11.

Machinery and Equipment

AS CHAPTERS 2 and 4 indicate, some of the major structural changes in agriculture have revolved around farm machinery. Machine capital not only has been a direct substitute for labor, but also the fixed costs associated with it provide cost advantages for larger units and create pressures for increased acreage per farm. Certainly a major portion of the decline in the agricultural labor force and in farm numbers must be attributed to mechanization. The process of mechanization is quantified as the demand for farm machinery.

On the surface it would appear that demand functions for machinery and farm labor might be easily and simultaneously specified through relative prices of the factors and change in technical coefficients. Quantification of labor and machinery demand relative to each other is difficult from time series data, however, because of multicollinearity in the several sets of relevant observations. Relative prices of labor and machinery, labor inputs of agriculture and mechanization are all highly intercorrelated through time.

In an aggregate sense, machinery also is a substitute for certain biological forms of capital. For example, more timely cultivation which controls weeds and increases yields is a substitute for weedicides. On an individual farm basis, mechanization is an economic complement with land inputs, due to the cost economies mentioned earlier. It is a technical complement with fuel and similar operating inputs. Again, however, because of the nature of the time series data, the exact relationships are not easily quantified.

The demand functions in the first part of this chapter largely represent an application of the investment concepts and models outlined in Chapter 10. The models outlined in the latter chapter are applied to all farm machinery, motor vehicles and machinery other than motor vehicles. Demand functions, following alternative models, then are presented for some specific categories of machines. The investment functions outlined in Chapter 10 are extended to include even broader aggregates of capital in Chapter 12.

THE DEMAND FOR ALL FARM MACHINERY

In this section the demand for all farm machinery is estimated by least-squares and limited information techniques, the function being specified in some detail in Chapter 10.

The Variables

The variables included in the least-squares demand equation are as follows:[1]

Q_{Mt} = the dependent variable and a weighted national aggregate of motor vehicle and other machinery purchases for the current calendar year. Quantities are weighted by 1935-39 prices prior to 1940 and by 1947-49 prices after 1940. Observations are in millions of 1947-49 dollars. Because the dependent variable roughly is a first difference of stocks, the statistical equations are estimated only in original values and logarithms of original values. The productive portion of machinery purchases (40 percent of automobiles) is included.

$(P_M/P_R)_t$ = the current year index of the ratio of the price of all farm machinery to prices received by farmers for crops and livestock.

$(P_M/P_H)_t$ = the current year index of the ratio of the price of all farm machinery to the hired labor wage rate.

S_{Mt} = the stock of productive farm machinery on January 1 of the current year in millions of 1947-49 dollars.

S_{Pt} = the total stock of productive assets in billions of 1947-49 dollars on January 1 of the current year including: real estate, machinery, livestock, feed, and cash held for productive purposes.

E_{t-1} = the past year ratio of proprietors' equities to total liabilities in agriculture.

Y_{Ft-1} = the net income of farm operators from farming during the past year, deflated by the index of prices paid by farmers for items used in production, including interest, taxes and wage rate. Net income includes cash receipts, government payments and nonmoney income less production expenses.

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[1]Sources of these and other time series variables in this study are in Tweeten, Luther G. An Economic Analysis of the Resource Structure of U.S. Agriculture. Unpublished Ph.D. Thesis. Library, Iowa State University. Ames. 1962.

Y_{DFt-1} = the declining three year arithmetic average of Y_F.

$$Y_{DFt-1} = \frac{3\ Y_{Ft-1} + 2\ Y_{Ft-2} + Y_{Ft-3}}{6}.$$

G_t = an index of government agricultural policies. Years when acreage allotments or production controls are in force are given the value -1. Years when farm prices are supported are assigned values of +1. If supports are fixed, an additional +1 is added. The values are summed to form the index G.

T = time, an index of the last two digits of the current year.

The price indices are expressed as a percent of the 1947-49 base, i.e. 1947-49 = 100. Variables are annual data for the United States from 1926 to 1959, excluding 1942 to 1947. The period is chosen to be long enough to allow variation in the variables and reasonably precise estimates of structural parameters. Since the variables are measured less accurately in earlier years, and since structural changes over extended periods cannot be accommodated in the models, observations prior to 1926 are not used. The years 1942 to 1947 are omitted because of farm machinery rationing during the period. During these years, explanatory variables in "true" demand structures would predict a higher demand quantity that it was possible to fill. Hence inclusion of data for these years when estimating structural relationships would result in biased parameter estimates. It can be argued that the demand structure had not returned to normal for several years following 1948. However, estimation of a function for years following (say) 1954 would not be possible.

Agricultural machinery has a low reservation price and marginal value productivity outside agriculture. Few opportunities exist to sell machinery during periods of farm depression to more prosperous sectors because the machinery is specialized to agriculture. Furthermore, severe income cycles in other sectors tend to be correlated with those of agriculture, further limiting the sale of surplus machinery. The maximum rate of decline in machinery stocks during an economic downswing largely is governed by the depreciation rates.[2] The limit on stock expansion is quite different, thus the optimum approach might include estimation of separate demand functions for expansion and depression periods. This procedure is not followed in this study because mechanization was only "well started" during the last major depression and sufficient time series observations are not available.

Structural changes which relate to farm machinery demand have been especially important since 1926. The quality and size of many

[2]The USDA estimate of average annual depreciation on all farm machinery is approximately 20 percent. This suggests potential for a comparatively rapid decline in machinery inputs with unfavorable prices. The above depreciation rate essentially is for accounting purposes, however, and machinery services as a farm resource decline less rapidly.

farm machines themselves have changed. A 1926 unit of machinery (e.g. tractor) is not strictly comparable to a 1959 unit, and it is not possible to compensate completely for quality change. Weighting quantities by prices partially compensates for this difference, because the improved unit of machinery is weighted by a higher price. The total number of machines may be the same, but the "quantity" weighted by prices may be greater if the improvement is reflected in the price.

The structure and magnitude of gross farm income have also changed greatly since 1926. Gross receipts are much greater because resources previously used to provide farm power (seed, feed, breeding stock, etc.) have been freed for sale. Substitution of nonfarm inputs has permitted greater farm product sales but also has added to cash costs. This structural change in income can be handled partly by use of net income rather than gross income as a variable relating to farmer capital position. Net income is included as a variable in the demand equations which follow to indicate the earning expectations and financial capabilities of farmers, measure farmers' expected return on durable resources and to correct for structural changes in farm income.

Least-Squares Demand Equations for All Machinery

Table 11.1 includes relevant statistics for machinery demand equations estimated by least squares. Some variables from the economic model presented in Chapter 10 are excluded either because they are insignificant (e.g., short-term interest rate) or because they are highly correlated with other variables (e.g., cropland per farm).

Only the coefficients of the variables $(P_M/P_R)_t$, E_{t-1} and T are significant in equation (11.1). The equation appears to indicate that lagged prices, S_p, G and the ratio of machinery and labor prices do not influence Q_M significantly. It should be remembered, however, that statistical complications (e.g., correlation among variables, observational errors, lack of variation in the data, etc.) may be important for the data under analysis. The relative prices of labor and machinery undoubtedly are influential in determining demand quantity of either resource.

To determine if both income and equity are important variables in the demand function, equation (11.2) includes both E and Y_F. The results indicate that either variable may be used. The inconsistent signs for E in the two expressions are caused by either the correlation between the income and equity variables or the inappropriateness of the

[3]Regressions were run including farm size (cropland per farm) and the short-term interest rate. The farm size variable was significant, the interest rate variable was not. The equations predicted about as well as those in Table 12.1 because the farm size variable is highly correlated with other explanatory variables.

logarithm transformation.[4] Hence, either income or equity (never both variables) is included in later equations. Since the logarithm transformation does not reflect the influence of E, equations involving this variable are estimated only in original values.

Equations (11.3) and (11.4) are estimated to determine the importance of wages in the demand for machinery without complications caused by other variables. Again the coefficients of wages are not significant, perhaps because machinery prices and wage rates have been highly correlated over time. The two equations also provide some basis for evaluating the relevance of current or past prices in the demand function. The magnitude and significance of the coefficient of the current variable P_M/P_R are greater, the R^2 is higher and the tendency for autocorrelation, indicated by d, is somewhat less evident in equation (11.4). While past prices are important, the influence of past values of P_R and resource prices tend to enter through the current price and income or equity variables. Equation (11.3) with only lagged values of the predetermined variables is useful, however, for predicting machinery purchases in the coming year since $(P_M/P_R)_t$ is unknown. Still, the prediction may be biased if, as equation (11.4) indicates, the current price is important. As a possible improvement over the results suggested by the above two equations, the ratio of current machinery price and lagged prices received by farmers, P_{Mt}/P_{Rt-1}, was included in a least-squares equation (not shown) with other explanatory variables, E and T. The magnitude and significance of the coefficient of the price variable P_{Mt}/P_{Rt-1} were lower than similar quantities in equation (11.5), and the modified price was rejected in favor of current price. (The current price ratio also represents some influence of past prices.)

The three variables in equation (11.5) explain 97 percent of the variation about the mean of Q_M, and the coefficients of each are highly significant. The test of the null hypothesis that the residuals are

[4] The simple correlation between Y_{Ft-1} and E_{t-1} in original values is -.87. The matrix of simple correlations between other specified variables in original values O and logarithms L is as follows:

		$(P_M/P_R)_t$	E_{t-1}	T	S_{Mt}
Q_{Mt}	O	-.48	.95	.80	.77
	L	-.54	.86	.75	.74
$(P_M/P_R)_t$	O	--	-.30	.05	-.08
	L	--	-.23	.10	-.09
E_{t-1}	O	--	--	.83	.81
	L	--	--	.89	.89
T	O	--	--	--	.91
	L	--	--	--	.89

The simple correlation between E and Q_M falls substantially when the variables are transformed to logarithms; thus the relationship between Q_M and E appears to be linear in original values. The insignificance of the coefficient of E in the logarithm equations is ascribed to a situation where the logarithm transformation is not appropriate. It should be noted that the time variable, T, is always in original values.

Table 11.1. Demand (Annual Gross Investment) for All Farm Machinery, Q_M, Estimated by Least Squares With U.S. Data From 1926 to 1959, Omitting 1942 to 1947; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Transformation and Model†	R^2	d‡	Constant	P_M/P_R t	P_M/P_R t-1	P_M/P_H t	P_M/P_H t-1	S_P t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_M t-1	S_M t
(11.1-O) B	.97	1.86	1954.30	-8.99	.83		-.70	-16.37	98.85					5.45	40.52		
				(1.59)	(2.36)		(1.63)	(11.73)	(33.02)					(6.64)	(11.97)		
(11.2-O) AB	.97	1.47	535.75	-7.66					100.99		.030				27.00		
				(1.32)					(27.62)		(.024)				(5.87)		
(11.2-L) AB	.97	1.77	2.27	-1.42					-.41		.81				.0218		
				(.17)					(.15)		(.17)				(.0028)		
(11.3-O) B	.92	1.23	188.94		-6.91		1.51		145.20						26.63		
					(2.90)		(1.96)		(36.83)						(12.60)		
(11.4-O) B	.97	1.38	766.78	-8.82		.41			126.01						27.45		
				(1.77)		(1.30)			(20.87)						(7.56)		
(11.5-O) B	.97	1.37	852.25	-8.41					124.60						25.99		
				(1.18)					(20.00)						(5.87)		
(11.6-O) A	.95	1.27	-111.99	-7.98							.092				42.63		
				(1.63)							(.022)				(4.94)		
(11.6-L) A	.96	1.22	2.94	-1.29							.57				.0156		
				(.18)							(.16)				(.0017)		
(11.7-O) A	.96	1.28	-191.26	-7.46							.056	.048			39.61		
				(1.46)							(.023)	(.018)			(4.54)		
(11.7-L) A	.96	1.26	3.01	-1.30							.59	-.034			.0157		
				(.19)							(.19)	(.144)			(.0018)		
(11.8-O) C	.97	1.29	-168.19	-7.57									.107		38.62		
				(1.26)									(.017)		(4.14)		
(11.8-L) C	.95	.98	3.87	-1.47									.42		.0167		
				(.19)									(.19)		(.0019)		
(11.9-O) BF	.97	1.43	771.38	-7.63					99.83						23.33	.15	
				(1.33)					(27.95)						(6.17)	(.12)	
(11.10-O) F	.96	1.41	109.92	-6.69							.056				31.39	.30	
				(1.58)							(.025)				(6.53)	(.12)	
(11.10-L) F	.96	1.19	2.98	-1.28							.53				.0153	.030	
				(.19)							(.23)				(.0021)	(.127)	
(11.11-O) BG	.97	1.57	760.25	-8.83					126.01						35.20		-.038
				(1.17)					(19.35)						(7.98)		(.023)

(11.12-O) G	.95	1.26	-122.34	-8.17			.091	45.36	-.0099
				(1.75)			(.022)	(9.69)	(.0300)
(11.12-L) G	.97	1.43	4.06	-1.41			.56	.0202	-.28
				(.18)			(.15)	(.0027)	(.13)
(11.13-O) H	.97	1.86	-648.85	-5.65	4.35	.045	.063	13.24	.46
				(2.10)	(2.22)	(.024)	(.025)	(7.72)	(.12)
(11.13-L) H	.98	2.04	-.61	-1.36	.85	.21	.70	.0072	.29
				(.29)	(.32)	(.20)	(.20)	(.0027)	(.13)

*Composition of the dependent variable, Q_M, and the indicated independent variables are discussed in the text.

† Equations estimated in original observations are designated by O; in logarithms of original observations by L. The time variable, T, is in original values in the L equations. Also $Y_{DF_{t-1}}$ in the logarithm equations is the logarithms of the simple declining arithmetic average. Expectation and adjustment models are presented in Chapter 10.

‡ The Durbin-Watson autocorrelation statistic d. Values near 2.0 indicate a random distribution of residuals, values less than 2 and approaching 0 indicate increasing positive autocorrelation, and values greater than 2 and approaching 4 indicate increasing negative autocorrelation. For probabilities see Friedman, Joan, and Foote, Richard J. Computational methods for handling systems of simultaneous equations. USDA Agr. Handbook 94. 1957.

uncorrelated is inconclusive. Model B, employing variable E which is a measure of farmers' financial position (and a proxy variable representing income expectations), apparently is one useful equation for expressing demand for farm machinery.

The remaining equations in Table 11.1 are included to evaluate the relevance of other distributed lag models. Equations (11.6) and (11.7) are model A (Chapter 10) with income lagged one and two years, respectively. While the logarithm transformation in (11.7) would indicate that income before the past year is not important in determining demand for machinery, the coefficient of Y_{Ft-2} in (11.7-O) is highly significant. The magnitudes of the lagged coefficients thus might indicate that incomes prior to the year t-2 also influence current demand. It seems appropriate to assume some structure of the coefficients permitting estimation of the lag with fewer variables. Equation (11.8), model C, is used where Y_{DFt-1} is a declining three year average of farm income. The coefficient of the variable is highly significant and is slightly larger than the combined coefficients of the two income variables in equation (11.7-O). The R^2 is increased by each additional income variable in equations (11.6-O), (11.7-O) and (11.8-O), and we select the last equation as "best" for prediction purposes.

Equations (11.1) to (11.8) essentially are expectation models. The appropriateness of the adjustment models F, G and H may be judged from equations (11.9) to (11.13). Equation (11.9) combines expectation model B and adjustment model F. The low significance of the coefficient of Q_{Mt-1} would suggest that farmers adjust purchases to the desired or equilibrium level in the short run if they are subjectively certain of favorable prices, income and other explanatory variables; and that the adjustment model is inappropriate for annual gross investment. Equation (11.10), however, indicates that if expectations are not adequately represented in the model, the adjustment coefficient may be significantly different from unity.

While annual machinery investment may be adjusted to the desired level in the short run, a long time may be required to reach the desired stock level. Thus, models B and G are combined to estimate the adjustment to the desired level of stocks (11.11). The coefficient of the lagged stock variable is not significant, suggesting that the adjustment coefficient, g, and depreciation rate, h, (see Chapter 10) are equal to each other. Since the depreciation rate is expected to lie somewhere between .14 and .25, the adjustment coefficient, g, is also expected to be within that range. Equation (11.12-L), however, indicates that the adjustment coefficient is somewhat larger.[5]

The R^2 is large and autocorrelation is not significant in the adjustment model H (equation 11.13). The positive sign of the past year price variable, $(P_M/P_R)_{t-1}$, does not appear reasonable, and the

[5] It is interesting to note that if g=h as indicated by (11.11) and (11.12-0), omission of lagged stock from the investment function causes few statistical complications (see model G, Chapter 10). Equations such as (11.5) and (11.8) then may serve as satisfactory expressions of machinery demand.

adjustment coefficient .54 in (11.13-O) is inconsistent with estimates of g in other equations.

The machinery demand models in Table 11.1 which assume net farm income to be an expectational variable appear appropriate in the equations estimated in original data. The logarithm equations, based on the R^2, d and a priori knowledge, give less acceptable coefficients. The more acceptable linear demand function is consistent with a quadratic production function (a linear marginal value productivity as in Chapter 6) for expressing physical relationships in agriculture.[6]

Limited Information Demand Equation for All Farm Machinery

Demand for all farm machinery, as part of an interdependent market structure with other farm resources and farm output, is now estimated by limited information. The result is:

$$(11.14)\quad Q_{Mt} = \underset{}{11907} - \underset{[-5.7]}{90.1\,P_{Ot}} - \underset{[-.3]}{5.0\,P_{Mt}} - \underset{[-2.9]}{59.2\,P_{Ht}} + \underset{[3.4]}{70.8\,P_{Rt}}$$
$$- \underset{[-4.3]}{113.9\,N_t} - \underset{[-.15]}{1.7\,(P_M/P_R)_{t-1}} + \underset{[.8]}{197.0\,E_{t-1}}$$
$$+ \underset{[2.8]}{66.3\,r_{S_{t-1}}} - 6.6\,T\ .$$

The demand quantity, Q_M, the number of farms, N, operating input price, P_O, machinery price, P_M, hired labor price, P_H, and farm output price, P_R, are endogenous variables. The equity ratio, E, short-term interest rate, r_S, time, T, and $(P_M/P_R)_{t-1}$ are predetermined variables. The variable, r_S, is coded as 100 times the short-term interest rate. Price variables are adjusted to a 1947-49 base and are deflated by the implicit deflator of the Gross National Product. The data extend from 1926 to 1959, omitting 1942 to 1945.[7] Standard errors were not computed. Elasticities, computed at the arithmetic mean of original observations for the 1926-59 period, are included in brackets below the coefficients of all variables except time, T, to aid in interpretation of the results.

[6] Some error may be introduced because the expectation variables are logarithms of simple arithmetic aggregates rather than the sum of logarithms in the "L" equations. Other specification and aggregation procedures might improve the comparability of the estimates from different transformations. The more favorable estimates from equations estimated from original data might result since the linear form may best approximate demand relationships in the particular period studied. Selection of a different period might reveal advantages of other transformations.

[7] Rather than sacrifice the data for 1946 and 1947 in the entire model because the backlog of demand for machinery had not been filled, the data for machinery are "corrected" for the condition by using predicted values of Q_M for 1946 and 1947 from a single-equation least-squares demand function estimated from data not including these years.

Table 11.2. Elasticities of Demand for Annual Investment in Machinery, Q_M, and for Machinery Stocks, S_M, With Respect to Price and Net Farm Income Computed From Selected Equations in Table 11.1*

Equation, Transformation and Model†	Elasticity of Q_M With Respect to:				Elasticity of S_M With Respect to:					
	P_M ‡		P_R		P_M			P_R		
	Short run (1-2 years)	Y_F §	Short run‡ (1-2 years)	Long run# (3-4 years)	Short run** (1-2 years)	Long run†† (many years)	Y_F	Short run** (1-2 years)	Intermediate run‡‡ (3-4 years)	Long run §§ (many years)
(11.5-O) B	-.79	.79	.79	2.37	-.18	-.90	.18	.18	.54	2.70
(11.8-O) C	-.71	.74	.71	2.19	-.16	-.80	.17	.16	.49	2.45
(11.8-L) C	-1.47	.42	1.47	2.31	-.33	-1.65	.10	.33	.52	2.60
(11.11-O) BG	-.83	.80	.83	2.43	-.19	-.95	.18	.19	.55	2.75

*See the text and Table 11.1 for discussion of data, methodology, coefficients, standard errors and related statistics.

† Elasticities for data in original values are computed at the full-period means.

‡ Computed from the coefficient of current price, $(P_M/P_R)_t$.

§ Computed from the sum of lagged income coefficients. The equity ratio, E, rather than income was included in equations (11.5) and (11.11). The coefficient of E was translated into elasticities with respect to Y_F by the least-squares regression

$$\text{(a)}\quad E_{t+1} = -5.57 + \underset{(.24)}{.71}\, Y_{Ft} + \underset{(.24)}{.86}\, Y_{DFt-1}, \qquad R^2 = .80$$

where E_{t+1} is the January 1 equity ratio, Y_F is net farm income and Y_{DF} is a declining three year average of Y_F. The variables are annual data in logarithms from 1926 to 1941 and 1946 to 1959.

The sum of the short-run elasticity plus the component P_R of Y_F, assumed to be twice the income elasticity based on the equation in text, footnote 9. For equation (11.8-O), the elasticity is .71 + (2.0)(.74) = 2.19.

**Found by multiplying the elasticity of Q_M with respect to $(P_M/P_R)_t$ by the ratio of mean of Q_M to S_M.

†† The short-run elasticity divided by the adjustment coefficient .20. The adjustment coefficient approximately is equal to the depreciation rate according to (11.11-O). The USDA estimated the machinery depreciation to be .19 percent of beginning year stocks for each of the six years from 1955 to 1960.

‡‡ Found by multiplying the ratio of means by the long-run elasticity of Q_M with respect to P_R. This is the approximate response in total stock after Q_M has been increased to the desired level.

§§ The intermediate-run elasticity divided by the assumed adjustment coefficient, as indicated in footnote ††. The long-run elasticity is the maximum level of stock achieved after an increase in P_R, and may not be reached for several years. If the adjustment coefficient is .20, approximately 90 percent of the total adjustment will be completed in 10 years.

The equation conforms with the least-squares functions in suggesting that the quantity demanded is more responsive to current price of machinery than to lagged price. The elasticity of machinery demand with respect to farm numbers, N, is -4, indicating that a 1 percent decrease in farm numbers tends to be associated with a 4 percent increase in machinery sales. We again run into difficulty with labor price, the P_H coefficient being negative and indicating labor and machinery to be short-run complements. The signs of the P_O and P_R coefficients are as expected, but the coefficients are unusually large.

Of predetermined variables, the coefficient of the equity ratio is larger than in the least-squares equation (11.5). The sum of P_M coefficients (-6.7) is slightly less in absolute value than the coefficient of price -8.4 in (11.5). The r_S and T coefficients in (11.14) conflict with a priori considerations possibly because the gradually changing r_S variable absorbed the influence of the time trend and vice versa. We conclude that the limited information equation, as we have specified it, is less acceptable than selected ones of our least-squares equations for expressing machinery demand.[8]

Price and Income Elasticities of Demand for All Machinery

Table 11.2 includes elasticities of demand for annual purchases, Q_M, and stock, S_M, with respect to prices and expected income for selected equations in Table 11.1. The elasticity of annual investment with respect to P_M or P_R approximately is unitary in the short run. The percentage increase in stock is less than one-fourth this amount because of the greater initial quantity. P_M essentially is a short-run variable and is not assumed to be a part of expectations, hence the elasticity of Q_M with respect to P_M is the same in the short and long run.

Because of the importance of P_R in Y_F, the long-run elasticity of Q_M with respect to P_R is greater than the short-run elasticity. Two equations are needed to translate E in equations (11.5) and (11.8) into P_R. The equations containing E but not Y_F can be translated by assuming that E is generated from past income. To determine the relationship between income and equity, the following least-squares equation (11.15) was computed from logarithms of annual data extending from 1926 to 1941 and 1946 to 1959.

[8] The limited information equation may be less satisfactory than selected least-squares equations because of the nature of the identification process. Those equations in the simultaneous model which are of greatest interest tend to be specified in detail. Equations of least interest tend to be specified less fully. But the conditions for identification indicate that the tendency for underidentification is most likely to be found in the equations including the greatest number of variables (most adequately specified). Unwittingly, the researcher gets less satisfactory results from the equations in which he has greatest interest because of a tendency for underidentification. Also, some difficulties undoubtedly arise because of multicollinearity when many variables are specified in the equation. Some variables were omitted, of course, to reduce collinearities in the matrix of predetermined variables of the reduced-form equations.

(11.15) $$E_{t+1} = -5.57 + \underset{(.24)}{.71}Y_{Ft} + \underset{(.24)}{.86}Y_{DFt-1}, \quad R^2 = .80$$

Equity is estimated as a function of net income Y_F and a declining average of net income Y_{DF}. The equation indicates that a sustained rise of 1 percent in net income will increase the equity ratio 1.57 percent. Since the elasticity of Q_M with respect to E in (11.5) is .50, the elasticity with respect to Y_F is approximately (.50) (1.57) = .79. The result is similar to the results of (11.8-O) in which income was directly included. The implication is that model B provides a relevant proxy variable for net income in the investment function.

A definitional equation used to relate net income to P_R/P_P provided a basis for translating net income into prices. The estimated elasticity of net income with respect to P_R/P_P is 2.0.[9] Therefore the elasticity of Q_M with respect to P_R computed from the income component of (11.5) is approximately (2.0) (.79) = 1.58. The total long-run elasticity of Q_M with respect to P_R is therefore .79 (due to P_M/P_R) plus 1.58 (due to E), or 2.37. The result agrees favorably with the estimates of other equations and indicates that a 1 percent increase in P_R tends to raise annual investment slightly more than 2 percent in the long run. Some disparity exists between the original value and logarithm equations in allocating the influence of P_R in P_M/P_R and Y_F. Since the logarithm equation tends to allocate more influence to P_M/P_R and less to Y_F, the short-run elasticity is greater in equation (11.8-L), but the long-run elasticities are surprisingly similar between transformations.

Once the desired level of annual purchases is reached, the stock of machinery continues to grow until gross investment equals depreciation. The maximum (long-run) level of stocks is reached much later than the maximum (long-run) level of annual investment. The estimates of stock elasticities in Table 11.2 are computed basically from the annual investment elasticities. The ratio of the investment mean to the stock mean was multiplied by the annual investment elasticities to form the short-run and intermediate-run stock elasticities. The long-run elasticity is based on equations (11.11-O) and (11.12-O), which indicate that the adjustment and depreciation rates are approximately

[9] The definitional equation relating net income, Y_F, to prices paid, P_P, and prices received, P_R, by farmers for the specified period is

$$Y_{Ft} = K + \underset{\substack{(13)\\ [1.66]}}{174}(P_R/P_P)_{1910-25} + \underset{\substack{(15)\\ [1.68]}}{192}(P_R/P_P)_{1926-41} + \underset{\substack{(12)\\ [1.99]}}{211}(P_R/P_P)_{1946-59}$$

$$d = 1.91 \qquad R^2 = .94$$

where K refers to the constant and other variables such as technology in the equation. Based on the equation, estimated from 1910-59 untransformed observations (excluding 1942-45), the marginal response of net income to a given price change is increasing over time. The average elasticity, in brackets, was 1.66 for 1910-25 and 1.99 for 1946-59. For further details see Tweeten, op. cit., Appendix B.

equal. From prior knowledge of the depreciation rate, the adjustment rate is assumed to be .20. Results in Table 11.2 suggest that stock is relatively unresponsive to changes in price in the short and intermediate run, a 1 percent rise in prices received, P_R, tending to raise stock only by one-fifth of 1 percent in the first one or two years. However, in several years stock may be increased between 2 and 3 percent.[10] The length of time required to reach this percentage depends on the adjustment rate. Because prices received by farmers fluctuate more extremely than machinery prices, a major portion of the past variation in investment activity is associated with farm output price, P_R.

Cromarty's least-squares estimates of short-run demand elasticities for machinery purchases with respect to P_M is -1.0, P_R is .7.[11] His results agree quite closely with those of this study. Cromarty makes no estimate of long-run elasticities, but if we use the above estimate to translate income elasticity to price elasticity, the long-run elasticity of annual purchases with respect to P_R is .7 plus (2.0) (.5) = 1.7. His study also includes farm assets as an explanatory variable, and if the P_R influence on assets is included, the total elasticity might be very near the estimates of this study.

Trends and Projections in All Machinery Purchases

Figure 11.1, showing actual and predicted values of annual farm machinery purchases, illustrates the wide variations which have taken place in purchases. The pattern reflects especially the importance of relative machinery and farm product prices and net farm income. Machinery purchases are much more sensitive than operating input purchases (see Chapter 13) to changes in prices received by farmers. Machinery purchases fell sharply in the depression years and again in 1938 when farm output prices dropped appreciably and farm machinery prices remained highly constant. Improved machinery, new models, favorable prices and other factors undoubtedly contributed to the large amount of purchases in the late 1940's. As the backlog of machinery orders was filled and farm income declined, demand for machinery fell rapidly in the 1950's. Based on actual observations, the downward

[10] The number of years, N, required for a specified proportion, A, of total adjustment, given the adjustment rate, g, is

$$N = \frac{\log (1-A)}{\log (1-g)} .$$

If A = .9, g = .2, then N = 10. That is, 10 years are required to make 90 percent of the adjustment to the equilibrium level of machinery stock. The number of years required for the adjustment of stock is conservative because the formula assumes the annual investment is at the equilibrium level. Because three or four years are required for annual investment to reach this level, an adjustment may be made in the time required to reach the equilibrium level of stock by adding two or three years to N above.

[11] Cromarty, William A. The demand for farm machinery and tractors. Michigan Agr. Exp. Sta. Bul. 275. East Lansing. 1959. p. 40.

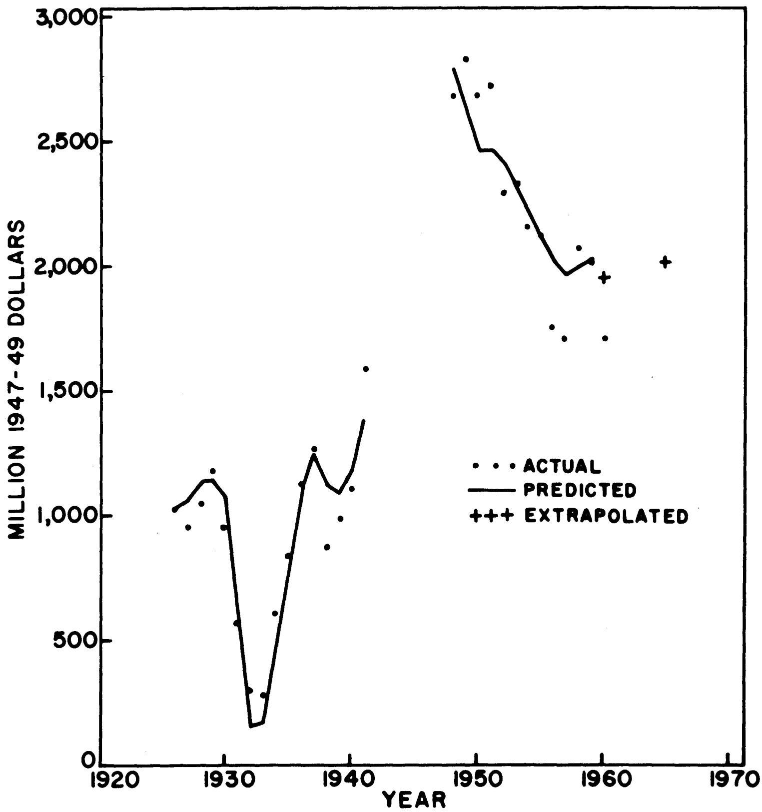

Figure 11.1. Trends in purchases of all farm machinery Q_M from 1926 to 1960 (predicted and projected estimates from equation 11.8-O).

trend in machinery demand, during the postwar era analyzed, showed few signs of reversal.

Although (11.8-O) appears, statistically, to be one of the better predicting models, our ex post comparisons show that it errs quite extremely in periods of rapid downturn in demand. As an example, the extrapolated value for 1960 considerably overestimates the actual quantity (a preliminary estimate).

Machinery purchases, projected for 1965 from (11.8-O), depend on the assumed future values of the major independent variables, prices and net farm income. The projected estimate is based on net income at the 1955-59 average value. Relative price P_M/P_R has increased 10 percent in the five years preceding 1960, and also is assumed to increase the same percentage from 1960 to 1965. The projected purchases, approximately 2 billion 1947-49 dollars, are slightly greater than the predicted 1960 value. At current depreciation rates, nearly 2 billion 1947-49 dollars gross investment is required to maintain existing stock. Thus, the projected gross investment is consistent with a projection of no appreciable change in stock level for 1965.

The projections imply (based mainly on technological and other influences reflected in the time variable) that the downward postwar trend in purchases will not continue. The extent to which the projections are realized depends on the structural validity of the equation and also on the prices received by farmers, the most volatile element in the price and income variables.

Limited Information Supply Estimate for All Farm Machinery

The decoded supply equation for all farm machinery paralleling (11.14) is

(11.16) $$P_{Mt} = -18.75 + \underset{(.0084)}{.0218}\ Q_{Mt} + \underset{(.27)}{.93}\ P_{ISt} - \underset{(.17)}{.32}\ C_t$$

where P_M is defined previously, P_{IS} is the wholesale price of iron and steel and C is a structural variable with a value of zero in each prewar year and 100 in each postwar year. Prices are deflated by the general price deflator of the Gross National Product, with the base 1947-49 = 100. The period analyzed again is 1926-59 with 1942-45 excluded.[12]

The computed price elasticity of machinery supply is 2.92. The coefficient of Q_M is more than twice the standard error (in parentheses) and probably is not equal to zero. The coefficient indicates the price flexibility, and if it is near zero the supply elasticity is very large. The approximate confidence limits for price elasticity, computed from the inverse of two standard deviations on each side of the price flexibility coefficient, are 1.8 to 4.1. The estimate indicates that the short-run elasticity of machinery supply is high, but not infinite. In an earlier, slightly modified and less acceptable structural model containing the same variables as in equation (11.16) but with actual rather than predicted values of Q_M for 1946 and 1947, the coefficient of Q_M was smaller than the standard error, a result consistent with the hypothesis that machinery supply is perfectly elastic. Although equation (11.16) indicates supply is not infinitely elastic, price is suggested to be relatively unresponsive to quantity changes in the short run.

The quantitative estimates are consistent with the discussion in Chapter 3; that is, the low supply elasticity for labor (Chapters 8 and 9) and high supply elasticity for machinery are a basis for low labor returns in agriculture.

The conclusion that farmers are price takers (quantity a function of price) and manufacturers are price setters (price a function of quantity)

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[12] To adjust for the latent demand in 1946 and 1947, values of Q_M predicted by a least-squares equation, estimated without the two years, were used as observations in the simultaneous model for 1946 and 1947.

Table 11.3. Demand (Annual Gross Investment) Functions for Motor Vehicles, Q_{MV}, Estimated by Least Squares With U.S. Data From 1926 to 1959, Omitting 1942 to 1947; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Transformation and Model †	R^2	d‡	Constant	P_{MV}/P_R t	P_{MV}/P_R t-1	P_{MV}/P_H t	P_{MV}/P_H t-1	S_p t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_{MV} t-1
(11.17-O) B	.95	2.16	1332.91	-5.77	.95		-.04	-14.39	60.17					2.82	27.38	
				(1.21)	(1.78)		(1.28)	(8.71)	(23.43)					(4.71)	(8.96)	
(11.18-O) AB	.93	1.57	335.94	-4.33					56.36		.015				15.31	
				(1.09)					(21.48)		(.19)				(4.73)	
(11.18-L) AB	.93	1.52	2.33	-1.15					-.23		.59				.0189	
				(.21)					(.19)		(.22)				(.0037)	
(11.19-O) B	.88	1.39	-27.09		-3.97		1.68		91.21						14.40	
					(2.03)		(1.33)		(23.41)						(8.43)	
(11.20-O) B	.94	1.64	235.61	-6.11		1.35			72.62						19.39	
				(1.40)		(1.00)			(15.20)						(5.68)	
(11.21-O) B	.93	1.51	490.84	-4.72					68.66						14.87	
				(.97)					(15.17)						(4.67)	
(11.22-O) A	.91	1.43	-24.51	-4.55							.050				24.15	
				(1.21)							(.015)				(3.71)	
(11.22-L) A	.92	1.43	2.77	-1.08							.44				.0153	
				(.21)							(.18)				(.0021)	
(11.23-O) A	.93	1.46	-63.32	-4.25							.030	.026			22.40	
				(1.16)							(.017)	(.013)			(3.61)	
(11.23-L) A	.93	1.47	2.88	-1.09							.48	.059			.0155	
				(.22)							(.21)	(.165)			(.0022)	
(11.24-O) C	.93	1.47	-51.38	-4.31									.058		21.90	
				(1.04)									(.013)		(3.40)	
(11.24-L) C	.92	1.28	3.51	-1.22									.32		.0164	
				(.21)									(.20)		(.0023)	
(11.25-O) BF	.93	1.61	458.87	-4.41					61.18						13.70	.095
				(1.11)					(19.79)						(5.12)	(.159)
(11.26-O) F	.92	1.64	37.46	-3.92							.037				19.31	.22
				(1.26)							(.018)				(5.12)	(.16)
(11.26-L) F	.93	1.41	2.72	-1.12							.54				.0163	-.098
				(.22)							(.25)				(.0027)	(.167)
(11.27-L) H	.95	2.30	-.64	-1.17	.73					.25	.71				.0085	.11
				(.35)	(.38)					(.24)	(.24)				(.0033)	(.17)

*Composition of the dependent variable, Q_{MV}, and the indicated independent variables are discussed in the text.

†Equations estimated in original observations are designated by O; in logarithms of original observations by L. The time variable, T, is in original values in the L equations. Also, Y_{DFt-1} in the logarithm equations is the logarithm of the simple declining arithmetic average. Expectation and adjustment models are presented in Chapter 10.

‡The Durbin-Watson autocorrelation statistic d (see Table 11.1).

should not necessarily be inferred because we normalize on quantity in (11.14) and on price in (11.16). The limited information coefficients are independent of the direction of normalization, and the results would have been the same for the equations normalized on other endogenous variables.

The coefficient of P_{IS} indicates that a 1 percent increase in iron and steel price is predicted to raise machinery price 1 percent (11.16). The variable reflects the price of iron and steel, but also includes the effects of wage rates correlated with P_{IS}.

DEMAND FOR MOTOR VEHICLES ESTIMATED BY LEAST SQUARES

The specification of the demand function for motor vehicles is similar to the previous model for all farm machinery. The logic of the specification is similar to that discussed previously in this chapter and in Chapter 10. Variables included in demand functions for motor vehicles are:

Q_{MVt} = the dependent variable, a weighted two-price aggregate of motor vehicle purchases during the current calendar year expressed in millions of 1947-49 dollars. The variable, including tractors, trucks and the productive portion of automobile purchases (assumed to be 40 percent), is weighted as discussed in the previous section on all farm machinery.

$(P_{MV}/P_R)_t$ = the current year index of the ratio of prices paid by farmers for motor vehicles to prices received by farmers for crops and livestock.

$(P_{MV}/P_H)_t$ = the current year index of the ratio of prices paid by farmers for motor vehicles to the hired labor wage rate on farms.

The remaining variables specified in the demand function (S_p, E, Y_F, Y_{DF}, G and T) are discussed in the previous section on all farm machinery. Variables are annual data for the period 1926-59, with 1942-47 excluded and 1947-49 = 100 for price indices.

The Estimated Demand Equations

Coefficients, standard errors and related statistics for motor vehicle demand equations presented in Table 11.3 are similar to the results in Table 11.1. The price of motor vehicles relative to prices received in the current year, equity or income, and time appear to be the uniformly significant variables in the numerous equations estimated.

Equation (11.18) indicates that either income or equity, but not both variables, needs to be specified in a given demand equation. The three coefficients in equation (11.21-O) are all highly significant. The coefficients of G and P_{MV}/P_H in equations (11.17), (11.19) and (11.20) do not suggest that farm wage rates and government programs, as measured here, have played significant roles in the rising demand for farm machinery.

The additional lagged values of net income, in equations (11.22-O), (11.23-O) and (11.24-O), show the sum of income coefficients to increase from .050 to .056 to .058 as successive income variables are included in the respective equations. Increments in the magnitude of the coefficients and R^2 suggest that additional lags beyond t-3 might improve the equation very little.

One conclusion from Table 11.3 is that gross annual investment in productive motor vehicles might be expressed simply by the current price, $(P_{MV}/P_R)_t$, time, T, and by one or more variables such as E or Y_F expressing financial or income structure in the demand function. However, inconsistencies exist between equations estimated in original values and in logarithms. While each is an acceptable form and the degree of autocorrelation is not high in either, those estimated in original values more clearly reflect the influence of past income on motor vehicle purchases.

A demand equation, not included, was estimated with Q_{MV} a function of current price, past year income, cropland per farm, the short-term interest rate and time. The coefficient of the short-term interest rate was highly insignificant; the coefficient of the farm size variable was significant and negative. Because farm size is highly correlated with other variables, did not improve the R^2 appreciably and raises questions about the direction of causality, the variable was not retained in the equation. Current year machinery prices may be known and current year prices received unknown when machines are purchased. Accordingly, the ratio of <u>current</u> machinery price to <u>past</u> year prices received was included in the demand equation with other explanatory variables, E and T. This price variable was considered inferior to current price and was not retained in subsequent equations.

Price and Income Elasticities of Demand for Motor Vehicles

Demand elasticities for motor vehicles, Q_{MV}, are slightly lower but similar to those for all machinery in Table 11.2. Based on equations (11.23-O) and (11.24-O), the price elasticity of demand computed at the means for the entire period with respect to $(P_{MV}/P_R)_t$ is -.64. The demand elasticity with respect to Y_F computed from the same equations is .66. Using a definitional equation (see footnote 9) to translate income to price elasticity, the elasticity of Q_{MV} with respect to P_P is -(2.0) (.66) = -1.32, and with respect to P_R is .64 plus 1.32, or 2.0 in the long run. Similarly, the respective total elasticities of Q_{MV}

with respect to P_{MV}, P_P and P_R from equation (11.23-L) are -1.1, -.84 and 1.9. It appears that the instability in relative magnitudes of the price and income elasticities between the original value and logarithm equations may arise from the importance of P_R in the variables. The logarithm equation indicates a heavier weight for current price, the original value equations a heavier weight for income (past price). But the total long-run elasticity of Q_{MV} with respect to P_R is approximately 2.0 for both forms.

Because mean annual purchases are approximately one-fourth of the mean stock of motor vehicles, the percent increase in stock from a 1 percent increase in P_{MV}/P_R is (.25) (-.64) = -.16 based on equations (11.23-O) and (11.24-O). The elasticity of stock at the time (three or four years) when annual purchases have reached the desired level is referred to as the intermediate elasticity of stock. It is approximately (.25) (2.0) = .5 with respect to P_R according to the above equations. If we assume the adjustment coefficient is .2, the long-run elasticity of stock with respect to P_R is .5/.2 = 2.5. If .2 is the correct adjustment rate, approximately 10 years are required to make 90 percent of the adjustment to the long-run level of stock. The 1 percent increase in P_R is assumed to be sustained at the same value throughout the entire period, of course.

Trends and Projections of Motor Vehicle Purchases

The purchases of motor vehicles fell appreciably in the depression years, in 1938, and after the postwar high (Figure 11.2). In the immediate postwar years, farmers spent more than twice as much for motor vehicles as in 1940. The demand quantity in the postwar years began a downward trend that continued through the period analyzed. In some recent years, annual investment has been below the 1941 level.

Equation (11.24-O) is used for the "ex post predictions" in Figure 11.2. The extrapolated quantity for 1960 overestimates demand by a sizeable amount. The prediction error, larger than expected from normal sampling variation, may stem from failure to account for recent structural changes in the demand function.

Motor vehicle prices increased approximately 10 percent in the five years preceding 1960. Using a price ratio, P_{MV}/P_R, 10 percent above the 1960 price and net income at the 1955-59 average, the 1965 projected quantity is slightly greater than the predicted 1960 quantity. The 1965 projection is approximately the level of purchases required to maintain the 1960 stock of machinery, assuming the past 21 percent depreciation rate. Again the projections depend heavily on the underlying price and income assumptions. The projection quantity for 1965 is nearly the same as the predicted 1960 quantity because increasing relative price, depressing Q_{MV}, tends to compensate for increases in demand through improvements in vehicle quality and other factors embodied in the positive coefficient of T. Other values of prices and

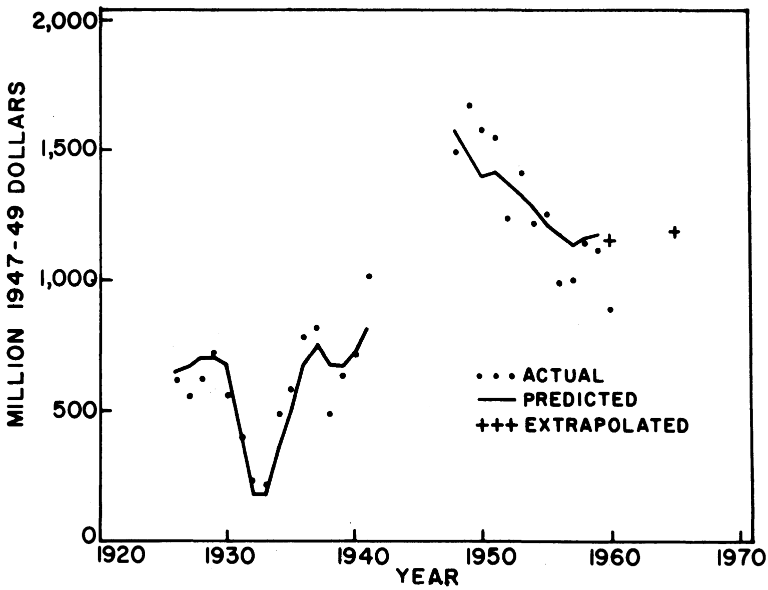

Figure 11.2. Trends in purchases of motor vehicles Q_{MV} from 1926 to 1960 (predicted and projected estimates from equation 11.24-O).

income would provide different projections. No estimate is made of the standard error for 1965 projections, but it is expected to be large for extrapolations several years in advance.

MACHINERY AND EQUIPMENT DEMAND FUNCTIONS ESTIMATED BY LEAST SQUARES

Using parallel models to those above, we now estimate demand functions for machinery and equipment. Machinery and equipment, as defined here, includes all farm machinery other than motor vehicles. Items ranging from milking machines to combines are included in the category. Variables included in the functions are:

Q_{MEt} = the dependent variable, a weighted two-price aggregate of farm machinery and equipment purchases during the current calendar year for productive purposes, expressed in millions of 1947-49 dollars. The variable includes planting, harvesting and tillage machines, farm wagons, sprayers, gas and electric engines, dairy machines and haying equipment; it excludes motor vehicles.

$(P_{ME}/P_R)_t$ = the current year index of the ratio of prices paid by farmers for machinery and equipment to prices received by farmers for crops and livestock.

$(P_{ME}/P_H)_t$ = the current year index of the ratio of machinery and equipment prices to the composite farm wage rate.

National aggregate data for the years 1926 to 1959, with 1942-47 excluded, are used with 1947-49 = 100 for price indices. Other variables (stock of productive assets, S_p, the equity ratio, E, net farm income, Y_F, government programs, G, and time, T) specified in the demand functions are defined in previous sections.

Estimated Demand Equations

Results of the estimated demand equations for machinery and equipment presented in Table 11.4 are similar to those in Tables 11.1 and 11.3. R^2's in Table 11.4 generally are greater than those in Table 11.3, and the adjustment coefficients in equations (11.36) and (11.37) suggest that about 70 percent of the shift to the equilibrium position for machinery and equipment purchases is made in the short run. The results in Table 11.4 thus support the same adjustment conclusions as Table 11.1 and Table 11.3: If farmers are subjectively certain that prices and financial circumstances are favorable, they are not severely restrained by institutional, psychological or technological barriers in making a rapid adjustment to desired annual investment levels. The adjustment to the desired level of stock may require considerable time despite the rapid adjustment of annual purchases, however.

Price and Income Elasticities of Demand for Farm Machinery and Equipment

Equations (11.34-O) and (11.35-O) indicate that the elasticity of demand for farm machinery other than motor vehicles with respect to $(P_{ME}/P_R)_t$ is -.75. The total elasticity with respect to income computed from the same equations is approximately .86. Assuming that a 1 percent rise in $(P_R/P_P)_t$ increases net income by 2 percent (see footnote 9), the long-run elasticity of Q_{ME} is -1.50 with respect to P_P, and .75 plus 1.50, or 2.25, with respect to P_R. Similar computations with equation (11.34-L) indicate an elasticity of Q_{ME} is -1.55 with respect to the price variable P_{ME}, -(2.0)(.86) = -1.72 with respect to P_P, and 1.55 plus 1.72, or 3.3, with respect to P_R (long run). (The elasticities from equations estimated in original observations are calculated at the means of the variables.) Using the average of these estimates, a sustained 1 percent increase in prices received by farmers is expected to increase machinery and equipment purchases slightly more than 1 percent in the short run, and nearly 3 percent in the long run.

The elasticities of machinery and equipment stock may be approximated from the above elasticities. Since, on the average, annual purchases are one-fifth of machinery and equipment stock, the short-run

Table 11.4. Demand (Annual Gross Investment) Functions for Farm Machinery and Equipment Other Than Motor Vehicles, Q_{ME}, Estimated by Least Squares With U.S. Data From 1926 to 1959, Omitting 1942 to 1947; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Transformation and Model†	R^2	d‡	Constant	P_{ME}/P_R t	P_{ME}/P_R t-1	P_{ME}/P_H t	P_{ME}/P_H t-1	S_P t	E t-1	Y_F t	Y_F t-1	Y_F t-2	Y_{DF} t-1	G t	T	Q_{ME} t-1
(11.28-O) B	.97	1.25	692.73	-3.32	.14		-.77	-3.67	38.82					2.95	14.61	
				(.68)	(1.10)		(.97)	(7.57)	(15.10)					(2.86)	(5.92)	
(11.29-O) AB	.97	1.25	191.64	-3.11					47.59		.014				10.96	
				(.54)					(12.16)		(.011)				(2.46)	
(11.29-L) AB	.96	1.90	.91	-1.81					-.69		1.28				.0254	
				(.25)					(.22)		(.24)				(.0038)	
(11.30-O) B	.94	1.29	173.26		-3.22		.38		55.82						12.18	
					(1.02)		(.71)		(14.97)						(4.34)	
(11.31-O) B	.97	1.23	433.73	-2.94		-.58			56.12						9.04	
				(.63)		(.49)			(8.94)						(2.68)	
(11.32-O) B	.97	1.18	346.25	-3.45					58.17						10.37	
				(.47)					(8.84)						(2.45)	
(11.33-O) A	.95	1.10	-121.88	-3.19							.044				18.18	
				(.68)							(.010)				(2.07)	
(11.33-L) A	.95	.90	1.87	-1.56							.29				.0151	
				(.28)							(.25)				(.0022)	
(11.34-O) A	.96	1.02	-161.47	-2.98							.027	.0224			16.91	
				(.61)							(.011)	(.0080)			(1.88)	
(11.34-L) A	.95	.83	1.75	-1.55							.86	.060			.0149	
				(.29)							(.28)	(.212)			(.0024)	
(11.35-O) C	.97	1.04	-147.18	-3.04									.0504		16.43	
				(.52)									(.0077)		(1.71)	
(11.35-L) C	.93	.58	3.15	-1.81									.69		.0161	
				(.29)									(.28)		(.0026)	
(11.36-O) BF	.97	1.35	305.48	-3.01					36.91						9.13	.26
				(.48)					(12.50)						(2.33)	(.11)
(11.37-O) F	.97	1.37	79.16	-2.69							.019				12.04	.39
				(.57)							(.011)				(2.38)	(.11)
(11.37-L) F	.96	.65	3.26	-1.52							.36				.0127	.28
				(.25)							(.31)				(.0023)	(.12)
(11.38-L) H	.98	1.14	-2.20	-1.46	1.06					.47	.60				.0038	.51
				(.37)	(.37)					(.25)	(.27)				(.0028)	(.11)

*Composition of the dependent variable, Q_{ME}, and of the indicated independent variables are discussed in the text.

† Equations estimated in original observations are designated by O; in logarithms of original observations by L. The time variable, T, is in original values in the L equations. Also, $Y_{DF t-1}$ in the logarithm equations is the logarithm of the simple declining arithmetic average net farm income. Expectation and adjustment models are presented in Chapter 10.

‡ The Durbin-Watson autocorrelation statistic d (see Table 11.1).

estimated elasticity of stock with respect to P_{ME}/P_R is (.2) (-.75) = -.15 based on equations (11.34-O) and (11.35-O). Since the adjustment rate and ratio between annual purchases and stock are assumed to be nearly equal for machinery and equipment, the long-run elasticity for stock and annual investment with respect to P_R are the same magnitude, or 2.25. But the "long run" for Q_{ME} is three or four years, whereas only about 90 percent of the adjustment to the "long run" of stock is made in 10 years (assuming the adjustment coefficient is .2). The adjustment coefficient .2 is based on the equations in Table 11.1. The long-run elasticity of stock is particularly sensitive to the magnitude of the adjustment coefficient.[13]

Trends and Projections of Farm Machinery and Equipment Purchases

The trend in machinery and equipment purchases, shown in Figure 11.3, is similar to the trend in motor vehicle purchases. The quantities appear to follow a somewhat more uniform trend in Figure 11.3, and there appear to be stronger signs of a reversal of the postwar decline in purchases. Equation (11.35-O) estimates the actual quantities somewhat better than those used for illustrations in previous sections.

Assuming prices 10 percent above the 1960 level and net farm

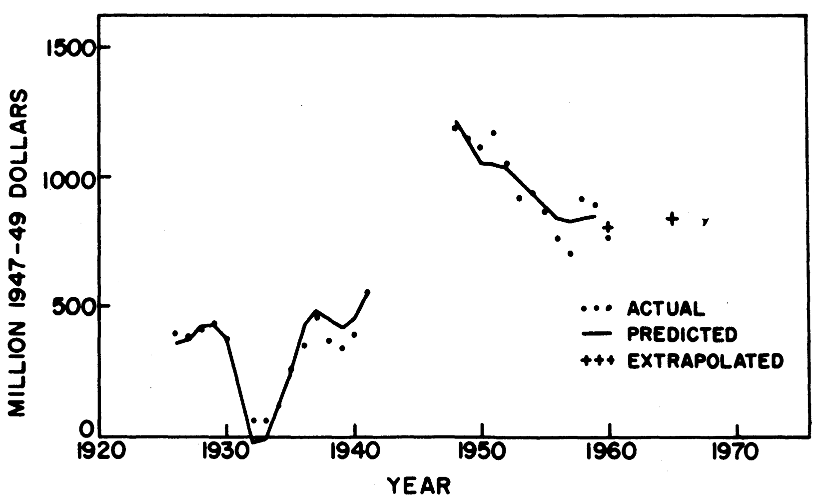

Figure 11.3. Trends in purchases of farm machinery other than motor vehicles from 1926 to 1960 (predicted and projected estimates from equation 11.35-O).

[13] We again emphasize that difficulty exists in obtaining an accurate estimate of the coefficient. The influence of other variables correlated with stock is confounded in the coefficient of the lagged stock variable. The reader may wish to consider the magnitude of the elasticity under alternative assumptions about the value of the adjustment coefficient.

income at the 1955-59 value, 1965 purchases of machinery and equipment are projected to be slightly above the predicted 1960 level.

The assumption that net income will remain at the 1955-59 level may be overly optimistic. It essentially is based on the assumption that demand for farm products will expand uniformly with farm output, and leave P_R unchanged. Gross receipts, however, are expected to be greater because more units of output will be marketed. Furthermore, farms will become more efficient, producing more output with the same or fewer resources. These tendencies to increase income may be offset by increased input prices and greater reliance on purchased inputs.

SHIFTS IN MACHINERY DEMAND

Shifts in demand for all machinery, Q_M, motor vehicles, Q_{MV}, and machinery other than motor vehicles, Q_{ME}, are similar. Hence, only the results for Q_M are discussed in detail in this section. Changes which have occurred in demand for machinery depend on the parameters of the demand functions as well as on the relative shifts in prices, income and other relevant variables. The standard partial regression coefficients indicate the relative impact that variables can have on the demand quantity, Q_M. These respective coefficients for the price, farm income and time variables computed from equation (11.8-O) are -1.4, 1.5 and 2.2. These coefficients indicate that the "slowly changing influences" represented by the time variable are potentially important in determining the demand quantity. The magnitudes of the other influences are sizeable also, and if historic trends in the price or income variables are large, either one could be responsible for a greater portion of the change in Q_M than the time variable.

Actual purchases (constant 1947-49 dollars) of all farm machinery increased 109 percent since 1926, or at an average compound rate of 2.25 percent per year. Equation (11.5-O) provides a basis for investigating the sources of the increase. Real machinery price (P_M/P_R) was over 60 percent greater in 1959 than in 1926. (More important, perhaps, machinery price declined relative to labor price over this period.) If other variables had been at 1926 values but P_M/P_R had been at the 1959 value in 1926, the demand quantity would have been 54 percent below the actual 1926 purchases according to equation (11.5-O). The more than 100 percent increase in demand for machinery during the 33-year period can hardly be attributed to a falling price of machinery relative to prices received.

Equation (11.5-O) suggests that machinery purchases would have been 60 percent greater in 1926 if farmers had experienced the financial or equity position present in 1959, *ceteris paribus*. More efficient methods of production, substitution of cheap operating inputs for farm labor and horsepower, improved management and inflation permitted a slight increase in net farm income and a considerable improvement in the equity of farmers from 1926 to 1959 despite the rise in the ratio

P_M/P_R. An "accelerator" influence may be evident, since adoption of machinery in early years partially was responsible for farmers' increased efficiency and improved financial position that permitted greater machinery purchases in later years.

A major source of the increased machinery demand evidently has been structural changes represented by the time variable. The two "economic" categories (a) price and (b) earnings or equity, nearly offset one another, leaving "structure" to explain almost the entire shift in machinery demand since 1926. Perhaps most important of the structural changes embodied in the time variable is the continuous improvement in the quality and adaptability of machinery. (This is less true, however, for shorter periods.) Concurrent with these improvements has been the increased awareness by farmers of the returns and convenience from using improved machinery. Of course, it is well to remember that the structural and financial categories are not entirely independent.

If the supply of farm machinery were not highly elastic and if a small increase in farm demand had brought sharp machinery price increases, farm mechanization undoubtedly would have progressed less rapidly. The fact that manufacturers have made farm machines available in quantities, and of the quality desired by farmers, has been an important element helping to explain the rapid growth of farm machinery stock. In turn, the rising stock of farm machinery and substitution of machinery for farm produced power has been a significant element in the rising farm labor efficiency.

DEMAND FOR INDIVIDUAL FARM MACHINES

We now estimate demand equations for individual farm machines by single-equation least squares. This analysis is made for specific machinery categories to circumvent some of the aggregation and technical considerations involved in the preceding classes. Estimates for individual machines also involve difficulties such as imperfect price series for each item, changes in quality of machine resources and special problems in intercorrelation among the price and quantity series being analyzed. The data are not adequate for estimating separate demand functions for large numbers of machines; only the functions for farm trucks, tractors and automobiles are presented.

Least-Squares Demand Equations for Farm Trucks

Variables included in the demand equations for farm trucks are the following:

Q_{Tkt} = the dependent variable, a price-weighted aggregate of farm truck purchases during the current calendar year in million 1947-49 dollars.

Table 11.5. Demand Functions for Farm Trucks Estimated by Least Squares With U.S. Data From 1926 to 1960, Excluding 1942 to 1948; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Dependent Variable and Model†	R^2	d‡	Constant	P_{Tk}/P_R t	Y_{DF} t-1	E t-1	T (1926-41)	T (1949-60)	T (1926-60)	S_{Tk} t
(11.39) Q_{Tk} C	.92	.910	-87	-1.60 (.42)	.0196 (.0045)				7.93 (1.21)	
(11.40) Q_{Tk} C	.94	1.072	86	-1.42 (.38)	.0156 (.0043)		3.01 (2.12)	5.36 (1.44)		
(11.41) Q_{Tk} B	.96	1.441	103	-1.55 (.28)		29.91 (3.92)			3.92 (1.19)	
(11.42) Q_{Tk} B	.96	1.433	136	-1.53 (.29)		27.81 (4.99)	3.05 (1.73)	3.64 (1.27)		
(11.43) ΔS_{Tk} CI	.63	.842	-192	-1.33 (.42)	.0184 (.0049)				9.50 (2.73)	-.245 (.058)
(11.44) ΔS_{Tk} CI	.79	1.120	-87	-1.39 (.33)	.0191 (.0038)		9.32 (2.12)	14.35 (2.44)		-.490 (.076)
(11.45) ΔS_{Tk} BI	.82	1.611	-74	-1.45 (.28)		32.74 (4.47)			8.72 (1.88)	-.330 (.044)
(11.46) ΔS_{Tk} BI	.86	1.841	-79	-1.54 (.26)		29.70 (4.30)	8.59 (1.73)	11.09 (2.01)		-.433 (.060)

*Variables are defined in the text.

†Expectation and adjustment models are presented in Chapter 10.

‡The Durbin-Watson d statistic (see Table 11.1).

S_{Tkt} = the stock of farm trucks on January 1 of the current year, in million 1947-49 dollars.

ΔS_{Tk} = a second dependent variable, $S_{Tkt+1} - S_{Tkt}$.

$(P_{Tk}/P_R)_t$ = an index of the current year ratio of prices paid by farmers for new trucks to prices received by farmers for crops and livestock (1947-49 = 100).

Other variables in the demand function are defined previously. All data are original (untransformed) observations for the United States from 1926 to 1960, excluding 1942 to 1948.

The highly significant coefficients of all variables in (11.39) and (11.41), Table 11.5, suggest that models B and C are structurally relevant for truck demand as well as for all motor vehicles (Table 11.3). The value of R^2 and the autocorrelation statistic d indicate certain advantages for including the equity ratio E rather than past net income in the demand functions for farm trucks.

Equations (11.43) to (11.46) are estimated with first differences of stock rather than gross investment as the dependent variable to obtain more accurate estimates of the influence of explanatory variables on truck stock. Based on the magnitudes of the R^2's, the independent variables predict net investment, ΔS_{Tk}, less accurately than gross investment, Q_{Tk}. Again, (11.45) and (11.46) with E display advantages based on the R^2 and d over (11.43) and (11.44) with Y_{DF}. The average adjustment rate (coefficient of S_{Tk}) is approximately .3, indicating that 6 to 7 years are required to make 90 percent of the adjustment to the desired level of stock after a change in price, income or equity.

The failure of previous equations to predict accurately in recent years implies that structural changes in demand may have occurred. To accommodate this possible structural change, (11.40) and (11.42) are estimated with separate time variables for the prewar and postwar periods, allowing a test of the null hypothesis that the trends in the two periods are equal. The similarity of the coefficients of the two trend variables in (11.42) provides little basis for rejecting the null hypothesis. The differences in trend coefficients in (11.40), (11.44) and (11.46) were not tested statistically, but the results suggest an increase in the coefficients in the postwar years. These results are surprising because of the decline in truck purchases in recent years (see Figure 11.4) and are consistent with the hypothesis that the postwar trend in truck purchases is explained by price, income and equity variables rather than by technological and other influences embodied in the time variable.

Inclusion of variables representing farm size, liquid assets and the short-term interest rate in the demand functions did not improve the results. Also estimates using truck numbers rather than a value aggregate as the dependent variable were less satisfactory.

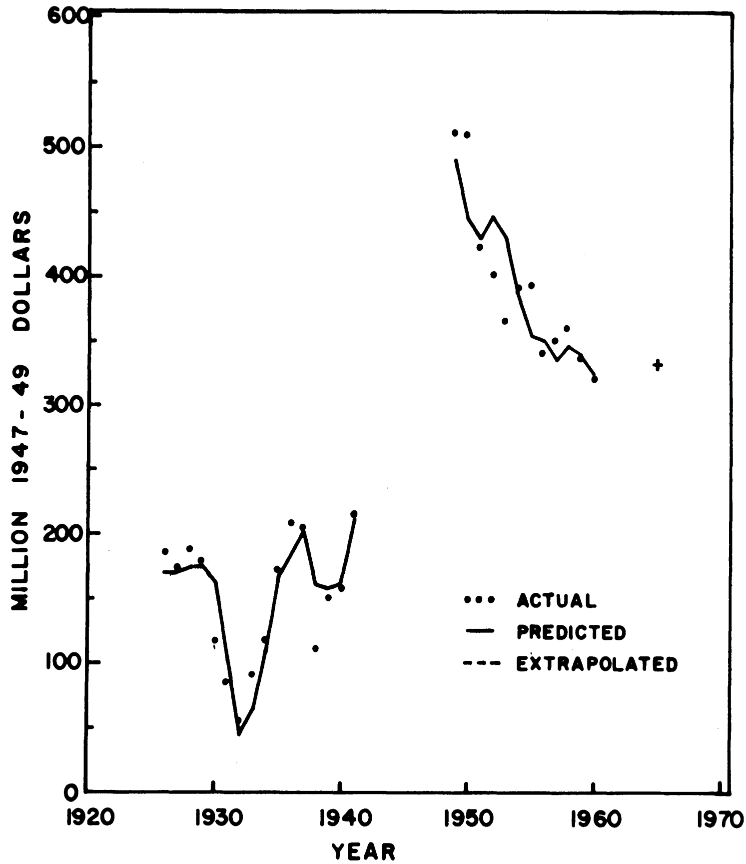

Figure 11.4. Trends in purchases of farm trucks from 1926 to 1960 (predicted and extrapolated estimates from equation 11.41).

Price and Income Elasticity of Demand for Farm Trucks

Computed at the 1926-60 mean from equation (11.39), the elasticity of Q_{Tk} is -.77 with respect to P_{Tk}/P_R, and .79 with respect to Y_{DF}. The long-run elasticity with respect to P_R is approximately -.77 + (2.0)(.79) or 2.3. A sustained 1 percent increase in P_R is predicted to raise annual truck purchases about 1 percent in one or two years and some over 2 percent in three or four years based on (11.39).

The elasticity of S_{Tk} with respect to P_{Tk}/P_R is -.19 and with respect to Y_{DF} is .22, according to (11.43). Based on the estimated adjustment coefficient .245 and the component of P_R in Y_{DF}, a once-for-all rise of 1 percent in prices received by farmers is expected to increase S_{Tk} .2 percent in one or two years, .6 percent in three or four years and 2.5 percent in eight years. These estimates, computed from (11.43) at the mean for the entire period, would differ if 1960 means were used.

Cromarty estimated the number of new truck shipments as a function of price P_{Tk}/P_R, net income and other variables.[14] Based on a least-squares equation estimated with data from 1920 to 1955, omitting 1942-50, he predicted the short-run elasticity of truck demand with respect to price to be -.3; with respect to net income to be .6. These estimates are for demand at the wholesale level, those of this study for demand at the retail level, and hence are not strictly comparable.

Trends and Projections

Purchases of trucks were at a considerably higher level in the postwar than in the prewar period. The downward postwar trend showed signs of reversal from 1956 to 1958, but 1959 and 1960 purchases were again in line with the postwar decline (Figure 11.4). Unlike the earlier predictions for all farm machinery, equation (11.41) accurately predicts the actual 1959 and 1960 observations. Based on 1955-59 average net income and a 10 percent increase in P_{Tk}/P_R over the 1960 value (the price increased 11 percent in the five years preceding 1960), the 1965 projected purchase of farm trucks is 337 million 1947-49 dollars. Since approximately 350 million dollars gross investment is required to meet replacement demand at the current 24 percent depreciation rate, the projection suggests that truck stock may decline somewhat from the current level.

Least-Squares Demand Equations for Farm Tractors

The following variables are specified in the demand function for tractors:

Q_{Trt} = the dependent variable, a price-weighted aggregate of tractor purchases during the current calendar year, in million 1947-49 dollars.

S_{Trt} = the stock of all tractors on farms on January 1 of the current year, in million 1947-49 dollars.

ΔS_{Trt} = a second dependent variable, $S_{Trt+1} - S_{Trt}$.

$(P_{Tr}/P_R)_t$ = an index of the current year ratio of prices paid by farmers for new tractors (30-39 horsepower) to prices received for crops and livestock.

$(P'_{Tr}/P_R)_t$ = an index of the current year ratio of wholesale prices for

[14] Cromarty, William A. The market for farm trucks. Michigan Agr. Exp. Sta. Tech. Bul. 271. East Lansing. 1959.

Table 11.6. Demand Functions for Farm Tractors Estimated by Least Squares With U.S. Data From 1935 to 1960, Omitting 1942 to 1947; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Dependent Variable and Model†	R^2	d‡	Constant	P'_{Tr}/P_R t	P_{Tr}/P_R t	Y_{DF} t-1	E t-1	A t-1	T (1935-41)	T (1948-60)	T (1935-60)	S_{Tr} t
(11.47) Q_{Tr} C	.89	1.70	316		-3.26	.0255					6.63	
					(.81)	(.0074)					(1.96)	
(11.48) Q_{Tr} C	.89	2.09	868	-1.67		.0258					-8.32	
				(.42)		(.0075)					(3.48)	
(11.49) Q_{Tr} C	.92	1.81	1020		-3.17	.0177		-32.47			37.86	
					(.70)	(.0071)		(12.48)			(12.12)	
(11.50) Q_{Tr} B	.91	1.68	1288		-2.86		19.30	-38.94			41.48	
					(.90)		(9.80)	(12.47)			(12.59)	
(11.51) Q_{Tr} C	.93	1.87	771		-3.49	.0207		-27.89	38.23	36.54		
					(1.01)	(.0099)		(16.35)	(12.48)	(12.80)		
(11.52) Q_{Tr} B	.92	1.73	1001		-3.09		25.40	-33.81	41.73	39.54		
					(1.05)		(16.73)	(17.04)	(12.95)	(13.61)		
(11.53) ΔS_{Tr} CI	.91	2.47	789		-2.95	.0183		-26.42	30.70	28.08		-.089
					(.90)	(.0090)		(14.77)	(11.17)	(11.48)		(.051)
(11.54) ΔS_{Tr} BI	.91	2.36	813		-2.57		28.07	-28.08	32.44	27.97		-.081
					(.89)		(14.18)	(14.51)	(11.05)	(11.66)		(.050)

*Variables are defined in the text.
†Expectation and adjustment models are presented in Chapter 10.
‡The Durbin-Watson d statistic (see Table 11.1).

tractors per horsepower unit to prices received by farmers.[15]

A_{t-1} = cropland acres per farm in the past year.

The equity ratio, E, time, T, and net income, Y_{DF}, variables are defined previously. The variables are U.S. data from 1935 to 1960, omitting 1942 to 1947. Adequate price data were not available prior to 1935, and the war and immediate postwar period was excluded because of a different structure of demand.

The coefficients of the variables in (11.47), Table 11.6, are highly significant and display the signs theoretically anticipated. The price variable in (11.48), the wholesale price per unit of horsepower, is also corrected for improvements such as rubber tires; electric and hydraulic systems. The coefficient is highly significant but the magnitude is somewhat less than that of the more "hybrid" price variable in the foregoing equation. It would also be desirable to correct the quantity Q_{Tr} for changes in quality, but data are not adequate for this refinement.

Inclusion of farm size A in (11.49) improves the fit of the equation and increases the coefficient of T. Farm size and other variables correlated with T influence Q_{Tr} in opposite ways, and the net influence moved the coefficient of the trend variable toward zero in (11.47) and (11.48).

Similar coefficients of the separate time variables in (11.51) and (11.52) support the hypothesis that structural influences represented by T have shifted tractor demand at the same rate in the prewar and postwar years.

Equations (11.53) and (11.54), with net investment ΔS_{Tr} the dependent variable, display slightly higher d values and slightly smaller (absolute value) coefficients than comparable equations (11.51) and (11.52). The adjustment coefficient is .09 according to (11.53); however, additional equations (not included) estimated without A and with a single T variable indicated the adjustment coefficient is approximately .13.

The results in Table 11.6 consistently indicate a negative relationship between farm size and tractor purchases. Of the categories of machinery examined, only the tractor demand function is considered to be "improved" by inclusion of A when price, income or equity, and time variables are adequately specified. This result is consistent with theory since tractors represent major discrete input units, and farmers often are able to profitably expand machinery investment only by expanding acreage. Greater output has been possible in recent years despite declining gross investment in tractors (see Figure 11.5) because larger farms allow existing tractors to be used more efficiently. According to Table 11.6, tractor purchases Q_{Tr} may decline up to 4

[15] Based on the John Deere B, 50, 520, 530, 3010 series. See: Facts about John Deere tractor wholesale prices in the United States, 1935-1961. Deere and Company. Moline, Illinois. 1961.

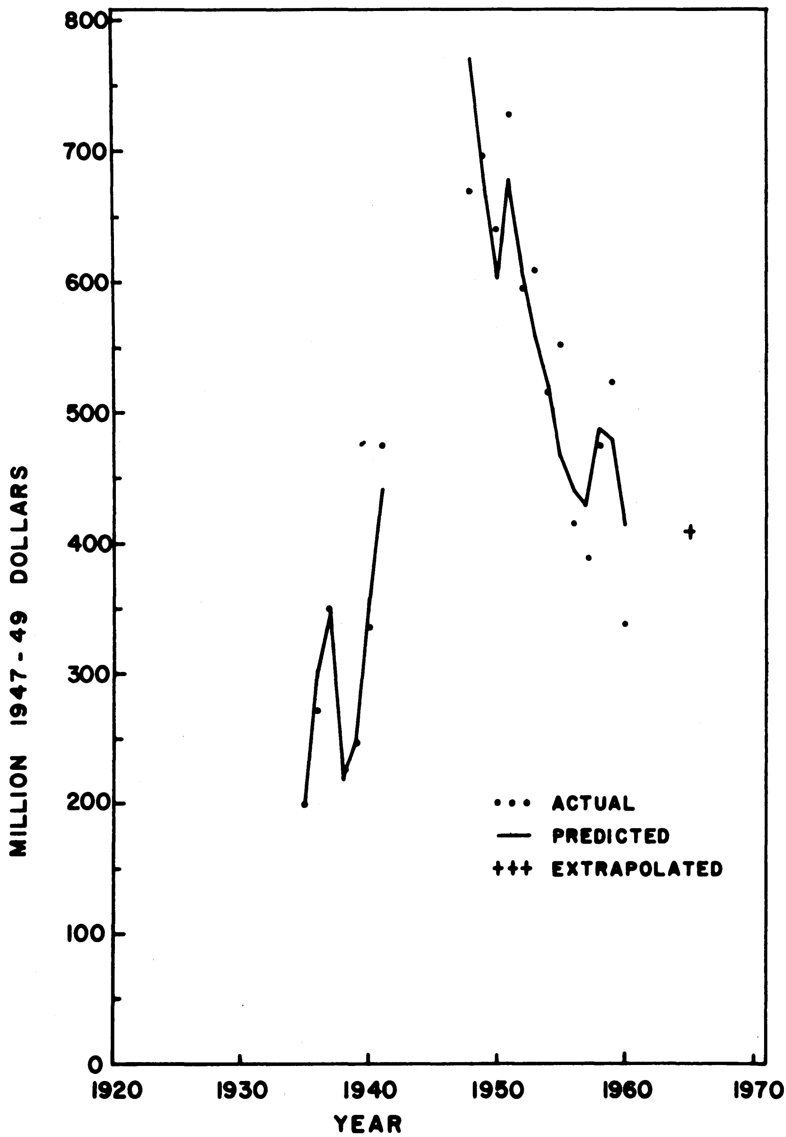

Figure 11.5. Trends in purchases of farm tractors from 1935 to 1960 (predicted and projected estimates from equation 11.51).

percent and stock, S_{Tr}, 1 percent by expanding farm size 1 percent. The results apply primarily to a short period; in the long run, machinery can be substituted for labor on larger farms and the net influence of farm size on tractor demand is less clear. Inclusion of the farm size variable introduces the question: Does an increase in farm size decrease machinery demand or does a decrease in machinery demand increase farm size? A joint causal structure dictates a simultaneous system such as (11.14) and suggests that the monocausal relationships including A in Table 11.6 be interpreted cautiously.

Price and Income Elasticity of Demand for Farm Tractors

The elasticity of Q_{Tr} with respect to P_{Tr}/P_R is -1.1, based on (11.51) and using means for the 1935-60 period. With respect to Y_{DF}, the elasticity is .52. The results indicate that if P_R increases 10 percent and remains at that level, tractor purchases will increase 10 percent in one or two years, and 21 percent in about four years.

The predicted elasticity of stock from (11.53) is -.25 with respect to P_{Tr}/P_R and .12 with respect to Y_{DF}. The results suggest that a 1 percent once-for-all rise in P_R tends to increase S_{Tr} .25 percent in one or two years, .5 percent in four years and up to 5 percent in roughly 20 years. Twenty-eight and 16 years respectively are required to make 90 percent of the equilibrium adjustment, with adjustment coefficients of .08 to .13.

Cromarty estimated the elasticity of tractor shipments to be -.5 to -.7 with respect to P_{Tr}/P_R and .2 to .4 with respect to net cash receipts.[16] Some reasons his estimates are lower than those in this study are: (a) he included an asset variable which contains elements of P_R not included in elasticity estimates, and (b) his estimates are for wholesale shipments of tractors rather than for farm purchases.

Trends and Projections

Purchases of farm tractors dropped markedly in 1938, then increased sharply to 1941 (Figure 11.5). The high demand quantity, 700 million dollars in 1951, was followed by a general decline to 340 million 1947-49 dollars in 1960. Because equation (11.51) predicted more accurately than others over the entire period, it is selected to depict the actual observations. However, it is apparent that inclusion of farm size A and separate time variables to account for recent structure changes did not prevent a sizeable prediction error in 1960.

For the 1965 projection, we assume farm size will continue to increase at the current rate and be 6 percent greater in 1965 than in 1960. Using a price, P_{Tr}/P_R, 10 percent above the 1960 level, and 1955-59 average net farm income, the 1965 demand quantity is projected from (11.51) to be 417 million 1947-49 dollars. This is less than the estimated 485 million dollars required to maintain the 1960 tractor stock, assuming a 21 percent depreciation rate.

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[16] Cromarty, William A. The demand for farm machinery and tractors. Michigan Agr. Exp. Sta. Bul. 275. East Lansing. 1959.

Table 11.7. Demand Functions for Farm Autos (as Production Durables) Estimated by Least Squares With U.S. Data From 1926 to 1960, Excluding 1942 to 1948; Including Coefficients, Standard Errors (in Parentheses) and Related Statistics*

Equation, Dependent Variable and Model†	R^2	d‡	Constant	P_A/P_R t	Y_{DF} t-1	E t-1	S_L t	T (1926-41)	T (1949-60)	T (1926-60)	S_A t
(11.55) Q_A C	.61	2.25	222	-2.11 (1.62)	.061 (.016)					1.08 (4.52)	
(11.56) Q_A C	.66	2.28	607	-2.68 (1.58)	.030 (.023)		56.3 (31.3)			-13.32 (9.10)	
(11.57) Q_A B	.60	2.15	788	-3.01 (1.54)		71.82 (19.09)				-5.28 (5.98)	
(11.58) Q_A B	.65	2.20	888	-3.20 (1.48)		31.50 (29.16)	59.41 (33.48)			-16.50 (8.53)	
(11.59) ΔS_A CI	.68	2.28	328	-3.39 (1.87)	.039 (.021)			17.26 (9.66)	22.22 (7.95)		-.434 (.100)
(11.60) ΔS BI	.70	2.69	417	-3.50 (1.72)		71.57 (31.40)		14.28 (9.40)	14.23 (9.10)		-.380 (.102)

*Variables are defined in the text.
†For expectation and adjustment models, see Chapter 10.
‡The Durbin-Watson d statistic (see Table 11.1).

Least-Squares Demand Equations for Farm Autos

Automobiles, more than other durables discussed above, embody characteristics of a consumption good. The USDA estimates that 60 percent of automobile purchases are identified with the farm consumption rather than production sector. It is not possible to determine the actual, or even the intended, purpose of auto purchases and therefore the classification necessarily must be arbitrary. Yet the specification of demand depends on the sector with which car sales and use is identified. The procedure in this section is first to specify the demand for autos as a production good, using substantially the same specification as above for other farm machinery. In a second formulation treating cars as consumption goods, we estimate a per capita demand equation with the demand quantity a function of prices and income deflated by prices paid by farmers for items used in living (consumption).

Variables not defined previously are as follows:

Q_{At} = a price-weighted aggregate of automobile purchases for all purposes by farmers during the current year, in million 1947-49 dollars. (Q'_A denotes purchases per capita where the farm population is the unrevised, higher estimate discussed in Chapter 18.)

S_{At} = the stock of farm autos on January 1 of the current year, in million 1947-49 dollars (S'_A is per capita stock).

ΔS_{At} = $S_{At+1} - S_{At}$.

$(P_A / P_c)_t$ = a current year index of the ratio of auto price to prices paid by farmers for items used in living (consumption).

Y'_{DFt-1} = a declining three year average of past net farm income per capita, deflated by P_c (constructed similarly to Y_{DF} discussed previously).

S_{Lt} = January 1 stock of liquid farm assets, including bank deposits and currency, savings bonds and investment in cooperatives, deflated by prices paid by farmers for items used in production, including interest, taxes and wage rates. S'_{Lt} is liquid assets per capita, deflated by P_c .

The above variables and equity, E, and time, T, discussed earlier are national aggregates for 1926 to 1960, omitting 1941 to 1948. The "prime" notation refers to quantities or income per capita, and all equations are linear in original observations.

Demand Equations for Autos as Production Durables

As expected, the adjustment and expectation models depict demand for automobiles (Table 11.7) less successfully than for other durables discussed earlier. The coefficient of Y_{DF} is highly significant;

Table 11.8. Per Capita Demand Functions for Farm Autos (as Consumption Durables) Estimated by Least Squares With U.S. Data From 1926 to 1960, Omitting 1942 to 1948, 1952, 1953; Including Coefficients, Standard Errors (in Parentheses), etc.*

Equation, Dependent Variable and Model †	R^2	Constant	P_A/P_c t	Y'_{DF} t-1	E t-1	S'_L t	T (1926-41)	T (1949-60)	T (1926-60)	S'_A t
(11.61) Q'_A C	.82	7.23	-.13 (.12)	.079 (.012)					-.0072 (.1956)	
(11.62) Q'_A C	.85	15.49	-.14 (.14)	.053 (.021)		.41 (.27)			-.11 (.28)	-.103 (.065)
(11.63) $\Delta S'_A$ CI	.82	-.98	-.23 (.15)	.036 (.023)		.60 (.29)			.76 (.30)	-.462 (.070)
(11.64) $\Delta S'_A$ CI	.83	3.23	-.20 (.15)	.046 (.019)			.83 (.28)	1.20 (.26)		-.431 (.062)
(11.65) $\Delta S'_A$ BI	.82	8.21	-.20 (.15)		2.74 (1.21)		.60 (.30)	.84 (.37)		-.341 (.084)

*The variables are discussed in the text.
†See Chapter 10 for expectation and adjustment models.

however, the coefficient of time is nonsignificant and that of price is significant only at the 80 percent (90 percent with one-tailed test) probability level in (11.55). Inclusion of liquid assets, S_L, in (11.56) raises the R^2 and significance of the T coefficient. The variable "competes" with other financial variables, E and Y_{DF}, and lowers the magnitude and significance of these variables according to the first four equations.

The R^2's, though still low, are enhanced slightly in regressions (11.59) and (11.60) on net investment. The divided time variables give no basis for rejecting the hypothesis that the time trends have been equal in the prewar and postwar periods. According to (11.59) and (11.60), the adjustment coefficient is .4 for autos, somewhat greater than for other machines.

Demand Equations for Autos as Consumption Durables

Comparing production equation (11.55), Table 11.7, with consumption equation (11.61), Table 11.8, the latter registers a higher R^2 but less significant price coefficient. The R^2 of equation (11.61), estimated in total rather than per capita and including 1952 and 1953 observations, was .61, the same as (11.55). The R^2 was increased from .61 to .76 by converting quantities and income to a per capita basis and from .76 to .82 by dropping the 1952 and 1953 observations. These observations were omitted because they deviated markedly from other estimates due to the unusual demand structure connected with the Korean War.

The coefficient of P_A/P_c is significant at the 80 percent level (one-tailed), other variables at the 90 percent level in (11.64) and (11.65). The coefficients generally display the expected signs, and the five independent variables in each equation together explain slightly over 80 percent of the variation in net auto investment. Some evidence points to an increase in the trend, T, after the war, a surprising tendency based on the downward trend in annual purchases (see Figure 11.6). The rate of increase in gross or net investment is low, however, increasing one dollar per person per year if the time coefficient is 1 in Table 11.7. The adjustment rate again is estimated to be approximately .4, indicating that the time required to make 90 percent of the total desired adjustment is five years.

Price and Income Elasticities of Demand

The elasticity of demand for Q_A with respect to P_A, computed at the 1926-60 mean from production equation (11.55), is -.33; from consumption equation (11.61) it is -.41. Both are lower than previous results for other durables. Based on the P_R component in income, the elasticity of Q_A with respect to P_R is .33 in the short run and 2.2 in about four years according to (11.55). The long-run demand elasticity thus appears similar to that for previous durables.

With respect to P_A, the short-run demand elasticity for stock, S_A, is -.14 and -.16 computed respectively from (11.59) and (11.64). The

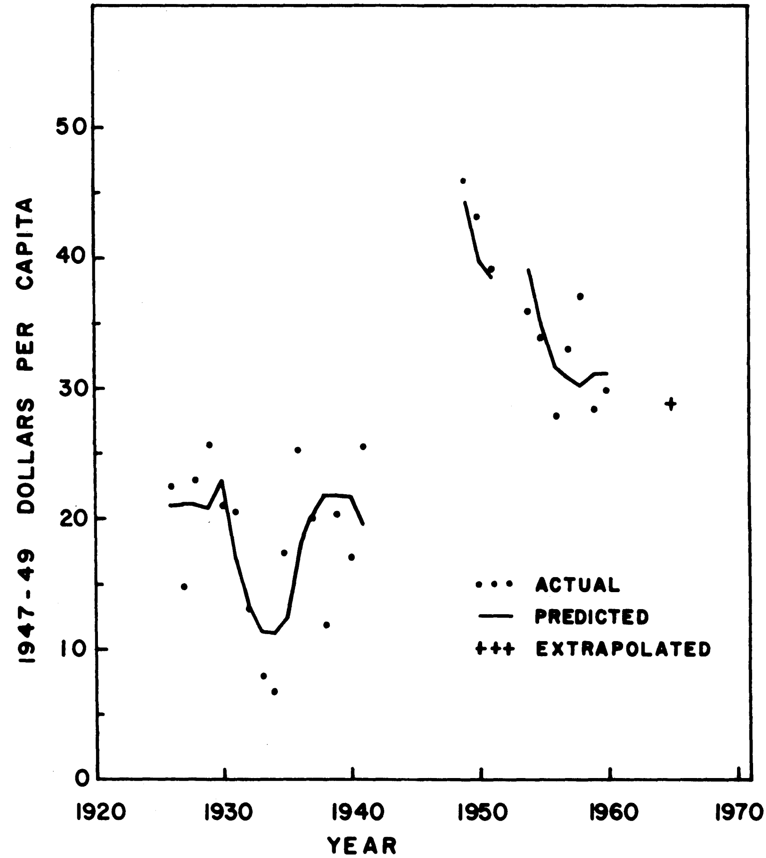

Figure 11.6. Trends in per capita purchases of automobiles by farmers from 1926 to 1960 (predicted and projected estimates from equation 11.61).

long-run elasticity with respect to P_A is the short-run estimate divided by the adjustment coefficient .4, or two and one-half times larger than the short-run elasticity. If production demand equation (11.59) is appropriate, the elasticity of S_A with respect to P_R is .14 in one or two years, .44 in approximately four years and 1.2 in roughly seven years.[17]

In 1957 Chow published U.S. demand equations for automobiles estimated from national time series for 1931 through 1953, with 1942 to 1946 excluded.[18] Variables specified in the per capita demand functions

[17]The adjustment rate .4 indicates that five years are required to make 90 percent of the adjustment after farmers are subjectively certain of price and income variables. It is especially important to adjust for expectations when the adjustment rate is large (say more than .2). Since about two or three years are required to form income expectations, we add two years to the indicated five year adjustment rate.

[18]Chow, Gregory C. Demand for Automobiles in the United States, a Study in Consumer Durables. North-Holland Publishing Company. Amsterdam, Netherlands. 1957. See also: Chow, Gregory C. Statistical demand functions for automobiles and their use for forecasting. In Harberger, Arnold C., (ed.) The Demand for Durable Goods. pp. 149-78. The University of Chicago Press. Chicago. 1960.

were prices and quantities of autos, disposable and expected income, money stock and time. He found the long-run stock elasticities with respect to own-price and income respectively to be -1 and 2. Equivalent elasticities -.4 and .4 computed from equation (11.64) are somewhat less than Chow's results. Because of differences in models, data and concepts, the estimates provide no basic inferences about the relative magnitude of price and income elasticities in the farm and nonfarm sectors.

The trend in auto purchases, characterized by a "trough" in the 1930's and a high and declining trend after the war, is similar to that for other machinery (Figure 11.6). The observations display considerable scatter due to measurement errors and other reasons, and (11.61) does not accurately predict the actual data. Because of unusually large deviations from the trend in 1952 and 1953 stemming from the Korean War, these observations are omitted.

The price variable P_A/P_c increased 9 percent from 1956 to 1960. Net income did not fall accordingly, as this and other machinery prices increased, because of increased farming efficiency and because many input prices remained quite stable. Adding 10 percent to the 1960 price and averaging 1955-59 net income, the projected 1965 per capita demand quantity is 29 1947-49 dollars. This estimate is slightly below the actual 1960 demand quantity, 31 1947-49 dollars, and is consistent with the tendency of the 1950's for auto purchases to decrease at a decreasing rate.

SUMMARY OF RESULTS

Considerable uniformity exists among productive machinery (other than autos) in the models, variables and elasticities which can express demand. Except for autos, a simple linear function of three variables, the machinery/commodity price ratio, income or equity, and time explain a major portion of the variation in machinery purchases. The variables predict less accurately in recent years in some instances, possibly because the actual data are preliminary and need revision, or because structural changes have occurred which cannot be isolated in the models because of few time series. Although the models are intended to be structural rather than simply predictive, statistical complications precluded obtaining estimates of the market interaction between labor and machinery. Undoubtedly, some of these and other influences are reflected by the significant and positive time coefficients.

Computed from the equations estimated in original observations at the full-period means, in round numbers a 1 percent increase in the price of either trucks, tractors or the equipment aggregate Q_{ME} is predicted to increase respective annual purchases 1 percent; stock .2 percent in one or two years. In four years the elasticity of machinery purchases Q_i with respect to P_i remains about unity, but with respect to P_R is 2 or more. A sustained 1 percent rise in prices received by farmers is expected to increase stock for these same items .2 percent in one or two years, .5 percent in four years and more than 2 percent in the long run. The "long run" is reflected in the adjustment rate and differs markedly by items. As expected, the lowest adjustment and depreciation rates (highest long-run elasticities) are for farm tractors and the highest rates are for autos.

Purchases of each machinery category are projected to be nearly the same level in 1965 as in 1960. The reason is that influences such as a decline in the machinery/labor price ratio and improvements in machine quality and versatility, tending to increase demand, are offset by rising machinery/commodity price ratios. Since projected annual investment roughly equals replacement rates, stocks are projected also to remain at or near 1960 levels. Future trends for some items not separately examined, e.g. feed handling equipment, are expected to deviate significantly from above trends.