1)}{649.077Y_6} = \underset{(244.9)}{273.789Z_2}$$

$$- \underset{(252.8)}{1219.404Z_3} + \underset{(3.6)}{16.760Z_5} + \underset{(18.0)}{30.482Z_6}$$

$$+ \underset{(1228.1)}{2620.361Z_7} - \underset{(123.6)}{444.105Z_9}$$

The results indicate that a 10 percent increase in machinery prices has, on the average, been accompanied by a 10 percent decline in machinery purchases.

A 10 percent increase in prices received by farmers was associated with a 7 percent increase in machinery purchases.

A 10 percent increase in the value of all farm assets was associated with a 6 percent increase in machinery purchases.

A 10 percent increase in net farm income for the previous year was accompanied by a 5 percent increase in machinery purchases.

The amount of machinery on farms at the beginning of the year appears to have no effect on the quantity purchased during the year. The rapid technological advance in farming and farm machinery seemed to explain the unimportance of this variable..

The variable concerned with the average size of farm was related to machinery purchases and included the influences of increased crop specialization and intensity of land use.

The negative sign of the farm labor cost variable was contrary to Cromarty's hypothesis that labor and machinery are substitutes. This sign was probably due to the strong influence of technological development. The productivity of the labor was increasing faster, due to the increased use of machines, than was the labor cost.

Cromarty reformulated the demand for all farm machinery utilizing the "limited information, maximum likelihood" method. This method permits estimation of one equation at a time, with the simultaneity implied by a system of equations taken into account in the computations, but information on the particular variables that appear in each of the equations in the system is ignored. The system of equations estimated included machinery production, sales and prices. In this multi-equational model the time period of sample observations were changed to 1926-1955 inclusive, omitting the year 1943. War demands on materials severely restricted the production of farm machinery in 1943.

Cromarty's equation using the limited information method for estimating the quantity of machinery shipped by manufacturers was:

1-3 $$Y_1 = 24970 - \underset{(10.0)}{20.76Y_6} - \underset{(10.27)}{8.60Z_1} + \underset{(0.27)}{0.27Z_2} + \underset{(4.4)}{8.96Z_4} + \underset{(391.7)}{512.83Z_5}$$

Y_1 = value of domestic farm machinery shipments, in thousands of dollars, deflated by the retail price index for farm machinery, (1947-49 = 100).

Y_6 = retail price index for farm machinery deflated by the wholesale price index for all commodities, (1947-49 = 1000).

Z_1 = the ratio of prices received by farmers to prices paid by farmers, (1910-14 = 1000).

Z_2 = the value of assets held by farmers at the beginning of the year, deflated by the wholesale price index, in tens of millions of dollars.

Z_4 = industrial wages rates deflated by the index of wholesale prices for all commodities, in tenths of cents per hour.

Z_5 = a quantified measure of farm price programs.

The results showed an even higher price elasticity using the limited information method. A 10 percent change in the retail price of machinery in real terms was, on the average, accompanied by a 25 percent change in machinery purchases in the opposite direction.

A 10 percent increase in farm assets was accompanied by a 4 percent increase in machinery purchases.

Cromarty debated whether he should use farm wage rates or industrial wage rates. He used the industrial wage rates hypothesizing that high industrial wages would encourage workers to move off the farm. To sustain current production more farm machinery would then be needed. Judging from the statistical estimates there was good evidence to support this.

The parity ratio variable yielded a negative sign, opposite to that expected. Cromarty suggested that possibly farmer's decisions to purchase machinery were not governed by prices as they develop during the year, but were made before farm prices were known and had only an expected value.

The quantified measure of farm price programs, Z_5, was actually an involved dummy variable which attempted to measure some of the political influences at work in the economy over time. The approach used was to consider the basic commodities and observe if:

(1) price supports were fixed at levels of 85 percent or more.

(2) flexible price supports were in operation.

(3) no price programs were in operation.

(4) soil bank or other similar types of programs were in operation.

(5) a Democrat or Republican held the presidency.

From those data a series on Z_5 was constructed with positive values resulting from (1) and a Democrat president, negative values from (2) and (4), and 0 values for (3). The results of the analysis showed that farm purchases have tended to be higher when a combination of high, fixed price supports, no soil bank and a Democratic president were in existence.

The second equation of the system using the limited information method was concerned with the retail price of farm machinery.

1-4 $$Y_6 = -914.12 + .042Y_1 + 1.407Z_9 + .004Z_8$$
$$\qquad\qquad (.011) \qquad (.228) \qquad (.017)$$

Y_6 = the retail price index for farm machinery deflated by the wholesale price index for all commodities, (1947-49 = 1000).

Y_1 = the value of domestic farm machinery shipments in thousands of dollars, deflated by the retail price index for farm machinery, (1947-49 = 100).

Z_9 = the wholesale price index for farm machinery deflated by the wholesale price index for all commodities, (1947-49 = 1000).

Z_8 = the change in manufacturers' inventories of farm machinery for the preceding year, in thousand dollars, deflated by the retail price index for machinery, (1947-49 = 100).

This equation, treating the wholesale price as pre-determined, assumed that the manufacturers set the price at the beginning of the period and all price fluctuations were then at the retail level. The statistical estimates of wholesale price indicates that wholesale and retail prices move together. The difference between the two being the price discounts or premiums charged by dealers.

Cromarty had no adequate measure of farm machinery inventories, either at the retail or wholesale level. He felt that inventories had important effects upon price, so he included as much of the effects of inventories on prices as possible by using a measure of the change in inventories at the manufacturing level rather than the absolute level by calculating the difference between manufacturers' production and sales of the previous year.

The third equation of the system using the limited information method deals with the production of farm machinery.

1-5 $$Y_7 = 537.54 + \underset{(.052)}{.140Y_1} - \underset{(.523)}{.884Z_6} + \underset{(.646)}{.262Z_9} + \underset{(.113)}{.096Y_{7-\bar{3}}}$$

Y_7 = the value of farm machinery produced by manufacturers, in thousand dollars, divided by the retail price of farm machinery, (1947-49 = 100).

Y_1 = value of domestic farm machinery shipments, in thousand dollars, divided by the retail price of farm machinery, (1947-49 = 100).

Z_6 = the price per ton of steel deflated by the wholesale price index for all commodities, (1947-49 = 1000).

Z_9 = the wholesale price index for farm machinery deflated by the wholesale price index for all commodities, (1947-49 = 1000).

$Y_{7-\bar{3}}$ = a measure of plant capacity, as measured by the average value of farm machinery produced during the past 3 years, in thousand dollars, divided by the retail price of farm machinery, (1947-49 = 1000).

The hypothesis that manufacturers adjust production in response to sales was supported by the positive sign for machinery shipments. Some caution is warranted here due to the assumption that shipments by manufacturers are synonymous with sales by retailers. Taken over a period of time, this was probably a justifiable assumption.

The price of steel was a measure of manufacturers' production costs. Cromarty omitted the industrial wage rate because of the high correlation between it and the price of steel. The negative sign suggests a cut-back in machinery production as steel prices and/or industrial wages rise.

The wholesale prices of machinery were again treated as pre-determined and, as such, they were a partial determinant of the quantity of machinery produced.

The variable which measures the industry's capacity to produce was added with the hypothesis that manufacturers attempted to approximate the production of a recent period. The positive sign supports this hypothesis, but one coefficient did not differ from zero at a 10 percent level of significance.

Cromarty's Study of the Demand for Farm Tractors

The tractor study was carried out in very much the same way as the study of all machinery.[2] Many of the variables are the same for both, which is to be expected since the same body of theory is used.

The time period of sample observations covered the period 1926-1956 inclusive, omitting 1943 for the same reason as before. Three equations were fitted by "least squares" methods. The first two equations estimating manufacturers' shipments of wheel-type tractors were linear in the original variables while the second was linear in the first differences.

Least squares estimates of manufacturers' shipments, $\bar{R}^2 = .84$.

2-1 $$Y_1 = 2072.47 - \underset{(.729)}{1.345 Y_2/X_1} + \underset{(.053)}{.043 X_2} + \underset{(.333)}{1.559 X_3} + \underset{(.011)}{.003 X_4} + \underset{(60.404)}{134.264 X_6} - \underset{(.184)}{.918 X_9}$$

Least squares estimates of manufacturers' shipments, $\bar{R}^2 = .78$.

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[2] Cromarty, Demand for Farm Machinery and Tractors, op. cit., p. 46.

$$\text{2-2} \quad Y_1 = 2210.69 - \underset{(.846)}{1.689 Y_2/X_1} + \underset{(.058)}{.092 X_2} + \underset{(.389)}{1.434 X_3} - \underset{(.195)}{.990 X_9}$$

Least squares estimates of first differences of original variables, $\bar{R}^2 = .73$.

$$\text{2-3} \quad Y_1 = 90.85 - \underset{(.650)}{1.201 Y_2/X_1} + \underset{(.070)}{.029 X_2} + \underset{(.006)}{.002 X_4} + \underset{(6.796)}{34.567 X_6} + \underset{(1.470)}{8.549 X_7} - \underset{(.172)}{.929 X_9}$$

Cromarty hypothesized that farmers consider the price of tractors relative to the prices they receive for crops and livestock when making tractor purchases. The consistently negative parameter estimate for retail tractor price relative to prices received by farmers supported this hypothesis. On the average, other things remaining constant, a 10 percent increase in the relative prices of tractors to those received by farmers for their products resulted in a 6 percent decrease in the number of tractors purchased.

Cash receipts from farming the previous year was included as a variable because of its importance in terms of down-payment requirements and ability to finance the farm business for the current year.

In all cases there was a positive relationship between tractor sales and net cash receipts of the previous year. As an indication of the responsiveness of shipments to farm receipts, a 10 percent increase in net farm cash receipts for the previous year resulted in a 2 to 4 percent increase in tractor purchases.

The variable dealing with the effects of government political policies was the same as the one used in the machinery model. The positive sign lends support to the hypothesis that high rigid price supports reduce uncertainty.

The variable dealing with the replacement rate of tractors was determined by observing annual purchases of tractors and computing the number scrapped from the January 1 stocks. The average length of life in this computation was seventeen years. This agrees with a recent study by Parsons, Robinson and Strickler[3] (using a survey technique) in which 16.5 years was estimated to be the average useful life of a tractor. In both of the equations in which it was used, the parameter estimates were significantly different from zero with positive sign.

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[3]M. S. Parsons, F. H. Robinson, and P. E. Strickler, Farm Machinery: Use, Depreciation, and Replacement, U.S.D.A. Statistical Bulletin No. 269, (U.S. Government Printing Office, 1960), p. 29.

The average tractor sales for the previous 5 and 6 years was included to reduce the unexplained variance. Cromarty found that by observing the January 1 stock relative to the current purchases, there was quite a pronounced cycle of approximately ten years. Cromarty first used a 5 year lag but discarded this because a considerable change in the purchases from 5 years earlier would force the estimate of current purchases way off. The average of two years removed some of the year to year variation. The negative sign of the parameter estimate suggests that if tractor purchases were low during the previous 5 and 6 years they would be high currently and vice versa. The parameter estimate was consistently negative in all equations and statistically different from zero.

Cromarty developed a three equational model to explain tractor purchases to be solved by the "limited information, maximum likelihood" method. This system is similar to the one developed in the case of farm machinery.

2-4 $Y_1, Y_2/X_1, /X_2, X_3, X_9, u_1$

2-5 $Y_2/X_1, Y_1/X_4, Z_{12}, u_2$

2-6 $Y_4, Y_1, Y_2/X_1, /X_4, Z_{10}, Z_{12}, (Y_4)_{-\overline{3}}, u_4$

Definition of variables:

Y_1 = manufacturers' shipments of wheel-type tractors (excluding garden) for domestic farm use, in hundreds.

Y_2/X_1 = ratio of retail price of farm tractors (1937-41 = 100) to prices received by farmers for crops and livestock, (1910-14 = 100). Resulting index multiplied by 1000.

X_2 = net cash receipts received by farmers during the previous year, in thousands of dollars.

X_3 = 8-year weighted average of number of tractors on farms, in thousands.

X_4 = change in manufacturers' inventories for the previous year, in units.

X_6 = a quantified measure of farm price programs.

X_7 = replacement rate for tractors, in thousands.

X_9 = average tractor sales for the previous 5 and 6 years, in hundreds.

Z_{12} = price of steel per ton (1947-49 = 100) deflated by the wholesale index of prices for all commodities, (1947-49 = 100).

The equation estimating manufacturers' shipments of tractors using limited information estimates was:

2-4 $$Y_1 = 3229.983 - \underset{(.960)}{2.726}Y_2/X_1 + \underset{(.061)}{.036}X_3 - \underset{(.391)}{1.817}X_3 - \underset{(.184)}{1.130}X_9$$

The variables are the same as those used in the least squares estimates and were discussed and explained there. In this model using limited information fit a 10 percent change in the relative prices of tractors to prices received by farmers the previous year is accompanied by a 10 percent change in tractor purchases. This compares with the least squares fit where tractor purchases changed 6 percent with a 10 percent change in relative price. Cromarty explains the difference was caused by not giving machinery prices a pre-assigned value in the estimation process.

Estimating equation of retail prices of tractors using limited information estimates:

$$\text{2-5} \quad Y_2/X_1 = -513.83 - \underset{(.017)}{.065Y_1} - \underset{(.002)}{.0014X_4} + \underset{(.167)}{1.277Z_{12}}$$

The variables in the above equation are the same as those in the previous one except for the price of steel. The cost of steel was used to represent the costs of production. Wages were omitted as in the machinery case because of the high correlation between industrial wages and the price of steel. The parameter estimate was positive as expected since manufacturers' pricing policies are based on costs.

If Y_1 were considered as representative of demand factors, then the negative sign of the parameter estimate was opposite to that expected. If, however, the variations in shipments are considered mainly caused by and were positively associated with the prices received by farmers, then it was logical that as X_1 and Y_1 increase Y_2/X_1 would decrease.

Cromarty rationalized that manufacturers' inventories of the previous year should have had some effect on current tractor prices, but the parameter estimate was not significant.

Cromarty's equation of the production of tractors was not a technological function (production function) but an attempt to explain the behavior of manufacturers.

Estimating equation of production of tractors using limited information estimates was:

2-6 $$Y_4 = 3140.543 + \underset{(.136)}{1.2574Y_1} + \underset{(2.258)}{3.1782Y_2/X_1} + \underset{(.009)}{.0075X_4} - \underset{(3.175)}{5.341Z_{12}} + \underset{(.126)}{.1242Y_{4-3}}$$

Y_4 = total production of wheel-type tractors (excluding garden), in hundreds.

Y_1 = manufacturers' shipments of wheel-type tractors for domestic farm use, in hundreds.

Y_2/X_1 = retail price of tractors (1937-41 = 100) deflated by index of prices received by farmers for crops and livestock, (1910-14 = 100).

Z_{12} = price of steel per ton (1947-49 = 100) deflated by the wholesale index of prices for all commodities, (1946-49 = 100).

X_4 = change in manufacturers' inventories of tractors for the previous year, in units.

Y_{4-3} = weighted average tractor production for the preceding 3 years, in hundreds.

Production plans of manufacturers were determined prior to the production year and adjusted during the year on the basis of several factors, two of which were current shipments or sales and level of inventories. Cromarty had difficulty getting adequate data to represent inventories which explains, in part, the low level of significance of the estimates.

Steel prices were included as a reflection of manufacturers' profits and costs of production. As costs rise and profits are squeezed there is a tendency to reduce production.

The variable dealing with weighted tractor production was included to give some measure of the capacity of the industry. The variable was weighted giving the preceding year a weight of 3, the year two years preceding a weight of 2, and the year three years preceding a weight of 1. The positive sign was expected where it was assumed that the industry tried to attain previous capacity.

In the aggregation of data for all these models Cromarty was faced with the problem of quantifying different pieces of equipment. Since it was impossible to use physical numbers, he was forced to use value series. Deflation was a problem when value series were used; the appropriate deflator was difficult to find. In the tractor study, part of the problem was alleviated because there was only one piece of equipment. The magnitude of the problem was only slightly reduced, however, because of the many different sizes and models within the category defined as tractors. A trend variable might have been used to account for the movement toward larger units, but no such variable was used. He remained aware of the phenomenon and observed annual residuals for possible sources of bias.

The replacement rate of farm machines is difficult to determine. The rate is partially determined by the number and age of the machines in question, but many other factors such as marginal value product (MVP) of the second unit, market price for used machines, cost of labor, and others, enter. Also, farmers can vary the life of equipment so that no definite period can be stated.

If the life span were known, sales of a previous period could be entered as a variable. As was pointed out earlier Cromarty introduced two variables, replacement rate for tractors and an 8-year weighted average of number of tractors on farms to take into consideration the life expectancy of tractors.

The elasticities yielded by the models were concluded to be of limited value. The conclusion was arrived at largely on the basis of studies completed at Michigan State University by Fettig[4] and Hathaway[5]. The results of Fettig's and Hathaway's studies of farm machinery purchases during upswings and downswings of the non-farm business cycle indicated that farmers act differently depending upon the phase of the cycle. Cromarty also found some evidence to indicate that the demand curve for farm machinery assumes varying shapes depending upon the earning power of the machinery in relation to the price of new machinery and market

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[4]Lyle P. Fettig, "Purchases of New Farm Tractors and Machinery in Relation to the Non-farm Business Cycle, 1910-1965" (Unpublished M.S. thesis, Dept. of Ag. Econ., Michigan State University, East Lansing, 1958).

[5]Dale E. Hathaway, "Agriculture and the Business Cycle", Policy for Commercial Agriculture (Washington, D.C., U.S. Government Printing Office, 1957).

values of similar used machinery. This suggests that elasticities will also vary with the changing shape of the demand curve. The elasticities yielded by the model were averages for the total sample period and, therefore, do not reflect shifts in the demand curve. It was primarily these two factors that led Cromarty to discount the usefulness of the derived elasticities.

Griliches' Study of Farm Demand for Tractors

Z. Griliches[6] of the University of Chicago, did a study on the farm demand for tractors similar to Cromarty's tractor study. Griliches' tractor study covered the period 1921 through 1957. In his first model using small letters to represent the logarithms of the variables he derived the demand for the stock of farm tractors.

1-1 $y_t^* = a_0 + a_1 x_{1t-1} + a_2 x_{2t-1} + a_3 x_{3t-1} + u_t$

where y_t^* is the "desired" stock of tractors given currently available information.

The distinction between the "desired" and "actual" stock of tractors is concerned with the adjustment to a disequilibrium. The length of time

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[6]Z. Griliches, "The U.S. Farm Demand for Tractors: 1921-1957" (Office of Ag. Econ., University of Chicago, June 6, 1958), Paper No. 5812.

of the adjustment is affected by the fluctuation of price and other variables and the purchasers' expectations of the permanence of the change. Griliches assumed the adjustment of the actual stock to be proportional to the difference between the desired and actual stock or:

1-2 $$y_t - y_{t-1} = b(y_t^* - y_{t-1})$$

where b is the elasticity of adjustment.

Substituting 1-1 into 1-2 and solving for y_t yields:

1-3 $$y_t = ba_0 + ba_1x_{1t-1} + ba_2x_{2t-1} + ba_3x_{3t-1} + (1-b)y_{t-1} + bu_t$$

where ba's are the "short run" elasticities.

The numerical results of the analysis were:

$$y_t = a^{7} - \underset{(.13)}{.26x_{1t-1}} + \underset{(.15)}{.05x_{1t-1}} - \underset{(.21)}{.81x_{3t-1}} + \underset{(.07)}{.89y_{t-1}}$$

$R^2 = .987$

$b = .11$

The variables used were:

Y_t = value of the stock of tractors on farms, year 1, in 1935-39 dollars. Unpublished U.S.D.A. estimates.

X_{1t} = index of prices paid for tractors divided by an index of prices received for all crops.

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[7]The Y-intercept is not presented and sufficient data to calculate it are lacking.

X_{2t} = index of prices paid for tractors divided by an index of farm wages.

X_{3t} = rate of interest (farm mortgage rate).

Griliches dropped the variable representing index of prices paid for tractors divided by index of prices paid for farm wages because it was not significant. The R^2 was still .987 with the coefficient of adjustment then equal to .14.

The first impression from the regression results is that a very high percentage of the variance is explained. This is a bit misleading. Since the R^2 can not be less than the r^2 between any independent variable and the dependent variable. The correlation (r^2) between the current period and the prior period is .974. This leaves at most 2.1 percent of the variance explained by the other three (or two) variables.

In another version using the same basic model the coefficient of adjustment was assumed equal to one. The resulting R^2 was .793.

The negative coefficient of index of prices paid for tractors divided by the index of prices received for all crops was expected. Griliches pointed out that the positive coefficient of the price of tractors to farm wages was incorrect. However, it was judged insignificantly different from zero at the conventional test levels. The negative coefficient of the rate of interest was significantly different from zero and "right".

In a second model Griliches derived a demand equation in which the dependent variable was the annual purchase of tractors.

G_t = farm gross capital expenditures on tractors, in 1935-39 dollars. Unpublished U.S.D.A. estimates.

Gross investment as used by Griliches was the sum of net investment and replacement demand or depreciation. Replacement demand was taken as proportional to the existing stock.

Again using small letters to represent the logarithms of the variables the equation is:

$$G_t = ba_0 + ba_1x_{1t} + ba_3x_{3t} + (d-b)y_{t-1} + bu_t$$

where d is the average rate of depreciation. That is, for the period 1921 through 1957:

$$G_t = ba_0{}^8 - \underset{(.22)}{1.15}x_{12} - \underset{(.72)}{2.70}x_{3t} + \underset{(.15)}{.38}y_{t-1}$$

$$R^2 = .792$$

Griliches improved the results considerably by changing the time period of the analysis. The results studying the years 1920 through 1940 and 1947 through 1954 were:

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[8] The Y-intercept is not presented and data necessary for calculation of it are lacking.

$$G_t = -354x_{1t} - 1333x_{3t} + .100y_{t-1}$$
$$\quad (58) \qquad (178) \qquad (.019)$$

The stock-demand model and the gross investment model both indicate a stock-price elasticity of demand of about -0.25 in the short run and about -1.5 in the long run. The short-run price elasticity of investment is about -1.9, much higher than the stock-demand elasticities. Thus a 10 percent rise in the relative price of tractors would have resulted in a 19 percent drop in the purchases in the same year for the output flow of the tractor industry. So, the low stock-demand elasticities imply very large fluctuations in investment. The low short-run stock elasticities also imply that the effect on agricultural output of a change in the relative price of inputs is small in the short run. This is consistent with the generally accepted concept of an inelastic short-run aggregate supply function of agriculture.

Summary

The studies of Cromarty and Griliches are important contributions to the understanding of the demand for farm machinery and tractors. They used slightly different approaches. Cromarty assumed adjustments toward equilibrium during the period while Griliches emphasized long-run adjustment (making use of the Nerlove Model).

The influence of both these studies will be evident in the models developed for combines, pick-up balers and forage harvesters in the next chapter.

CHAPTER III

MODELS AND EQUATIONS OF THE ANALYSIS

Introduction

Each of the models used in the analysis will be presented in this chapter. However, before presentation of the models, those factors relevant to the study as a whole will be considered in order to avoid needless repetition. The sources of data as well as the data themselves will be discussed in the chapter. The actual data used in the analysis may be found in Appendix II.

Data

The data used in this study are secondary data selected mainly from federal government publications. The "Farm Machines and Equipment" section of The Facts for Industry series of the Bureau of the Census of the U.S. Department of Commerce, is the source for both the number and value of manufacturers' shipments. These data are based on a survey which covers from 1,000 to 1,100 manufacturers of farm machines, attachments and parts; the number of manufacturers varying only slightly over the period covered by this study. The survey is taken via mail questionaire to the individual manufactuers.

Physical units were used throughout the analysis. Value of sales were available and could have been used, but there is a complication of price deflation; a problem that it is possible to avoid in this instance. Using physical units does not yield a solution to all the problems.. There is still a wide variance in the size of machines and variety of optional features available with any of the machines in the study, presenting a problem of accurate denumeration. By using physical units another problem is created. Over time there are changes in the basic machine. For example, with both the balers and forage harvesters there has been a shift in the source of power from motor driven to power-take-off (hereafter referred to as P.T.O.). Similarly, the size of the combines has gradually increased until recently the major demand has been for either large or small machines with medium sized units rapidly declining in importance. Ideally one might like to use some measure of capacity of machines shipped since farmers who purchase the machines are interested in a flow of services. However, no statistical data of this nature exist.

The inventory data of number of specific machines on farms are collected by the U.S.D.A. The data were used with reservation because of some discrepancies revealed when an attempt was made to determine salvage rates of each classification of equipment. Salvage rates were estimated by summing the number of units shipped by manufacturers in the given year, then subtracting the number of units on farms the following January first. A positive number of units salvaged was expected. These computations were made for balers and harvesters only. For the years 1954 through 1957, there was a negative rate of salvaging for harvesters according to this method. One or two years with reactivation of machines could possibly be rationalized as inventory adjustments or minor discrepancies in the data collected. Periods of severe depression or war might also lead one to rationalize that machines were being reactivated, but none of these rationale are applicable. However, there was an underlying assumption which must not be overlooked; the number of units shipped by manufacturers was treated as synonomous with the number of units sold meaning that dealer's inventories would not fluctuate significantly from year to year. For any one year the assumption of constant dealer inventories is weak, but for four consecutive years it seems valid. It is unlikely that inventories were great enough in 1953 to enable dealers to draw from them for the following four years. Another possible explanation for the negative junking rate arises from the manner in which the data are collected. The survey may include only machines in use. If this is true, there might be machines on farms which are held in reserve and used only in years of above average crop yields or years of poor weather.

Data for the farm income variables were taken from Farm Income Situation, Balance Sheet of Agriculture and Handbook of Basic Economic Statistics. The income of the previous period was used in all the models. Income from the previous period is important for several reasons: (1) it affects current asset position, (2) it largely determines the amount of operating capital available during the year, (3) it affects the ability to make down-payments, (4) it affects the planning horizon of the farmer.

More important than enumeration of data sources is the reason for using secondary data in lieu of a primary source. The censuses taken by the U.S. Commerce Department and Bureau of Labor Statistics are consistent over time. Admittedly, there are definitional changes and changes in coverage, but there is normally some device (that is, a formula) for removing the change or the change is noted and explained. Data of past years are readily accessible and are usually revised as additional information is accumulated. The ease of acquiring this data and the negligible cost of acquiring it encourage the use of this type of data in estimating the demand for these and similar items. The cost of comparable data from the primary sources would be prohibitive.

The general arguments against the use of secondary data are relevant to this study. Secondary data are general and not patterned to the particular problem in question. The weaknesses and strengths are not fully known to those other than the collector, making it easy to use and draw conclusions from the material in a manner which can not be justified. Explicit definition of terms is often omitted as are important data, those which are of great value to a particular problem but were considered unimportant to the general area. Items of critical importance to the particular question are often collected under a more general heading, losing identity and usefulness in the process as happened in the data on forage harvesters in this study.

Other sources of secondary information were investigated. Inquiries were made to two different organizations[1] representing manufacturers and retailers of the machines of this study. It was found that these organizations collect very little data themselves and that for studies of the nature of this paper they too would use the data compiled by agencies of the federal government. Their primary function is the compilation and organization of data from scattered sources to be used by the members of the respective groups.

Period Covered in the Analysis

Annual data for the years 1947 through 1959 were used in the study. The availability of annual data was probably the primary reason, but aside from this reason, the aim of the study was to aid in annual scheduling by manufacturers of these machines. From a statistical viewpoint, for any period less than a year the conditions within the period would not be sufficiently homogeneous because of the highly seasonal demand for farm machine service. The period must be long enough to average out the effect of these irregular or non-measurable factors and short enough to insure

[1]Personal correspondence with Farm Equipment Institute and Implement and Tractor Publications, Incorporated.

that a relatively homogeneous set of factors be operating. Further work in this field might involve experimentation with the length of time period or the use of crop year rather than the calendar year as the basis of the annual data.

The most evident weakness of the analysis is the small number of observations. The analysis was conducted with only thirteen observations: a primary factor underlying the lack of strong conclusions. There is justification for the use of only thirteen observations. Data for the period prior to 1947 are not available in a form which would be useful and relevant to this analysis. Of the items considered in this study, data on production were available from the date that the item reached limited significance as defined by the Commerce Department. Data on forage harvesters and pick-up balers were not available prior to World War II because neither had attained the specified level of significance. During the war they were not adopted at a rapid rate, largely due to the restrictions on production. Self-propelled combines were not listed separately from combines as a group until 1941. During World War II the production of these machines was curtailed as the national resources were mobilized for the war effort. From mere observation of the data, it appears that 1943 was the year in which curtailment of production was the most significant. However, the amount of curtailment in the years of the war is difficult to ascertain since annual production was regularly increasing, with the exception of 1943. If there had been a census of production of these machines for a period of more than one year prior to the war an evaluation could more easily be made of the war-time restrictions.

Lack of price data for all machines prior to 1947 is another primary reason for the use of only thirteen observations. The wholesale price index (hereafter called W.P.I.) tabulated by the U.S. Bureau of Labor Statistics was used for the years 1947 through 1959, with the years 1947 through 1949 as the base period. This index represents the price at the manufacturer's level necessitating the assumption that the mark-up at the dealer level is some constant amount. An index of retail prices would be superior to a wholesale price index, but a complete set of retail prices is not available. There is a suggested retail price published by the manufacturers and reprinted by Farm Equipment Institute, an association of farm machinery manufacturers; but this does not depict the true price situation. There is variation in discounts, variation in trade-in allowances and service benefits which can not be considered.

The wholesale price index used in this study is the index of prices of large lot sales. The price data used in constructing this index are those which apply at the primary market levels. That is, most of the quotations are the selling prices of representative manufacturers. Machinery is priced free on board (f.o.b.) factory in such a way as to conform with the concept of seller's net realization per unit of precise specification. Net realization, as used by the Bureau of Labor Statistics means actual sales of precisely defined commodities, less normal discounts, in approximately similar quantities to similar classes of buyers. It does not mean an average realized price for a range of similar commodities. For example, net realization means the price of a pull-type combine with a seven foot cutting bar, P.T.O. driven, a given quality and sold to a precise class of buyers (dealers). It is not an average of all pull-type combine models. Prices are selected f.o.b. production points to avoid inclusion of transportation costs in the index. Excise taxes (applicable to tires only on farm machinery) are also excluded from the index.

The manner in which the war years and the immediate postwar years should be treated is not well defined. Even if the price data were available back to 1940 or thereabouts, it might be inadvisable to use wartime data because of the restrictions on machinery production and prices. Another factor making specification difficult during this period was the above normal weather. Using Stallings' indexes of the influence of weather on gross farm production the years 1941 through 1946 were all above normal.[2]

During the war period there was increased pressure to substitute capital for labor because of the drain on the farm labor supply. However, equipment was also rationed during this period. This indicates that equipment must have been used more intensively resulting in a back-log of demand for the post-war years. It might be suggested that this back-log would be dissolved, in part, by the increase in the farm labor force with returning veterans and from the reduction in demand for agricultural products. However, many of the men entering the military from the farm did not return after the war or returned for only a short time.

[2]J. L. Stallings, "Indexes of the Influence of Weather on Agricultural Output" (Unpublished Ph.D. thesis, Dept. of Ag. Econ., Michigan State University, East Lansing, 1958), Table 9, p. 91.

In summary, there seems to have been a change in structure over the two decades from the late 1930's to the late 1950's. Conditions that constitute structure, as used here, are the relations describing human behavior and institutions as well as technological relations. The structure which existed prior to the war was different from that during the war years with the structure of the postwar period differing from both of these earlier periods. To utilize all the observations of these three periods would necessitate the specification of the structural relation over the period. But since this could not be done, it was necessary to take observations from a period over which the structure did not change appreciably.

Estimating Models for Combines, Pick-up Balers and Forage Harvesters

The statistical estimation of the hypothesized models is done with a least squares estimating procedure. The linear model was used because of the results of graphic analysis where the dependent variables were plotted against various independent variables. The underlying structure appears to be more nearly represented by constant absolute changes than by constant percentage changes as would be represented by the logarithmic function.

Power functions were not used because in none of the models is there graphic evidence of a change in the sign of the first derivative.

A limited explanation of how the equations are to be interpreted follows. The regression coefficients indicate the additional product that would be shipped, on the average, other factors held constant, if a particular independent variable is increased by one unit.

The standard deviation of the regression coefficient (given in parenthesis below the coefficient in question) yields a measure of the error in estimating the slopes.

The standard error of the residuals, frequently referred to as the standard error of estimate is a measure of the deviations about the regression line. The standard error of the residuals indicates how well the estimated values of the dependent variable approximate the observed values.

The coefficient of multiple correlation (R^2) is an estimate of the correlation of the estimated dependent variable explained by the independent variables. In regressions where the number of observations is small, R^2 will be a biased estimate of the true multiple correlation coefficient squared. To reduce the amount of bias R^2 can be adjusted for degrees of freedom; a sizeable adjustment in a small sample such as the one in this analysis. The notation for the adjusted R^2 is $\bar{R}^2$.

Calculation of the statistics is not central to this study and will not be discussed in detail.[3]

Self-propelled Combine Model

Combines were divided into two groups, self-propelled and pull-type. Originally it was planned to work with combines as a group, but examination of the data indicates a structural change in the market. Starting with the period about 1954 through 1958 self-propelled combines have

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[3]Coefficient of multiple correlation: Where x and y are deviations from their means

$$R^2 = \frac{\sum_{i=1}^{p} bi \sum_{k=1}^{n} x_{ik} y_k}{\sum_{k=1}^{n} y_k^2}$$

Squared standard error of residuals:

$$S^2_{Y.X} = \frac{\sum_{k=1}^{n} y_k^2 - \sum_{i=1}^{p} b_i \sum_{k=1}^{n} x_{ik}\ y_k}{n}$$

Adjusted coefficient of multiple correlation:

$$\bar{R}^2 = 1 - (1-R^2)\ (\frac{n-1}{n-p-1})$$

been substituted at an increasing rate for pull-type machines. Introduction of smaller self-propelled machines better adapted to corn belt farming has been a major reason. Concurrent with this trend has been the increase in acreage of farms (and fields) in the Midwest and elsewhere which intensifies this change. The greater diversity with respect to crops of the small self-propelled machines has also been a contributing factor to this substitution rate.

Shipments of self-propelled combines were estimated by:

1-1 $$\hat{Y}_1 = -78622 + \underset{(3.41)}{1.88X_5} + \underset{(16.97)}{.326X_8} + \underset{(772)}{1277X_{15}}$$

$\bar{R}^2 = .719$

Standard error of residuals = 3365.8

$\hat{Y}_1$ = Estimates of manufacturers' shipments of self-propelled combines, in units.

X_5 = Cash receipts from food grains lagged one year, in millions of dollars.

X_8 = Thousands of grain combines on farms, January 1.

X_{15} = Average acres of crops per farm.

Cash receipts from food grains were used as the representative of combine purchasers' income. It was hypothesized that since a large share of the self-propelled combines were used in the areas producing food grains, net receipts of food grains would more nearly approximate the income of these

buyers. The instability of income in the food grains areas may be an explanation for the limited significance of the coefficient. The increased importance of self-propelled combines in the harvesting of crops such as corn, soybeans, and sorghums may imply that income from all farms is better than income from food grains alone. For example, soybean production increased from 186 million bushels in 1947 to 538 million bushels in 1959.[4]

High correlation between combines on farms and acres of crops per farm (.95) along with the lack of significance of the inventory of combines on farms led to the reformulation of the model in which the number of combines on farms was dropped as a variable. The number of grain combines on farms includes both self-propelled and pull-type so that the data tend to over-emphasize the importance of pull-type machines. The life of the machines is such that because the number of pull-type combines sold recently is declining, the number still in use over-estimates their current importance. The positive sign is expected considering many pull-type units are being replaced by self-propelled machines.

The variable representing the average number

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[4]U.S. Dept. of Agriculture, Agricultural Statistics 1960 (Washington, D.C., U.S. Government Printing Office), Table 195, p. 136.

of acres of crops per farm was used to partially account for the trend toward bigger specialized machines. Self-propelled combines have become more and more commonly used at the expense of pull-type units. Since the size of the combine largely depends upon the acreage to be harvested, it is clear that the size of the farm will strongly influence what type of combine is purchased. A one acre change in the average acres of crops per farm results in a 1277 unit increase in the sales of combines. This variable is more than a measure of acreage. It accounts for other trends such as increased mechanization of farms and improvements in yields (through improved varieties.

The low $\bar{R}^2$ and high intercorrelation between the stock of combines on farms and average acres of crops per farm prompted a change in the equation. The revised equation is:

1-2 $$\hat{Y}_1 = -68914 + \underset{(.36)}{1.14X_1} + \underset{(122.7)}{391.0X_6} + \underset{(410.2)}{325.4X_{15}}$$

$\bar{R}^2 = .904$

Standard error of the residuals = 1964.5

$\hat{Y}_1$ = Estimates of manufacturers' shipments of self-propelled combines, in units.

X_1 = W.P.I. of self-propelled combines, (1947-49 = 100).

X_6 = Total net income of farm operators the prior year, in millions of dollars.

X_{15} = Acres of crops per farm.

The results indicate that a change of 1 unit in the wholesale price index for self-propelled combines results in a 1.14 unit change in the sales of self-propelled combines. It must be pointed out that the positive coefficient of the variable representing price is contrary to that which is normally hypothesized in economic models. However, in the period sampled for this study a factor which is assumed constant in static economic theory is changing. Namely, the 1947 model self-propelled combine was not the same machine as the self-propelled combine of 1959. The capacity and efficiency of the machine had increased at the same time price was increasing. An analogy can be drawn between the self-propelled combine and the general-purpose farm tractor. Deere amd Company distributed a brochure[5] tracing the development of their Model "B" Tractor from its introduction in 1935 up to its modern present-day counterpart (1961), the "2010" Row-Crop Tractor. The changes in specifications, work output, features and prices are indicative of the kinds of changes which have taken place over the years in the many tractors and machines produced by the farm equipment

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[5]Deere and Company, "Facts About John Deere Tractor Wholesale Prices in the United States 1935-1961" (Moline, Illinois: Deere and Company, 1961).

industry. Two different periods are involved but this does not negate the validity of the analogy. The total price of this general purpose tractor increased 29 percent in constant dollars (using W.P.I. for "Agricultural Machinery Including Tractors" as the deflator) over the period 1935 through 1961. The cost per maximum drawbar horsepower fell 59 percent; cost per maximum belt horsepower was down 52 percent; and cost per pound of shipping weight dropped 31 percent over this same 1935 through 1961 period.

It is reasonable to assume that changes in the price and productivity of self-propelled combines and the other machines in this study would be in the same direction as for the tractor, but possibly less pronounced. Therefore, positive coefficients of price should be expected where this argument applies.

The total net income of farm operators the prior year was used as an indication of farmer's purchasing power. Income from the prior year is not generally indicative of total asset position but it is important in such areas as down-payment on a machine and the ability to cover variable costs during the present year. The results show that an average increase of approximately one million dollars in income the prior year will cause a 391 unit change in self-propelled combine shipments in the current year.

The average acres of crops per farm was used in the reformulation to again account in part for the trend toward larger and more specialized machines.

Pull-type Combine Model

Pull-type combines were treated separately from self-propelled combines because of an apparent change in structure in the period covered by this study. In the early part of the sample, shipments of pull-type combines are increasing, but the number shipped by manufacturers in the latter part of the sample is markedly lower. The original estimating equation was:

2-1 $$\hat{Y}_2 = 154742 + \underset{(3.85)}{1.65X_6} - \underset{(806)}{668.61X_2} - \underset{(83)}{43.44X_8}$$

$\bar{R}^2 = .534$

Standard error of residuals = 20085

The variables used were:

$\hat{Y}_2$ = Estimates of manufacturers' shipments of pull-type combines, in units.

X_6 = Total net income of farm operators lagged one year, in millions of dollars.

X_2 = W.P.I. of pull-type combines, (1947-49 = 100).

X_8 = Thousands of grain combines on farms.

The net income of farm operators was used because of the generally widespread use of this machine. There is no one crop to which the demand for the services of pull-type combines can be attributed. Pull-type combines are used in all geographical areas of the United States and are used in harvesting a wide variety of crops. The positive sign of the income coefficient is expected. It is normally expected that increases in income will lead to an increase in purchases.

The coefficient of the W.P.I. of pull-type combines has a negative sign. Earlier in this chapter it was argued that the price of machines had been falling relative to the productive capacity; therefore a positive sign of the coefficient of price would be expected. Pull-type combines could be, and apparently are, an exception to this argument. Pull-type combines were well established from the beginning of the sample period and no major changes have taken place in the machine over the sample period. The major improvements in combines have been in the self-propelled units.

The number of grain combines on farms represents the inventory of machines farmers currently own. It was hypothesized that a negative coefficient would be expected. That is, as the stock of machines on farms increases the demand for machines is satiated and the purchases of new machines declines. This hypothesis was also proposed by Parsons, Robinson and Strickler[6]. They stated that it appeared the saturation level had been reached for many machines and that only a replacement market existed. This hypothesis is supported by this equation for pull-type combines.

The usefulness of this equation is questionable; the question arising because of the variable representing inventories on farms. The number of combines on farms may be misleading because of the recent shift to self-propelled combines. The bias of this variable will be more important each successive year this model is used. Early observations of the sample have positive correlation with on-farm inventories and later ones have negative correlation. It was this weakness which led to a reformulation of the equation.

The revised estimating equation is:

2-2 $$\hat{Y}_2 = 163382 + .249X_6 + 113.4X_2 - 250756X_{11}$$
$$(3.50) \quad (782.5) \quad (154413)$$

$$\bar{R}^2 = .628$$

Standard error of residuals = 17930

X_{11} = W.P.I. of pull-type combines divided by prices received for all crops.

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[6]Parsons, Robinson, and Strickler, op. cit., p. 1.

The variables $\hat{Y}_2$, X_6 and X_2 are the same as in the original model.

The ratio of wholesale price index of pull-type combines to the index of prices received for all crops was used in lieu of the number of combines on farms. The new variable was used to indicate the influence of the cost of the item relative to its return in use. The coefficient conforms to the inverse price-quantity relation held by static economic theory. It is expected that if the W.P.I. rises more rapidly than the prices received index, the demand for machines will decline where it is assumed that the total cost per unit of product remains constant, rises, or falls by less than the decline in prices received.

Pick-up Baler Models

Three different estimating equations were used with pick-up balers: one linear in logarithms and two linear single equation models. No one of them yields a high adjusted coefficient of multiple correlation.

The original estimating equation was:

$$\text{3-1} \quad \hat{Y}_3 = -427276 - \underset{(3.61)}{2.82X_7} + \underset{(118636)}{255515X_{13}} + \underset{(.374)}{.262X_3} + \underset{(638)}{2378X_{12}}$$

$\bar{R}^2 = .624$

Standard error of residuals = 9222

The variables were:

$\hat{Y}_3$ = Estimates of manufacturers' shipments of balers, in units.

X_7 = Receipts from dairy and beef in the prior period, in millions of dollars.

X_{13} = W.P.I. of balers divided by W.P.I. of harvesters.

X_3 = W.P.I. of balers, (1947-49 = 100).

X_{12} = Thousands of balers and harvesters scrapped during the prior period.

The receipts from both dairy and beef were used as the representative of income. This necessitates making the assumption that farmers treat enterprises separately when making decisions regarding the enterprise in question. For equipment which is restricted to one or two enterprises, this is probably a realistic assumption. It was hypothesized that income and purchases move together, but it is not illogical that as receipts fall, the farmer is trapped into mechanizing his operation or going out of business.[7]

The use of the relative price of balers to

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[7]The production trap is presented by G. L. Johnson, "An Evaluation of U.S. Agricultural Policies and Programs, 1956 to 1960", A background paper for the Committee on Economic Development, Draft subject to revision before printing, 1960, Chapter III.

harvesters is a serendipitous result of another model. By error the first regression used to determine shipments of forage harvesters had the price of balers as a variable rather than price of harvesters. The favorable results stimulated speculation about the substitutability of the two machines. For haying operations the two are very good substitutes. Which machine is bought depends on such factors as the availability of labor and the type of auxiliary equipment on hand. But, if silage is to be used as roughage in lieu of hay, the machines become poorer substitutes.

The reasons for using the W.P.I. are the same as was cited in prior models. Here again, the sign of the coefficient is positive, but is not unexpected considering the improvements in balers during the sample period.

The number of balers and harvesters scrapped in the prior period (X_{12}) is used to represent two factors; a measure of the length of life of the machine and a measure of the possible remaining use in the machine. Cromarty[8] used the scrapping rate in a slightly different manner. He linked scrapping rate to sales of a previous period to get an average

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[8]Cromarty, The Demand for Farm Machinery and Tractors, op. cit., p. 28.

length of life estimate. Neither the length of life nor the proportion of useful machine life consumed (or remaining) are variables which are easily measured. Length of life may be extended if the supplies are restricted or if the purchasing power of the farmer falls. The proportion of the useful machine life consumed depends on the cost of new machines, the cost of repair parts and the degree of obsolescence.

A revision of the original model in an attempt to improve the coefficient of multiple determination was unsuccessful. The revised equation is:

3-2 $$\hat{Y}_3 = -77635 - \underset{(5.68)}{4.05X_7} + \underset{(1113)}{1717.3X_4} - \underset{(92.51)}{102.13X_9}$$

$\bar{R}^2 = .312$

Standard error of residuals = 12491

Variables different from those used in the previous model:

X_4 = W.P.I. of forage harvesters, (1947-49 = 100).

X_9 = Balers on farms January 1, in thousands of balers.

The sign of the coefficient for receipts from beef and dairy is contrary to expectation as in the previous model.

The W.P.I. of forage harvesters was used as the variable indicating the close relationship (substitutes) between pick-up balers and forage harvesters. If the substitute relation is valid then a positive coefficient of the price of the substitute would be expected. The positive coefficient of price of the substitute is also expected where the productivity of both machines is increasing at a comparable rate greater than the price increase of the two machines. For example, suppose that the price of forage harvesters increases. Then the reduction in real price of harvesters is less than the reduction in real price of the pick-up balers; hence, an increase in purchases of balers is expected.

The inventory variable represents the stock of machines on farms and gives some indication of the age of the machines on farms. The negative coefficient was expected as it was in the previous models.

Forage Harvester Model

The development of an estimating equation for forage harvesters is hampered by a basic change in the machine. In addition to the continued improvement which has taken place in all the machines in the study, forage harvesters have undergone a radical change over a short period of time. Until

1957, the shear-type machine was the only one marketed in any quantity. In 1952 the flail-type was introduced, but did not gain wide acceptance until 1956-1957. The shipments of the flail-type were not large enough to be published individually in 1956 or 1957 and were included in a miscellaneous category. Since then the flail-type machine has increased rapidly in importance. In any models developed in the future the possibility of omitting these two years (residuals, $Y-\hat{Y}$, for 1956 = -4217, 1957 = -6787) should be investigated. Consideration should also be given to using only 1958 and later data because of this change in the basic machine.

The estimating equation for forage harvesters was:

$$\text{4-1} \qquad \hat{Y}_4 = 103207.5 + \underset{(1.55)}{2.15X_7} - \underset{(66951)}{15168X_{14}} + \underset{(261)}{493.2X_4} + \underset{(.16)}{.15X_{12}}$$

$\bar{R}^2 = .454$

Standard error of residuals = 3961

The variables were:

$\hat{Y}_4$ = Estimates of manufacturers' shipments of forage harvesters, in units.

X_7 = Receipts from dairy and beef the prior year, in millions of dollars.

X_{14} = Relative price of harvesters to balers.

X_4 = W.P.I. of forage harvesters.

X_{12} = Thousands of balers and harvesters junked last year.

The rationale for using beef and dairy receipts is the same as for the use of this variable in the estimating equation for balers. In an earlier model, only the receipts from dairy were used. Here it was assumed that dairy farmers were the primary sector of agriculture using the forage harvester. Further inquiry into the amount of silage and chopped hay fed to beef brought about a re-evaluation of the importance of the beef producer's demand for forage harvesters. The increases in purchases were expected under the normal assumptions regarding income and demand.

The relative price variable (X_{14}) was used for the same reason the W.P.I. of forage harvesters was used in the estimation of the shipments of balers. In this equation as in the baler equation, there is a positive sign on the coefficient of the price relative.

The number of balers and harvesters junked last year (X_{12}) is again used in an attempt to consider both the age of machines being junked and some measure of the proportion of the machine consumed. The positive coefficient is expected.

In another estimating equation for forage harvesters the variables used were receipts from dairy, W.P.I. of forage harvesters and shipments of forage harvesters the average of fourth and fifth prior years. The last variable was the only unique one in the equation. It was an attempt to take into consideration the life expectancy of the machine estimated to be 8 to 10 years by persons working closely with the dairy industry. Although forage harvesters have been of importance only since the late 1940's, observation of the volume of shipments indicates the possibility of a cycle of this length. (However, no conclusions can be reached from this short period). The reason for averaging the two years, rather than taking either one, was to avoid extreme values of the variable caused by some factor not accounted for by the equation. In this way the effect of an extreme observation on the independent variable is much less marked. Prior to 1949 this variable was included as a zero because of the very limited numbers produced in 1941 through 1943.

These models were developed utilizing secondary data and the calendar year as the period. A sequence of years longer than 1947 through 1959 would be desirable to increase the statistical significance of the results, but limitations on available price data and structural changes of the respective markets make it impossible. Use of periods of less than one year is not an available alternative because of the lack of homogeneity.

Even considering these problems some of the results appear quite useful in the prediction of annual shipments. In the next chapter there will be a more stringent evaluation and discussion of the results.

CHAPTER IV

DISCUSSION AND EXPLANATION

Introduction

The purpose of this study is to predict the shipments of combines, pick-up balers and forage harvesters. This chapter is concerned with the presentation of the results of the analysis.

A comparison of the results of the analysis with the results using a particular naive model follows an evaluation of the significance of each of the independent variables used in the models. A discussion of various problems confronted in this analysis is presented in the latter part of the chapter.

Significance of Results

This section is divided into two main parts. The first part evaluates the significance of the independent variables, and the second part examines the residuals.

The traditional method for testing significance in regression analysis is based on the standard error of the regression coefficient. Discussion of the significance of the regression coefficient utilizes the t-ratio[1], or ratio of a coefficient to its standard error. The t distribution was used because of the small number of observations in the study. As the number of observations increases the t distribution approximates the normal distribution with zero mean and unit variance. It should be noted that independence of the observations is assumed in the derivation of the statistic t; an assumption which may present difficulties when time series data are used.

In this analysis β_i is assumed equal to zero under the null hypothesis, and each of the regression coefficients of all equations are tested to determine if they differ significantly from the assumed β.

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[1]In the case of a least-squares regression with m independent variables the statistic t is derived as follows:

$$y = a + b_1 x_1 + b_2 x_2 + \ldots + b_m x_m + u$$

$$E(b_i) = \beta_i \qquad (i = 1, \ldots, m)$$

$$S_{b_i} = \frac{\bar{S}_{y.x}}{s_{x_i}\sqrt{n}} = \frac{\text{standard error of residuals}}{(\sqrt{n})\text{ standard deviation of } x_i}$$

$$t = \frac{b_i - \beta_i}{S_{b_i}} \qquad \text{where } \beta_i = \text{hypothesized value}$$

The probability of rejecting the null hypothesis[2] when it is, in fact, true was set at 0.05. Table 4-1 presents the equations, the standard errors attached to each coefficient, the estimated t values, and a statement of the significance at the 0.05 level. Below each regression coefficient is the respective standard error followed by the ratio of each coefficient to its standard error (t). The coefficient of the independent variable is regarded as significant if the ratio of the coefficient to its standard error falls outside the critical region; it is not significant if the t-ratio falls within the critical region. That is, if the t value is in the critical region, we accept the hypothesis that the β is equal to zero.

In this study each variable was rationalized before it was used, and if, when the equations were reformulated, the variables still seemed relevant and not highly intercorrelated, they were not dropped from the equation. This explains, in part, the large number of variables which are judged insignificant by the t test at the 5 percent significance level. The limited number of degrees of freedom is another

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[2]In symbols, the probability of a type one error is: $P\{ |t| > k | H_o \} = .05$ where k is the critical value for the specified level of significance. L. R. Klein, Econometrics (Evanston, Illinois: Row, Peterson and Company, 1953), p. 139.

TABLE 4-1

SIGNIFICANCE OF REGRESSION COEFFICIENTS

Equation				
1-1	$\hat{Y}_1 = -78622 + 1.88X_5 + .326X_8 + 1277X_{15}$			
	Std. error of b's	(3.41)	(16.97)	(772)
	Statistic t	.55	.019	1.65
1-2[a]	$\hat{Y}_1 = -68913 + 391X_6 + 1.14X_1 + 325.4X_{15}$			
	Std. error of b's	(122)	(.357)	(410)
	Statistic t	3.18*	3.18*	.79
2-1	$\hat{Y}_2 = 154742 + 1.65X_6 - 668.61X_2 - 43.44X_8$			
	Std. error of b's	(3.85)	(806)	(83)
	Statistic t	.42	-.82	-.52
2-2[b]	$\hat{Y}_2 = 163382 + .249X_6 + 113.44X_2 - 250756X_{11}$			
	Std. error of b's	(3.50)	(782.5)	(154413)
	Statistic t	.07	.144	-1.62
3-1[c]	$\hat{Y}_3 = -427270 - 2.82X_7 + 255510X_{13} + .2626X_{12}$			
	Std. error of b's	(3.61)	(118636)	(.3747)
	Statistic t	.78	2.15*	.701
	$+ 2378X_3$			
	Std. error of b's	(638)		
	Statistic t	3.72*		

TABLE 4-1--Continued

Equation				
3-2	$\hat{Y}_3 = -77635 - 4.05X_7$	$+ 1717.3X_4$	$- 102.13X_9$	
Std. error of b's	(5.68)	(1113)	(92.51)	
Statistic t	-.71	1.54	-1.10	
4-1[d]	$\hat{Y}_4 = 103234 + 2.15X_7$	$- 154168X_{14}$	$+ 493X_4$	$+ .15X_{12}$
Std. error of b's	(1.55)	(66951)	(261)	(.16)
Statistic t	1.38	2.3*	1.88	.926

*Significant at 5 percent level.

[a]Equation used for predicting shipments of self-propelled combines.

[b]Equation used for predicting shipments of pull-type combines.

[c]Equation used for predicting shipments of pick-up balers.

[d]Equation used for predicting shipments of forage harvesters.

reason for the large number of insignificant variables. As the degrees of freedom decrease, a greater value for the statistic t is necessary to include the same probability of a type one error.

Only two equations were estimated for each machine in this study. Using a series of equations for each machine may have yielded a "better fit"; however, a series of equations were not run because of the small sample size. With small samples the number of degrees of freedom is an important consideration and each equation using the same sample, in an intuitive sense, costs a degree of freedom.

The price elasticities of demand and the income elasticities of demand calculated from the regression were very erratic. Because of their very erratic nature, they can not be used with any confidence in explaining the sensitivity of purchases to price or to income.

The erratic nature of the elasticities is brought about, at least in part, by the problem of multicollinearity.[3] The independent variables are theoretically independent, but they move together in the samples examined in this study. The multicollinearity problem also offers an explanation as

[3]H. Wold and L. Jureen, Demand Analysis (New York: John Wiley and Sons, 1953), pp. 46-47.

to why some of the independent variables are significant in one equation and not in the next, even though only one variable is changed.

To exemplify the problem of intercorrelation, take the case of a regression with two independent variables, say: $Y = b_0 + b_1x_1 + b_2x_2 + u$. The method of least squares yields estimates of the coefficients b_1 and b_2. Now, assuming that the two independent variables are linearly related, say: $c_0 + c_1x_1 + c_2x_2 = 0$, then the equation becomes indeterminate in that an arbitrarily large number of combinations of b_1 and b_2 are solutions. If some arbitrary value is assigned to either b_1 or b_2, the equation would be just identified and regression would give a unique solution. But, unless there is some prior way of choosing one of the b's no unique solution is available. In this study there are some cases where the intercorrelation between independent variables is greater than .90 which yields a relation between the independent variables that is not narrowly restricted. This can best be demonstrated by examination of this calculation:

$$S_{b_{y1.2...m}} = \sqrt{\frac{\bar{S}^2_{y.123...m}}{nS_1^2\,(1 - r^2_{1.23...m})}}$$

Where $S_{b_{y1.2...m}}$ is the standard error of a net regression coefficient,

$\bar{S}^2_{y.123...m}$ is the unexplained variance about the regression line,

n is number of observations,

s_1^2 is the variance of x_1,

r_1^2 is the intercorrelation between the independent variable x_1 and the other independent variables.

This formula can be used to calculate the standard error of the b's. Intercorrelation between the independent variables adversely affects the standard deviations of the coefficients of the independent variables. That is, as the intercorrelation approaches one, the denominator of the right hand side of the equation approaches zero resulting in a very large standard error of the b's. As the standard error increases the ratio of the coefficient to its standard error decreases making it less likely the coefficient will be significant.

Where multicollinearity is present (and it is not a problem in all the models) the importance of the individual regression coefficients is reduced, but the residuals will not be changed by the changes in the level at which either of the b's is specified. It should also be noted that the dependent variable may be the "best" linear unbiased estimate even if two independent variables are highly intercorrelated.

The Regression Models Compared with Naive Models

A criterion for evaluating the usefulness of the models is the size of the residuals over the period of study. The residuals are the difference between the estimate of the dependent variable and the observed value. To further facilitate evaluation, the mean residual $\left(\frac{\sum_{i=1}^{n} \left| Y_i - \hat{Y}_i \right|}{n}\right)$ was also calculated for both the naive and regression models. The mean residuals from each of the models is used as an estimate of the scattering of the observations. The mean residual is smaller than the standard deviation because the squaring of the deviations from the arithmetic means and taking the square root of the total lends greater emphasis to the large deviations than does merely averaging the residuals. These two statistics, the standard deviation and the mean residual, provide a basis for comparing the two models.

Table 4-2 is a comparison of the regression models and the naive models. The final prediction model is used for comparison in each case. The standard deviation (S_y) is given for each model as is the mean absolute residual $\left(\frac{\sum_{i=1}^{n} \left| Y_i - \hat{Y}_i \right|}{n}\right)$.

TABLE 4-2

REGRESSION MODELS VERSUS NAIVE MODELS

Machines	Prediction Equation	Standard Deviation	Mean Deviation
Self-propelled Combines	1.2	1,964	1,300
	naive	5,802	3,242
Pull-type Combines	2.2	17,930	11,390
	naive	25,640	11,968
Pick-up Balers	3.1	9,222	5,701
	naive	20,018	10,261
Forage Harvesters	4.1	3,962	2,598
	naive	6,525	4,635

The single-equation model appears to be much better than the naive model in terms of a predictive model, with one exception. That is, the mean residual of pull-type combines is somewhat greater using the naive model than using the regression model. If the period of the analysis for pull-type combines were changed to include only the years 1951 through 1959 the regression model might prove to be much better than the naive model. This

is because there appears to have been a structural change in the combine market; through 1950 the shipments of pull-type combines increased annually, but since that time annual shipments have fallen steadily.

Discussion of Problems Confronted in the Analysis

In studying the demand for durables, many complications arise. Some of the problems confronted in this study could be dealt with in the analysis; others could only be considered by remaining aware of the problem in drawing conclusions.

Specialization of Machines

All the machines in this study are generally considered to be specialized machines. Each machine is used primarily for only one purpose: the combines, especially the self-propelled units, being somewhat more diverse. The use of self-propelled combines in the harvesting of corn is presently in the acceptance or adoption stage[4] and was not taken into consideration in this study. A representative of a leading manufacturer[5] of combines pointed out that

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[4]Adoption stage is that period in the cycle of a machine after the new invention or use has been established as practical and before the machine has reached the period when it is commonly used by a wide segment of the industry in question.

[5]Dr. Sartorius, Deere and Co., Personal communication, August, 1960.

at this stage of adoption, the prediction of future demand is particularly difficult, for the sales depend heavily on the rate of adoption into the new use as well as the level of demand maintained in the established use. This expanded use also affects the demand for related durable goods such as corn pickers, pull-type combines and tractors.

Specialization is evident in other machines in the study also. Forage harvesters are used only for the harvesting of silage, chopped hay and for green-chopped hay operations. The latter has not been widely accepted to date; therefore is not of great importance in total demand. Balers are used only for baling field-cured hay and straw. Pull-type combines are used for a variety of small grains, but only small grains. Pull-type combines are at an increasing disadvantage because of the increasing size of fields and farms where self-propelled combines tend to be more efficient.

This limited latitude in use greatly restricts the number of factors affecting the demand for the unit, but also increases the importance of random shocks. Fluctuation in the price and yield of any of the crops harvested by these machines will have a marked effect on the demand for the machines. Weather, as it affects yield, will also be an important factor in determining demand. Since the demand for these machines is a derived demand, the fluctuation of the price of the products they produce (that is, forage and grain) will effect the demand for the machines.

The degree of substitutability referred to above, and supported by the sign of the coefficient of the price of balers and harvesters, also enters in. Where there exists a high degree of substitutability between machines, the sensitivity to price will be increased as will the sensitivity to other factors such as slight changes in technology or machine repair service. In the United States most commercial farms are of sufficient size to warrant a forage harvesting machine and a small grain harvesting machine. However, most of these farms are not of sufficient size to warrant two of each. In an attempt to take into consideration the high degree of substitutability between balers and harvesters, both the actual price and the price relative were used.

Not taken into consideration in this study is the substitution between the machines of various sizes. This is of special importance with combines where size varies from a cutting bar of less than six feet to those of over fifteen feet. The non-

availability of consistent data over the period of study is one reason it was not considered. The data by the commerce department are published in summary tables grouping several sizes together. Over the period of study the categories were changed making it impossible to follow the changes in purchases with any precision. Some consideration was given to the difficult problem of accounting for the trend to larger machines in the equations for self-propelled combines. Average acres of tilled crops per farm was used as an independent variable; the trend to larger farms is closely related to increases in machine size. Cromarty, in his tractor study, did some experimenting with the use of horsepower ratings as a guide to increased size of tractor, but was unsuccessful in developing a method of taking the change into consideration. Increased horsepower ratings for tractors may aid in explaining the shift from forage harvesters, pick-up balers and pull-type combines with mounted engines, to power-take-off machines more prevalent now.

Another possible means of taking trend into consideration is to use time as a variable. Time might be used where it is believed that there are continuous systematic variations for which there are no data available. However, it is preferable to use some other variable because time itself does not really explain.

Income as a Variable

What is the proper variable to use as a representative of income? In static economics there is no problem of defining income. Here, a person's income can be taken without qualification as equal to his receipts. On a dynamic level this simplification is not available. Income does not arrive in an even flow, nor is there a definite time period. In this analysis net income of the past year including government subsidy payments was used in two equations. In some of the models the cash receipts of the product directly related to the machine being studied was used. The rationale being that farmers study the enterprise in which the machine will be used to collect information for purchase decisions, ignoring the situation of the other enterprises. The government subsidy is not included in this case; an apparent inconsistency. It is not included because it is questionable whether a farmer regards the subsidy for a particular crop as income from that crop. It is more plausible that he considers it only as general income just as he regards income from off-farm employment when purchase decisions are made.

The farm business and farm household share the same income. However, farm records often do not separate the part of income which is allocated to the household and that part allocated to the business precisely enough to be of value in demand studies. The possibility of shifting receipts between the two as the situation demands is also present. In addition, production expenditures, beyond a given level of variable expenditures, are readily changed over a short period as are consumption expenditures above the subsistence level.

Effects of Federal Agricultural Policy

Price supports are also important as a part of farm income in two ways. They are a subsidy and also contribute to the removal of price uncertainty. The subsidized price encourages production on land which under unsupported price conditions would be considered sub-marginal. It is, of course, impossible to determine the exact reaction of farmers to this subsidy. Throughout the period of the analysis, price support programs have been in effect. This eliminates the problem of dealing with the market under conditions of support and non-support, but an awareness of the possible increased stability of the market must be maintained. In this study there was no attempt to take this into consideration. Although there were changes in farm policy in this thirteen year period, the policies did not entail a revamping of the general policy making it doubtful that much change in the attitude of farmers toward the expected prices developed.

The emphasis has been on price supports as a form of government agricultural programs, but there have also been acreage controls employed. Acreage controls may be more important than price supports for the haying machines. The acreage control programs reduce the production of the controlled commodities leaving the land available for lower economic uses resulting in increases in the production of hay and other related crops with a consequent increase in demand for forage harvesters and balers.

Purchaser's Liquid Asset and Equity Position

Liquid asset position of farmers is related to the income variable. As the general liquidity improves expenditures on new equipment is likely to increase, with possibly some lag occurring when farmers expect the economic climate to become less favorable toward themselves in the future. In this case an attempt may be made to increase liquidity until there is a change in expectations. When a higher liquidity position is achieved expectations are likely to rise and investment in capital goods will again increase. There is no variable in the analysis which takes liquidity position into consideration. Savings deposits in rural banks might possibly be used to approximate liquidity position of farmers. This would be only an approximation because of the many implicit assumptions. It assumes that farmers hold a given proportion of their assets in savings accounts; that they hold the more liquid part of their assets as savings; and that the level of the savings deposits fluctuates by some function of the actual level of liquidity.

Proprietors' equity is closely related to the liquid asset position of farmers, but was not used as a variable primarily because of lack of observations. Theoretically one would expect this variable to be important in estimating demand, but Z. Griliches[6] in his tractor study found that his "equity" variable contributed nothing beyond what was already contributed by the previously included variables. ("real price", rate of interest and the stock of tractors) Cromarty[7] used the asset

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[6]Griliches, op. cit., p. 4.

[7]Cromarty, op. cit., pp. 38-39.

position of farmers deflated by W.P.I. for all commodities, 1947-1949 = 100. In the equation for all farm machinery this variable was found to be significant. However, when asset position of farmers deflated by W.P.I. was used in the limited information procedure for all farm machinery the variable was not significant.

Specification of Behavioral Relations

In demand studies or any other studies using econometric models, the specification of the behavioral relations is the most difficult. Farmers' income and its relation to the quantity demanded is one behavioral relation; another is the planning horizon of farmers. Specification of the planning horizon is important because it facilitates the determination of the period that variables should be lagged if they should be lagged at all. It is possible that rather than lag income one year as was done in this study, a weighted average of the two prior years, or some other combination, should be used. A study comparing intended and actual tractor purchases by Michigan farmers in 1959 was made by K. T. Wright and W. H. Vincent[8] at Michigan State University. The general objectives of the

[8]Wright and Vincent, op. cit., p. 334.

study were to determine the number of farmers intending to make major capital investments in the coming year, the quarter of the year of the intended investment, the amount of the intended investment, and the strength of the intention to make the investment. Although this is not directly concerned with the length of planning horizons, some observations can be made from their data. Contrary to intuition and Friedman's[9] estimation of two and one half years, there seems to be evidence that for the purchase of a tractor--a machine of generally greater importance than any of the machines in the study--the planning period appears to be less than two years. Thirty-five percent of farmers who were "very certain" (made or making a deal) they would buy a tractor within the next year did not buy. Twenty-eight percent of the farmers who considered the probability to be considerably greater than fifty-fifty that they would buy, did not buy. And fourteen percent of farmers responding that there was "no chance" that they would buy a new tractor did buy one.[10]

In a survey by Parsons, Robinson and

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[9]Milton Friedman, A Theory of the Consumption Function (Princeton, New Jersey: Princeton University Press, 1957), p. 150.

[10]Wright and Vincent, op. cit., pp. 334-335.

Strickler[11] farmers were asked the number of years they expected to use specified pieces of machinery, and the authors of the survey noted that the answers tend to reflect attitudes at a particular time rather than firm commitments as to the future courses of action. Table 4-3 briefly summarizes the results of the survey.

Inventory Level of Machines

Inventory level at the farm, dealer and manufacturer level is very important where future shipments of machines are being predicted. The number of machines on farms has increased gradually since World War II. According to Parsons, Robinson and Strickler, "The inventory of machinery on farms has reached a high level. Apparently, the saturation level has been reached for some machines and a near-saturation level for others. The future market for farm machines will become more and more a replacement market rather than one that depends on the further building up of machine numbers on farms."[12] This indicates that inventories of manufacturers and retailers are an important determinant of the number of units to be shipped the following period by the manufacturers. Inventories at neither

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[11]Parsons, Robinson and Strickler, *op. cit.*, p. 27.

[12]Ibid., p. 1.

TABLE 4-3

USE EXPECTATION FOR SELECTED MACHINES
BY AGE OF MACHINE, 1956

Machine	Machines 6 years old and less, expected life		
	Percent less than 3 years	Percent 3 to 6 years	Percent 7 years or more
Grain Combine	17	48	35
Pick-up Baler	16	45	39
Field Forage Harvester	17	41	42

Source: M. S. Parsons, F. H. Robinson, and P. E. Strickler, Farm Machinery: Use, Depreciation, and Replacement, U.S.D.A. Statistical Bulletin No. 269, rows 4, 5, and 6 of TABLE 30, p. 36.

TABLE 4-3--<u>Continued</u>

Machines 7 to 11 years old, expected life			Machines 12 years old or more, expected life		
Percent less than 3 years	Percent 3 to 6 years	Percent 7 years or more	Percent less than 3 years	Percent 3 to 6 years	Percent 7 years or more
30	50	19	34	46	20
36	37	27	44	40	16
27	39	34	32	52	16

of these levels is available for the period of time over which this analysis was run. Since 1955, the U.S. Commerce Department has collected data of manufacturers' inventories, but there is no consistent data of the retailers' inventories over any of the period.

The prediction of expected sales of any one company will be unaffected by this lack of inventory data if the total expected sales can be predicted without these data. A single company, by knowing its own share of the market and any expected change in that share, can predict its own shipments in the future period.

The Used Machinery Market

Used machinery competes with new machinery in the market place, but the amount of competition offered by used machinery is difficult to evaluate. An index of the price of used machinery could possibly be developed to portray this relationship. An inverse relationship would be expected because the two are nearly perfect substitutes. In this study there was an attempt to find an effect of price of used equipment. The intent was to find if there was any particular year in which there was a particular model which had a relatively low or high price on the market. The supposition being that a model of low or high resale value would pull the average of the market down or up. All of the prices plotted formed very smooth curves over time which invalidated the supposition.

On the supply side of the used machinery market there has been no shortage in the last decade of this study. The average exodus of approximately one million persons annually from farms entails the consolidation of farms which usually adds to the supply of machinery because of closing-out sales. In addition to this source of supply, rapid advances in technology have created a high rate of obsolescence in the industry and, hence, a substantial addition to supply. The repercussions of obsolescence of equipment on the used machinery market in agriculture is less severe than in other industries where the range of technology in use varies much less at any given time. This variance in the state of technology has made the transportation of used equipment between regions of the United States (for example, Midwest to East) profitable over much of the time period in question.

The increase in the number of machines on farms is reflected in the decreased annual usage. The survey quoted earlier by Parsons, Robinson and Strickler shows a decrease in average annual use from 1941 to 1956. The average acres harvested by tractor-drawn pick-up balers fell 37 percent while average acres harvested with pull-type combines declined 52 percent.[13] Data regarding other machines of interest in this study were not available, but similar results would be expected as average use declined for all other machines included in the study.

The process of replacement of grain combines, pick-up balers and forage harvesters is characterized by a strong used machinery market. Of the combines (both self-propelled and pull-type) on farms January 1, 1956, 63 percent had been purchased new, while 68 percent[14] of balers and forage harvesters had been purchased new. As would be expected, farmers with large farms and mechanized units tend to buy more new machinery while small non-tractor farmers with small units tend to buy used equipment.

Replacement practices vary greatly depending on the intensity of use, rate of obsolescence, the type of machine, the variable costs of operating the machine, the differential between the value of the current machine and the price of the replacement and other factors. The useful life of the machine can

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[13] Ibid., Percentage calculations were made from Table 4, p. 7.

[14] Ibid., p. 32.

normally be extended by repairing worn parts and making adjustments so that under any set of circumstances the "average" life of the machine will be different. Parsons, Robinson and Strickler calculated the average useful life for a grain combine to be 11.7 years; the average life of a pick-up baler to be 7.9 years; and 9 years was the average life for the field forage harvesters.[15]

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[15] Ibid., p. 29.

CHAPTER V

SUMMARY AND CONCLUSIONS

Review of Purpose

The main objective of this study was to predict shipments of combines, pick-up balers and forage harvesters. This objective was satisfactorily achieved by some of the models. The results of the analysis will be compared with results of other studies for durable goods later in the chapter.

Problems in the Analysis

The demand for any input is derived from the demand for the product, the cost of the other inputs, and the production function. The demand for a durable input is a demand for a flow of services. It is the flow of services of the machines that enters the production function as an input, but what is being predicted is the number of machines purchased in a year, a flow of machines. Prediction of the number of machines to be produced next year was confronted with many problems in the analysis. The number of possible observations was limited to thirteen due to a lack of sufficient price and quantity data for the machines in the study. Each of the machines in the analysis is somewhat specialized and subject to sizeable random shocks; the latter making specification difficult. The data was subject to question since the inventory data was found to be inconsistent. These problems and others discussed in the text are one source of error in the analysis. Another source of error is the possible exclusion of relevant variables.

Relative Success of the Predicting Models

Considering the problems confronted, the results are still quite useful. The results are generally far superior to those using the naive model and compare favorably to other published results of demand studies for durables. The unadjusted coefficient of multiple determination, R^2, of the better models in this analysis were .928 for self-propelled combines, .721 for pull-type combines, .749 for pick-up balers, and .636 for forage harvesters. For comparative purposes these results can be compared with results of a series of essays concerned with the demand for various durable goods assembled by Arnold C. Harberger.[1]

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[1]Arnold C. Harberger, The Demand for Durable Goods (Chicago: University of Chicago Press, 1960.

Richard F. Muth reports in his essay that in studying the demand for non-farm housing he developed equations for two situations, one where a complete adjustment was assumed and the second one where partial adjustment was considered. The equation where complete adjustment was assumed yielded an R^2 of .448.[2] In the equation where the adjustment was not assumed complete in one year the R^2 was .621.[3] In later equations in which the dependent variable was lagged one year and treated as an independent variable an R^2 of about .95 was achieved.

The results of equations developed to predict the demand for household refrigeration by M. L. Burstein were exceptionally good. Using only price, income and trend as independent variables (not always using trend) Burstein's equations yielded R^2's greater than .96 [4] in nearly all the various equations.

Gregory C. Chow in studying the demand function for automobiles estimated the new purchases of automobiles per capita with three models yielding R^2 in the first model of .628, in the second model

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[2]<u>Ibid.</u>, p. 48.

[3]<u>Ibid.</u>, p. 49.

[4]<u>Ibid.</u>, pp. 110-119.

of .858 and .859 in the third.[5]

Evaluating the results of this study for four farm machines relative to other demand studies of durable items, this study compares favorably.

Suggestions for Further Study

Some changes in the models which might be investigated in future studies of these farm machines may further improve the overall results. The years 1956 and 1957 in the forage harvester model might be omitted from the analysis. The data for these two years omits a large segment of the forage harvesters--those with flail-type cutting devices. Another suggestion is with reference to the model for pull-type combines; years prior to 1950 and the years 1950 and later should be studied separately. Apparently the backlog of demand built up during World War II was still being satisfied during the early period. The satiation of the backlog of demand in conjunction with the shift from pull-type combines to self-propelled units from 1950 on has resulted in a falling demand for the units. For this reason, separation of the two periods would yield improved estimates.

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[5] *Ibid.*, pp. 161-162.

APPENDIX I

RESIDUALS

TABLE 1

RESIDUALS OF THE PREDICTING EQUATIONS[1]
(Units)

Year	Self-propelled combine	Pull-type combine	Pick-up baler	Forage harvester
1947	335	-25782	-9215	429
48	160	-8944	8139	-1029
49	-2145	20146	505	-4114
1950	1435	34154	-3178	2398
51	-814	14493	2918	3862
52	29	-10207	2458	-745
53	1651	1099	2353	1660
54	1925	-12241	-1509	1926
55	878	3234	15966	2976
56	-3862	-4443	-10223	-4218
57	-1634	906	-2520	-6787
58	1467	-7436	4720	2248
59	575	-4979	-10415	1396

Source: All columns computed from observed shipments minus the estimated shipments.

[1]Regression models used for prediction are equations 1-2, 2-2, 3-1 and 4-1 of Chapter III.

APPENDIX II

TIME SERIES USED IN THE ANALYSIS

TABLE 1

MANUFACTURERS' ANNUAL SHIPMENTS OF FARM MACHINES
(Units)

Year	Y_1 Self-propelled combines	Y_2 Pull-type combines	Y_3 Pick-up balers	Y_4 Forage harvesters
1947	5394	71506	76900	15596
48	9788	80611	90399	16394
49	13048	90108	103156	19139
1950	11255	104343	115598	24159
51	14122	92752	106874	25300
52	18449	63056	81505	29257
53	19695	58699	78394	31729
54	18147	39683	57830	23943
55	17609	43914	61523	26313
56	13646	30487	44133	21452
57	18187	30059	48246	14461
58	24993	22064	47057	23807
59	29566	14074	43640	27726

Source: U.S. Department of Commerce, "Farm Machines and Equipment" section of Facts for Industry series, TABLE - Summary of Production and Manufacturers' Shipments, annual issues 1947-1959.

TABLE 2

WHOLESALE PRICE INDEX OF MACHINES
(1947-49 = 100)

Year	X_1 Self-propelled combines	X_2 Pull-type combines	X_3 Pick-up balers	X_4 Forage harvesters
1947	91.8	87.9	91.9	89.4
48	101.3	102.2	100.8	102.2
49	106.9	110.0	102.3	108.4
1950	108.1	112.3	109.1	111.4
51	116.3	123.6	116.2	124.8
52	117.4	124.4	118.9	127.6
53	118.1	126.0	119.7	128.0
54	118.2	126.7	119.8	129.4
55	120.3	130.1	120.0	131.9
56	124.9	134.5	124.4	136.2
57	131.5	143.8	123.3	143.1
58	139.5	153.8	125.1	149.6
59	144.2	158.7	128.4	153.4

Source: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Index (1947-1949 = 100), Price and Price Relatives for Individual Commodities, Machinery and Motive Products.

TABLE 3

RELATIVE PRICES

Year	X_{11} W.P.I. pull-type combines divided by index of prices received	X_{13} W.P.I. balers divided by W.P.I. harvesters	X_{14} W.P.I. harvesters divided by W.P.I. balers
1947	.3185	1.0280	.9739
48	.3561	.9863	1.0139
49	.4400	.9899	1.0103
1950	.4353	.9794	1.0211
51	.4093	.9311	1.0740
52	.4319	.9318	1.0732
53	.4941	.9352	1.0693
54	.5150	.9258	1.0801
55	.5608	.9098	1.0992
56	.5848	.9134	1.0949
57	.6119	.8616	1.1606
58	.6152	.8362	1.1958
59	.6613	.8370	1.1947

Source: Col. 1 computed from Col. 2 of Table 2 divided by Col. 1, p. 123, Basic Economic Statistics, January 15, 1960. Col. 2 computed from Col. 3 of Table 2 over Col. 4 of Table 2. Col. 3 computed from Col. 4 of Table 2 over Col. 3 of Table 2.

TABLE 4

INCOME ORIGINATING IN AGRICULTURE
(Millions of Dollars)

Year	X_5 Cash receipts from food grains	X_6 Total net income of farm operators[1]	X_7 Cash receipts from beef and dairy[2]
1946	1841	15252	7470
47	2753	15544	8980
48	2629	17789	9674
49	2253	12926	8596
1950	1941	14000	9399
51	2004	16334	11278
52	2556	15337	10791
53	2456	13278	9258
54	2327	12691	9213
55	1991	11767	9396
56	2154	11617	9839
57	1861	11780	10618
58	2387	14017	11979

Source: Farm Income Situation, Tables 4, 13, 12, July 1960.

[1]Includes government payments.

[2]Computed from Table 12 Farm Income Situation, Col. 1 plus Col. 4, July, 1960.

TABLE 5

ANNUAL INVENTORIES OF MACHINES ON FARMS JANUARY 1
(Thousands of Units)

Year	X_8 Grain combines	X_9 Pick-up balers	X_{10} Forage harvesters
1947	465	65	30
48	535	90	45
49	620	135	60
1950	714	196	81
51	810	240	102
52	887	298	124
53	930	345	148
54	965	395	175
55	980	448	202
56	1000	505	225
57	1020	550	240
58	1040	580	253
59	1060	620	270

Source: *Balance Sheet of Agriculture*.

TABLE 6

BALERS AND HARVESTERS SCRAPPED AND ACRES OF CROPS PER FARM

Year	X_{12} Balers and harvesters scrapped (Units)	X_{15} Acres of crops per farm (Acres)
1947	12530	63.5
48	4936	65.1
49	9724	67.6
1950	16474	66.7
51	13103	68.8
52	33106	70.0
53	35216	71.5
54	10146	73.0
55	30922	74.1
56	25307	74.2
57	34269	73.9
58	39935	75.1
59	38572	78.4

Source: Col. 1 computed Col. 1 plus Col. 2, Table 5 plus Col. 4 of Table 1 minus the sum of next observation of Col. 1 and Col. 2 of Table 5.

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