14.

Demand Structure for Five Operating Inputs

THE DEMAND for each of five components of operating inputs is analyzed in this chapter. The categories included are: (a) seed, (b) machinery supplies, (c) building repairs, (d) feed and (e) miscellaneous inputs including dairy supplies, hand tools, electricity, etc. The livestock component is not considered because only a small portion of livestock inputs are of nonfarm origin. Livestock marketing costs are included in miscellaneous inputs. The structure of the livestock market has been analyzed in some detail in another study.[1]

This analysis of operating inputs represents some attempt at disaggregation. The optimum degree of aggregation in econometric analyses depends on both the research resources available and the intended purpose of the analyses. Some implications of policy proposals can be observed more conveniently from a single macro equation. While some aggregation bias may be present, the macro equation may provide a better over-all guide than a series of highly refined but somewhat unrelated micro equations. For some purposes it is desirable to estimate the individual demand functions for several categories of operating inputs, Q_O. The various components of operating inputs do not react uniformly to prices and other economic stimuli. For example, some operating inputs such as seed are more closely identified with the rising output and efficiency in agriculture than are building repairs.

In each section of this chapter we review relevant literature and specify the demand function derived from time series. All demand functions are estimated by single-equation least-squares methods for the periods 1926-59, excluding 1942-45. After the characteristics of the estimated demand equations are discussed, computed price elasticities are presented and demand quantities are projected to 1965.

DEMAND FOR SEED

Seed purchases by U.S. farmers increased over 200 percent, or at an average compound rate of 3.5 percent per year over the period

[1]Mauldon, Roger Gregory. An Econometric Analysis of the Supply of Livestock Products and Demand for Feed Grains. Unpublished Ph.D. Thesis. Library, Iowa State University. Ames. 1962.

1926-59. Substitution of purchased seed for farm produced seed is a notable characteristic of the changing resource demand structure of agriculture.

Although there have been no previous estimates of the demand function for seed in the United States, Griliches explored the factors responsible for the differential rate of adoption of hybrid corn in a study published in 1957.[2] He fitted a logistic curve to data from crop areas in several states. The rate of adoption was best predicted by the relative profitability of hybrid corn, market density, corn acres per farm, date of origin of hybrid introduction and other less important factors.

Specification of the Demand Function

The above variables provide a basis for the specification of the seed demand function. The relative profitability of seed is represented by price variables. At a national level, several technological influences have appeared gradually and can be represented by a time variable. The lag effect in adoption of innovations and in adjustment to price is allowed by lagging the dependent variable. In the following analysis the quantity of seed purchases is estimated as a function of the ratios of seed prices to prices received and to prices paid, the scale of the agricultural plant, government policies, weather and slowly changing factors represented by the time variable. The variables are defined as:

Q_{St} = the annual seed purchases by U.S. farmers during the current year in millions of 1947-49 dollars, including inter-farm sales. Total farm expenditures for seed are divided by the index of prices paid by farmers for seed to convert expenditure data to "quantity" measured in constant 1947-49 dollars.

$(P_S/P_R)_{t-1}$ = the index of the past year ratio of seed prices to prices received by farmers for crops and livestock. Livestock prices are included because, for many crops fed to livestock, the crop price is not the only decision variable.

$(P_S/P_P)_{t-1}$ = an index of the past year ratio of seed price to prices paid for items used in production, including interest, taxes and wage rates.

S_{pt} = the stock of all productive farm assets on January 1 of the current year (see Chapters 12 and 13).

G_t = a current year index of government policies. Years with production control in force are given a -1 value. Years when farm prices are supported are given a +1 value. A +1 value is added if price supports are fixed. These values are summed to form G.

[2]Griliches, Zvi. An exploration in the economics of technological change. Econometrica. 25:501-22. 1957.

W_t = an index of the influence of weather on farm output in the current year.[3] (See Chapter 13.)

T = time, measured as the last two digits of the current year.

The Estimated Demand Equations

The coefficients, standard errors and other statistics of single-equation estimates of seed demand are presented in Table 14.1 where O and L refer respectively to functions with observations in original and logarithmic form. The F refers to observations in first differences. A large percent of the annual variation ($R^2 = .95$) is explained by the six independent variables in (14.1). The institutional variable, G, is significant at the 95 percent probability level, but the approximate nature of the variable prohibits placing great reliance on its coefficient. The significance of the coefficient is not surprising, however, since acreage restrictions that reduce cropland acres are expected to reduce seed demand. Because of the somewhat dubious construction of the G variable, it is dropped to form equation (14.2) where the coefficients of

Table 14.1. Demand Functions for Seed Q_S Estimated by Least Squares With U.S. Data From 1926 to 1959, Omitting 1942 to 1945 (Coefficients, Standard Errors, in Parentheses, and Related Statistics Are Included)*

Equation and Transformation†	R^2	d‡	Constant	P_S/P_R t-1	P_S/P_P t-1	S_p t	G t	W t	T	Q_S t-1
(14.1-O)	.95	1.29	-156.93	.80	.47	-3.49	2.89	.85	16.02	
				(.84)	(.76)	(2.28)	(1.08)	(.67)	(1.87)	
(14.2-O)	.94	1.09	-61.57	-.59	1.55	-4.43		.88	17.28	
				(.73)	(.72)	(2.52)		(.75)	(2.03)	
(14.2-L)	.92	1.30	4.23	-.12	.43	-1.81		.19	.0222	
				(.25)	(.19)	(.72)		(.21)	(.0027)	
(14.3-O)	.93	.63	-322.64	-.31	2.02				14.35	
				(.74)	(.69)				(.91)	
(14.3-L)	.90	.69	.76	.028	.56				.0162	
				(.259)	(.19)				(.0012)	
(14.4-O)	.93	.61	-357.38		1.93				14.55	
					(.65)				(.76)	
(14.4-L)	.90	.69	.81		.57				.0162	
					(.18)				(.0010)	
(14.5-F)	.33	2.25	--§		1.84				17.20	
					(.52)				--§	
(14.6-O)	.97	2.03	-229.75		1.80				5.70	.62
					(.47)				(1.84)	(.12)
(14.6-L)	.95	2.21	-.23		.52				.0064	.60
					(.14)				(.0022)	(.13)

*Sources and composition of the dependent variable, Q_S, and the indicated independent variables are discussed in the text and 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.

†Equations are estimated in the transformations indicated: original values, O, logarithms, L, (T is in original values in L equations), and first differences of original values, F.

‡The Durbin-Watson autocorrelation statistic d.

§The intercept, or constant, coefficient in the first-difference equation is comparable to the coefficient of T in the O and L equations. The standard error of the coefficient was not computed.

[3] Stallings, James L. Weather indexes. Journal of Farm Economics. 42:180-86. 1960.

the weather variable are not significantly different from zero. If weather affects seed demand, the specification in (14.1) and (14.2) does not detect it. The coefficient of S_p is not significantly different from zero in equations (14.1) and (14.2-O) and is just significant at the 95 percent level in equation (14.2-L). Because of the low significance of S_p in original values, its relatively high correlation with T and the questionable sign of its coefficient, the variable S_p and W are dropped to form equation (14.3). The omission of the variables reduces the R^2 only slightly and increases the magnitude and significance of the coefficient of $(P_S/P_P)_{t-1}$. Since the coefficients of $(P_S/P_R)_{t-1}$ are not significantly different from zero in the first equations, the variable is dropped and equation (14.4) results. The two variables $(P_S/P_P)_{t-1}$ and T evidently predict seed purchases as well as possible in the single-equation approach and from the time series data available.

Unfortunately, autocorrelation in the residuals increases considerably as variables are dropped. The presence of autocorrelation as measured by d is inconclusive in (14.1) and (14.2), but is significant in (14.3) and (14.4). Equation (14.5-F), estimated in first differences of original values, reduces autocorrelation to a nonsignificant level. The magnitude and significance of the price coefficients in equations (14.4-O) and (14.4-F) are not appreciably different.

Statistical properties of (14.6), estimated with lagged Q_S, and considerations from previous analyses suggest that the distributed lag equation might be a useful model of seed demand. The R^2 is increased, autocorrelation is reduced (the test is biased, however) and significance of the price coefficients is greater in (14.6) than in (14.4). Furthermore, the lagged adjustment to new seed varieties, because of limitations on seed stock expansion, or lack of awareness and cautious recognition of new varieties by farmers, may justify the lagged adjustment model. The coefficients indicate that approximately 40 percent of the adjustments to equilibrium prices and technological conditions indicated by T are made in the short run.

Price Elasticity of Demand

The equations in Table 14.1 would suggest that the price elasticity of seed demand with respect to prices received by farmers is zero in the short run. That an increase in seed prices relative to prices received would depress seed purchases very little seems reasonable from considerations of the production process. Important substitutes for seed do not exist in the production process. If production is to take place, seed must be used. Seed represents a small portion of total production costs, hence, a change in seed price normally is expected to influence production decisions but slightly. Complementarity of seed with a relatively fixed land input also causes stability in seed sales since land inputs have a low reservation price and are highly fixed in the short run.

The coefficient for P_S/P_P is not significantly different from zero in equation (14.1). If the equation is specified correctly, changes in seed prices relative to other input prices can be expected to result in little change in seed purchases. In the remaining equations in Table 14.1, however, the coefficient of the variable is significant. The significant coefficient may reflect the influence of variable G, omitted in subsequent equations. The variable P_S/P_P contributes significantly to the explanation of Q_S and is useful from a positivistic, predictive standpoint. Additional analyses are needed, however, to determine the structural role of the variable in the demand function.

Shifts in Demand

Structural changes represented by a linear trend evidently account for a major portion of the 213 percent growth in seed demand from 1926 to 1959. The dominance of time in the demand equation (14.4-O) in Table 14.1 is illustrated by the standard partial regression coefficients .15 and .97 for P_S/P_P and T, respectively. If price is at the 1959 level and T is at the 1926 value, the demand quantity is predicted at approximately 14 percent less than the predicted quantity for 1926 in equation (14.4-O). Nearly the entire 3.5 percent annual compound rate of increase in demand is explained by structural, rather than price, changes.

The most important element in changing the structure of the seed market is the introduction of improved seeds such as hybrid corn. The improved seeds are more resistant to insects and fungi. In many instances, improved varieties not only maintain yields against natural enemies, but their genetic vigor provides opportunities for raising yields and increasing factor-product transformation rates despite declining product prices. Other related factors responsible for the rising demand for purchased seed, through the effect of changed production coefficients, are the weakened resistance of farm produced seeds to natural enemies, shifts toward more seed intensive rotations, and improved management encouraged by the cost-price squeeze. According to the theory of Chapter 3, changes in production coefficients and price ratios primarily determine demand for a resource. We believe technical change, which has increased the productivity (production coefficients) over time, to be a dominant factor explaining changes in farmer demand for seed. This explanation does not rule out price as a potentially important variable relating to seed demand. Obviously, if wheat seed cost $1,000 per bushel, little of it would be used. But with a relatively favorable price of seed resources, as compared to their productivity and the prices of products, technical change has dominated in driving seed purchases upward.

Trends and Projections

Figure 14.1 indicates that seed purchases remained relatively stable during the late 1920's and early 1930's. Purchases rose sharply after the depression and continued to increase in the postwar years, but at a lower rate. This phenomenon perhaps suggests that technical change was somewhat lacking in the earlier period and that capital limitations (a factor highly related to price relatives) were important during the depression. However, we could not specify a model which served to bring out these details.

Predicted values of seed purchases from equation (14.6-O) provide reasonable approximations to the actual values for past years. Extrapolation of the quantity estimate for 1960 from past data underestimated the actual 1960 purchases by 2 percent. Seed purchases, estimated from this equation for 1965, indicate a quantity of 706 million 1947-49 dollars which is 12 percent above the 1960 predicted level. The projection is based on the assumptions that prices will remain at average 1955-59 levels, and that the structure will continue to change as indicated by the time coefficient. Since errors accumulate in equations containing lagged dependent variables, caution must be used in interpreting projections several years in advance. The projected estimate for 1965 is comparable to a linear extension of the postwar trend in seed purchases.

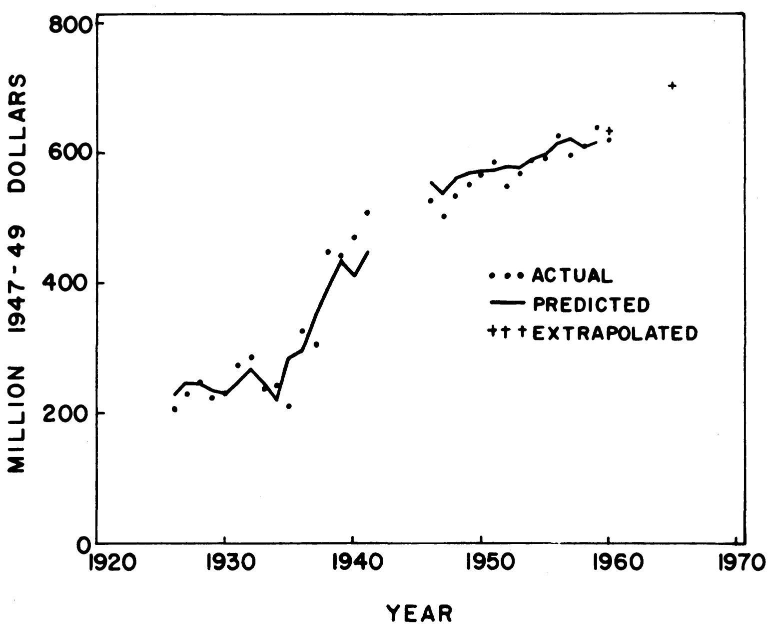

Figure 14.1. Trends in seed purchases Q_S from 1926 to 1960 (predicted and projected estimates from equation 14.6-O).

DEMAND FOR MACHINERY SUPPLIES

Inputs of machinery supplies — fuel, oil, lubrication and repairs — increased 365 percent between 1926 and 1959. The average compound growth rate was 4.8 percent per year. Growth in purchases of machinery supplies has been closely associated with the growth of machinery inventories because the inputs are complements. Price factors also may have been important in causing the demand structure for machinery supplies to change. The purpose of this section is to analyze the role of prices and other factors in determining the demand quantities of machinery supplies.

Specification of the Demand Function

The demand quantity of machinery supplies is considered to be a function of current and past year prices of machinery supplies, prices received by farmers, prices paid by farmers for production items, the stock of productive assets, government agricultural policies, weather and gradually shifting influences represented by a time variable.

Due to the anticipated strong complementarity between machinery stocks and machinery operating inputs (supplies), the specification of machinery stocks in the demand function was deemed appropriate. Productive assets other than machinery stocks also influence sales of machinery supplies, but due to the high correlation between machinery inventories and other components of productive assets, it was not feasible to include more than one variable. The variable included, total stocks of productive assets, S_p, is correlated with machinery stocks from 1926 to 1959 to the extent $r = .98$. Thus the coefficient of S_p in the demand equation must be interpreted as the joint influence of machinery stocks and other productive assets on the demand quantity.

The variables in the demand function are:

Q_{MSt} = the annual U.S. purchases of machinery supplies, the variable to be predicted, during the current calendar year in millions of 1947-49 dollars. Machinery supplies included fuel, lubrication, oil and repairs of motor vehicles and other farm machinery used for productive purposes.

$(P_{MS}/P_R)_t$ = the current year index of the ratio of prices paid by farmers for motor supplies to prices received by farmers for crops and livestock. Both current and past year prices are included in the demand function.

$(P_{MS}/P_P)_{t-1}$ = the past year index of the ratio of prices paid by farmers for motor supplies to prices paid by farmers for items used in production, including interest, taxes and wage rates.

The demand function also includes an index of government policies, G, a weather index, W, the stock of productive assets on January 1, S_p, and a time variable, T. The logic and sources of these variables is discussed in more detail in the section on seed demand. The resulting equations are presented in Table 14.2. The O denotes observations in original values, and L denotes observations transformed to logarithms.

The Estimated Demand Equations

Equation (14.7-O) in Table 14.2 contains current and past prices of motor supplies and other variables which together explain 99 percent of the variance around the mean of Q_{MS}. If government policies influence demand for machinery supplies, it is not strongly expressed from the nonsignificant coefficient and standard errors of G in equation (14.7). The variable is dropped in estimating equation (14.8). The coefficient of the past year price of motor supplies relative to prices received is not significantly different from zero for this equation. The complete dominance of current price over past year price is inconsistent with a priori considerations. The magnitude of the $(P_{MS}/P_R)_{t-1}$ coefficient may partially be explained by high correlation (r=.89) between current and past year price, with the current price variable tending to absorb the effect of past year price. A similar result is avoided for the second major price variable, P_{MS}/P_P, by including only past price. It is impossible to differentiate effects of the variable between years because of the high correlation (r=.96) between current and past year values of P_{MS}/P_P.

The tendency for current or past year price to absorb the effect of the other in regression analysis is apparent in (14.9) and (14.10). The weather and current price variables are nonsignificant and are deleted from (14.8) to form (14.9). Equation (14.10) is similar to equation (14.9), with current values substituted for past values of P_{MS}/P_R. The coefficient of $(P_{MS}/P_R)_{t-1}$ is negative and significant in equation (14.9) although it was not significantly different from zero in equation (14.8). Equation (14.9) is useful for predictive purposes when current price is unknown. If current and past year prices continue to be related, prediction from past prices can be made with suitable accuracy.

All coefficients are significant in (14.9) and (14.10) except the coefficient of S_p in the equations estimated in logarithms. S_p is specified in the demand function to reflect the influence of durable assets, particularly machinery inventories, on the demand for machinery supplies. Previous knowledge of the complementary relationship between machinery inventories and purchases of Q_{MS} suggests a significant positive coefficient of S_p is appropriate. From this standpoint, the equations in original values are most acceptable. The equations estimated in logarithms, however, display less autocorrelation as indicated by d. The test of the null hypotheses that the residuals are uncorrelated in the logarithm equations is inconclusive in (14.8-L) and (14.9-L), but is rejected at the 95 percent level in equation (14.10-L).

Table 14.2. Demand Functions for Machinery Supplies Q_{MS} Estimated by Least Squares With Annual Data From 1926 to 1959, Omitting 1942 to 1945; Coefficients, Standard Errors and Related Statistics Are Included*

Equation and Transformation †	R^2	d‡	Constant	P_{MS}/P_R t	P_{MS}/P_R t-1	P_{MS}/P_P t-1	S_p t	G t	W t	T	Q_{MS} t-1
(14.7-O)	.99	.96	-798.38	-2.02	.78	-7.72	22.55	3.82	1.09	26.58	
				(.64)	(.86)	(2.42)	(4.68)	(2.71)	(1.22)	(3.63)	
(14.8-O)	.99	.97	-162.97	-2.28	.95	-10.00	19.16		1.14	26.58	
				(.62)	(.87)	(1.84)	(4.10)			(3.70)	
(14.8-L)	.996	1.23	4.05	-.298	-.067	-.72	.27		.084	.01448	
				(.072)	(.109)	(.18)	(.25)		(.067)	(.00096)	
(14.9-O)	.99	.98	-383.08		-1.47	-7.95	17.78			31.66	
					(.67)	(2.10)	(4.85)			(4.15)	
(14.9-L)	.99	1.25	3.91		-.412	-.49	.21			.0159	
					(.091)	(.22)	(.31)			(.0011)	
(14.10-O)	.99	.91	-270.65	-1.79		-8.56	19.80			27.82	
				(.41)		(1.25)	(4.02)			(3.46)	
(14.10-L)	.996	.98	4.30	-.336		-.80	.29			.01423	
				(.049)		(.12)	(.24)			(.00092)	
(14.11-O)	.997	1.29	350.56	-1.11		-1.75				9.35	.765
				(.25)		(1.18)				(3.47)	(.077)
(14.11-L)	.998	1.45	1.16	-.264		.046				.0044	.72
				(.029)		(.148)				(.0016)	(.11)
(14.12-O)	.997	1.29	143.95	-1.20						6.63	.855
				(.25)						(3.02)	(.050)
(14.12-L)	.998	1.40	1.33	-.264						.00479	.690
				(.028)						(.00091)	(.044)

*For sources and composition of the dependent variable Q_{MS} and the indicated independent variables, see Table 14.1.
†Equations are estimated in the transformations indicated: O, original values; L, logarithms (T is in original values in L equations).
‡The Durbin-Watson autocorrelation statistic d.

Equations (14.11) and (14.12) are equivalent to equation (14.10) with the lagged quantity substituted for S_P to form an alternative estimate of the long-run properties of the demand function. Equations (14.7) to (14.10) indicate that the particular distributed lag model may be inappropriate because a large proportion of the variation in demand quantity is explained by variables lagged no more than one year. The coefficient of $(P_{MS}/P_R)_t$ is relatively stable and is significant in (14.11). The coefficient of $(P_{MS}/P_P)_{t-1}$ is insignificant, however, perhaps because of inappropriate model specification. The latter variable is omitted in equation (14.12) where all variables are significant and possess the anticipated signs. Together the variables explain over 99 percent of the annual variation about the mean of Q_{MS}. The distributed lag equation (14.11) suggests that about 25 percent of the adjustment in Q_{MS} to the equilibrium level is made in the short run.

Price Elasticity of Demand

From Table 14.2 the estimated price elasticity may be computed with respect to each of the price variables P_R , P_P and P_{MS} . Considering P_{MS} first, the total price elasticity of demand with respect to P_{MS} is the sum of the direct component (P_R) and the substitution component (P_P). On the basis of (14.10-O) the estimated total elasticity with respect to P_{MS} is -.22 (the direct component) plus -.82 (the substitution component) or -1.0. Similarly, the estimated elasticity from equation (14.10-L) is -.34 (the direct component) plus -.80 (the substitution component) or -1.1. These estimates are comparable to the long-run estimates of elasticity with respect to P_{MS} from (14.12-O) and (14.12-L) of -1.0 and -.9, respectively.

Equation (14.10) suggests a short-run demand elasticity of .22 with respect to P_R. The same equation in logarithms gives a point estimate and 95 percent confidence interval of $-.34 \pm .10$ for the elasticity. The results imply that the short-run price elasticity with respect to P_R is approximately .3. The long-run elasticity is much greater, however; a sustained rise in prices received by farmers is predicted to increase machinery stock from 2 to 3 percent according to the estimates in Chapter 11 on machinery demand. Equation (14.10) indicates that a 1 percent rise in S_p increases demand for Q_{MS} by more than 1 percent. Hence, the demand elasticity of machinery supplies may be more than 2 in the long run. Purchases of motor supplies are more sensitive to P_R than to P_{MS} in the long run because of the complementarity of the input with durables, particularly with machinery. The "long run" is more than 10 years, however, according to Chapter 11.

Shifts in Demand

Equation (14.10) predicts, with prices at 1959 levels and other variables at 1926 levels, a demand quantity of machinery supplies 119 percent greater than the predicted 1926 demand quantity. Even if allowances are made for lagged adjustment to short-run price changes, it is likely that much of the increase in demand remains to be explained by factors other than price. The strongest influence on demand for machinery supplies has been the rising investment in farm machinery, particularly motor vehicles. The complementarity between machinery stock and Q_{MS} is indicated by the positive coefficient of S_p and T. Due to incomplete specification and correlations among trend variables, the exact influence of machinery investment on purchases of supplies is not ascertainable. Stocks of all farm machinery increased nearly 150 percent from 1926 to 1959. If purchases of machinery supplies increase accordingly, this would explain a considerable portion of the total increase in demand for machinery supplies.

After exhausting (a) the short-run price and (b) the above complementarity hypotheses, approximately one-third of the total increase in annual sales remains to be explained by additional influences. One important influence is the increased requirement of fuel and oil per unit of machinery stock. As motor vehicles become a more prominent component of machinery stock, requirements for gasoline and oil increase accordingly.

Trends and Projections

Except for a small dip during the early 1930's, the quantity of machinery supplies purchased by farmers has increased steadily until 1949 (Figure 14.2). From 1950 to the early 1960's the upward trend has not been so steep and some slight depressions in sales are apparent. The predicted values of annual purchases from (14.9-O) provide reasonable approximations to the actual data of the various years. The equation predicts the downturns in the early 1930's, in 1950 and 1954, but does not correctly gauge their magnitudes. The extrapolated demand "quantity" in 1960 is 2,415 million 1947-49 dollars, and is 3 percent greater than the actual estimate of 2,341 million 1947-49 dollars. (The 1960 figure is preliminary from USDA statistics. The "actual" estimates are often revised and the percent of error may change.) Assuming prices at average 1955-59 values, stocks of productive assets at 112.4 million 1947-49 dollars in 1965, and that the influence of technology and other variables represented by the time variable continue as in the 1926-59 period, purchases of Q_{MS} totalling 2,622 million 1947-49 dollars are estimated for 1965. If productive assets increase to 114.4 billion 1947-49 dollars, the projected estimate of machinery supply purchases is estimated at 2,659 million 1947-49 dollars by 1965. The estimates are 9 and 10 percent, respectively, above 1960 predicted levels. The projections are approximately equivalent to projections from a linear extension of the postwar trend. Of course, the validity of the projections are subject to conformity with the underlying assumptions of the model.

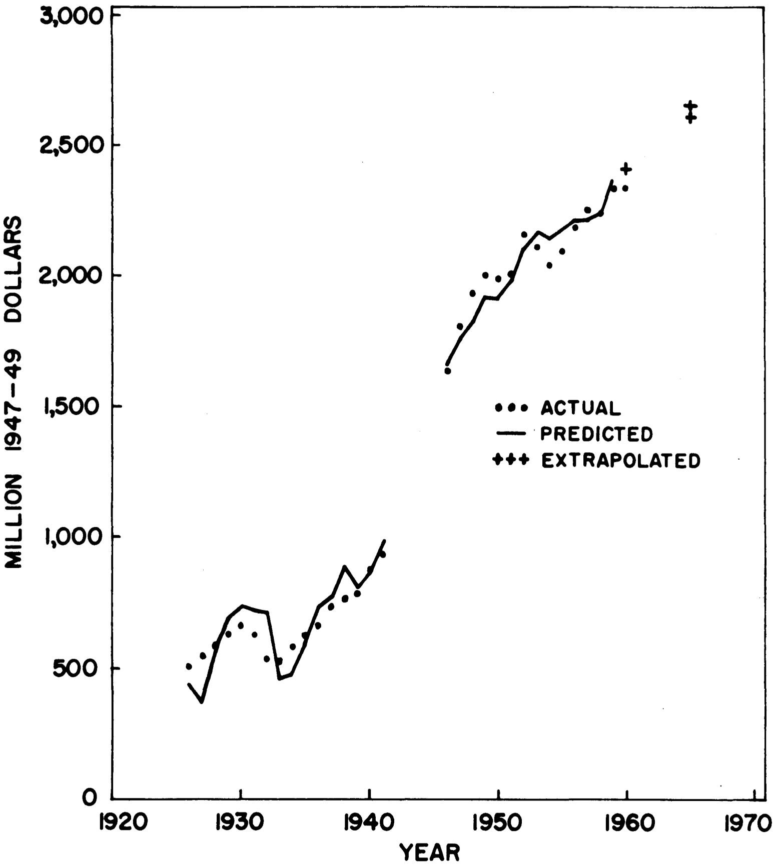

Figure 14.2. Trends in machinery supply purchases Q_{MS} from 1926 to 1960 (predicted and projected estimates from equation 14.9-O).

DEMAND FOR PURCHASED FEEDS

This section includes single-equation estimates of feed demand functions. Feed purchases, measured in constant 1947-49 dollars, increased 218 percent from 1926 to 1959. The compound growth rate was 3.6 percent per year.

In this study, feed purchases include feed grains and protein feeds. Components of operating inputs such as commercial fertilizer and motor supplies are produced almost completely by the nonfarm sector. Feeds, and to some extent seeds, even when purchased from nonfarm sources, contain an important portion produced on farms. Because of this connection, the index of the ratio of prices paid for feed to prices received by farmers for crops and livestock has been quite stable since

1926. The index was 98.9 in 1926 and 97.4 in 1959. The ratio of prices paid for feed to prices received for livestock displays a similar lack of trend, but annual variations in the series provide a basis for appraising the effects of prices on demand quantities of feed.

Hildreth and Jarrett estimated the demand for feed grains by single and simultaneous equations.[4] They specified the following variables in the demand equations: the quantity of feed grains fed, feed grain price, livestock price, protein price, beginning year animal units of livestock and roughage consumed by livestock. In the single equations the quantity of feed grains fed to livestock was the dependent variable. Additional details of their study, including elasticity estimates, are discussed later in this section.

Specification of the Demand Function

Feed demand quantity by farmers is estimated in this chapter as a function of feed prices, livestock prices, prices paid by farmers, stocks of productive assets, government policies, weather and time. The specification is somewhat similar to that of Hildreth and Jarrett except prices paid, P_P, rather than protein prices, are included. Also, inventories of productive assets are substituted for livestock inventories. The model in this study contains no estimate of roughage consumption, but contains variables G, W and T, representing the influence of institutions, weather and technology on feed demand. S_p is highly correlated with livestock inventories (r=.91), thus the coefficient of S_p broadly may be interpreted as the effect of livestock inventories, as well as of other assets, on feed demand.

The exact form of the variables in the feed demand function is as follows:

Q_{Fdt} = the dependent variable and is the purchases of feed by U.S. farmers during the current calendar year in millions of 1947-49 dollars. The "quantity" is derived by dividing expenditure data by prices paid by farmers for feed. Inter-farm sales are included. The estimate includes protein and feed grain purchases.

$(P_{Fd}/P_R)_t$ = the current year index of the ratio of prices paid by farmers for feed to prices received by farmers for crops and livestock. Both current and past year prices are included in the demand function.

$(P_{Fd}/P_{Lk})_t$ = the current year index of the ratio of prices paid by farmers for feed to prices received by farmers for livestock. The past year index is also included in the demand function.

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[4]Hildreth, Clifford, and Jarrett, F. G. A Statistical Study of Livestock Production and Marketing. John Wiley and Sons. New York. 1955.

$(P_{Fd}/P_P)_{t-1}$ = the past year index of the ratio of prices paid by farmers for feed to prices paid by farmers for items used in production, interest, taxes and wage rates.

In addition, productive assets, S_p, an index of government programs, G, weather, W, and a time variable, T, are included in the demand function. The logic of these variables is discussed in a previous section. All equations (Table 14.3) are estimated with data from 1926 to 1959, excluding the war years.

Estimated Demand Equations for Feed

The independent variables in (14.13) and (14.14) of Table 14.3 explain a large proportion (R^2=.98) of the annual variation about the mean of Q_{Fdt}. Current and past prices, stocks of productive assets and time primarily are responsible for the high R^2. Coefficients of G, W and P_{Fd}/P_P are not significant in these equations. This, however, is not certain evidence that the effects of the "real" variables which they are constructed to represent lack influence on demand. Instead, given the form of the variables, coefficients of the magnitudes estimated occur frequently when the true coefficients are zero. Other variables, constructed differently but representing the same influences, might indicate a significant influence on feed demand.

Because the demand for feed is derived primarily from the demand for livestock, P_{Lk} is substituted for P_R in the remaining equation of Table 14.3. Equation (14.15) is the result of this substitution and the deletion of insignificant variables from (14.13) and (14.14). The coefficients of current and lagged price, P_{Fd}/P_{Lk}, in (14.15) are significant at lower probability levels than are comparable coefficients of P_{Fd}/P_R in (14.13). Based on the various transformations in equation (14.15), the significance of current and lagged price variables is inconclusive.

The Durbin-Watson statistic indicates significant autocorrelation in the residuals of (14.15-O) and (14.15-L). To reduce the autocorrelation in the residuals and to provide more consistent statistical tests of the coefficients, the equation also is estimated in first differences of original values. The d value is raised from .75 in (14.15-O) to 1.50 in (14.15-F). The degree of autocorrelation in the residuals as indicated by d is reduced somewhat, but the test of the null hypothesis of zero autocorrelation is on the borderline between insignificant and inconclusive. The drop in the R^2 from .95 in (14.15-O) to .12 in (14.15-F) indicates that a very large proportion of the variance around the mean of Q_{Fd} is explained by linear trends removed by the first-difference transformation. The instability of the coefficients of S_p and T in equation (14.15) may be explained by the high correlation between the variables (r=.92). Because of the expected complementary relationship between durable inventories and Q_{Fd}, the significant positive coefficient of S_p in equation (14.15-O) is most meaningful.

The magnitudes of the coefficients in the distributed lag equations

Table 14.3. Demand Functions for Purchased Feed Q_{Fd} Estimated by Least Squares with U.S. Data from 1926 to 1959, Omitting 1942 to 1945; Coefficients, Standard Errors (in Parentheses) and Related Statistics are Included*

Equation and Transformation†	R^2	d‡	Constant	P_{Fd}/P_R t	P_{Fd}/P_R t-1	P_{Fd}/P_{Lk} t	P_{Fd}/P_{Lk} t-1	P_{Fd}/P_P t-1	S_p t	G t	W t	T	Q_{Fd} t-1
(14.13-O)	.98	1.05	800.06	-18.78	-27.10				39.53	-7.33	3.57	70.79	
				(8.67)	(8.37)				(15.75)	(7.08)	(4.64)	(12.53)	
(14.14-O)	.98	1.02	2117.02	-24.10	-25.80			-3.23	35.66	-7.19		73.18	
				(8.13)	(8.52)			(5.47)	(17.15)	(7.28)		(13.10)	
(14.15-O)	.96	.75	-3809.35			-11.09	-8.94		70.27			57.03	
						(5.03)	(5.20)		(16.80)			(14.21)	
(14.15-L)	.94	.71	2.56			-.62	-.70		1.55			.0116	
						(.29)	(.30)		(.75)			(.0029)	
(14.15-F)	.21	1.50	-- §			-2.34	-8.48		-14.14			94.03	
						(3.27)	(3.31)		(38.62)			-- §	
(14.16-O)	.98	1.74	119.46		-3.39	-3.20						31.02	.765
					(3.60)	(3.74)						(10.82)	(.096)
(14.16-L)	.97	1.68	2.16		-.23	-.37						.0065	.65
					(.20)	(.21)						(.0019)	(.10)
(14.17-O)	.98	1.73	-144.15			-4.19						29.63	.788
						(3.58)						(10.69)	(.092)
(14.17-L)	.97	1.65	1.73			-.43						.0062	.674
						(.20)						(.0019)	(.099)

*For sources and composition of the dependent variable, Q_{Fd}, and the indicated independent variables, see text and Table 14.1.

†Equations are estimated in the transformations indicated: original values, O, logarithms, L (T is in original values in L equations), and first differences of original values, F.

‡The Durbin-Watson autocorrelation statistic d.

§The intercept or constant coefficient in the first-difference equation is comparable to the coefficient of T in the O and L equations. The standard error of the coefficient was not computed.

(14.16) and (14.17) are not consistent with the coefficients in previous conventional models. When a strong complementarity is expected to exist between inputs such as feed and livestock, the validity of a distributed lag model of the form indicated in these equations is questionable because different rates of adjustment of purchases apply to changes in complementary stocks, prices or other variables. The coefficient of the lagged quantity variable was insignificant in feed equations including durable assets. The implication is that there is no long-run adjustment of feed purchases, given the level of stock. In the long run, as inventories of livestock and other assets are changed, feed purchases also change. If this reasoning is accepted, equations such as (14.13), (14.14) and (14.15) are more appropriate expressions of feed demand than are (14.16) and (14.17).

The price coefficients in the latter equations are insignificant. An exception is the coefficient of $(P_{Fd}/P_{Lk})_{t-1}$ which is significant at the 95 percent probability level in (14.17-L). The coefficients of the lagged quantity and time are significant in the distributed lag equations. The results indicate that approximately one-fourth of the adjustment to the equilibrium or desired level of feed purchases is made in the short run. Whether the result can be taken seriously without specifically including complementary inventories such as livestock in the equation is, however, subject to doubt.

Price Elasticity of Demand

The total demand elasticities with respect to current and past year feed prices estimated from (14.15-O) and (14.15-L) are respectively -.8 and -1.3. Since price ratios are employed, the elasticities with respect to livestock prices are the same values but with positive algebraic signs. Because the reliability of the data from which the demand equations are generated is questionable, it is desirable to consider the estimated elasticities as hypotheses suitable for further testing rather than as accurate and final coefficients. It is notable, however, that these estimates conform closely with the results of the study by Hildreth and Jarrett.[5] Their average estimates from single and simultaneous equations of the demand elasticity of feed grains are, with respect to livestock prices, 1.1, and with respect to feed prices, -.8.

The estimated demand elasticity with respect to S_p from (14.15-O) is 2.3; from equation (14.15-L) is 1.6. A comparable statistic from Hildreth and Jarrett, the elasticity of demand for feed grains with respect to livestock inventories (an average of several estimates), was 1.6.

The techniques of this study are not suited for estimating the responsiveness of feed purchases to changes in cattle prices through the inventory effect. A more fundamental explanation of the responsiveness of feed demand to long-run changes in farm product prices

[5]Ibid.

through S_p is available. If a sustained 1 percent increase in P_R increases S_p 1 percent, then feed inventories are predicted to increase from 1 to 2 percent according to (14.15). Because the data and procedures are somewhat crude, no attempt is made to evaluate the exact long-run elasticity with respect to P_R. It is expected, however, that a sustained 1 percent increase in product prices would increase feed purchases more than 2 percent in the long run.

Shifts in Demand

On the basis of equation (14.15-O), if prices had been at 1959 levels in 1926, the quantity demanded of feed would have been approximately 12 percent greater than the predicted quantity in 1926. Thus, nearly 200 of the total 218 percent increase in demand from 1926 to 1959 remains to be explained by factors other than short-run price changes.

Several factors other than short-run price changes have tended to increase demand for the two major components of feed purchases — high protein concentrates and feed grains. Improvements in the nutritive content of protein feeds may be defined as an improvement in feed quality or as a decrease in real cost per nutrient unit of feed. However defined, improvements in the vitamin, mineral, protein and other contents of "balancer" feeds, coupled with greater knowledge by farmers of these improvements, undoubtedly have been an important element in increased demand for them. Aside from price effects, these technologies have increased the productivity coefficients discussed in Chapter 3. The expected result is an increase in demand for the resources. Both commercial and public interests have assumed an important role in improvement of livestock rations and dissemination of knowledge about them to farmers.

Large increases in feed grain purchases, the second major component of total feed purchases, have also occurred since 1926. The rise in purchases reflects the tendency toward specialization in production of agricultural commodities. Whereas more Midwest or Great Plains farmers formerly produced both feed and livestock, many now raise grains only. More grain is shipped to the East where it is purchased by farmers specializing in broiler production and similar activities. As farming becomes more specialized, the proportion of purchased inputs tends to rise.

Trends and Projections

Figure 14.3 compares actual and predicted feed purchases from 1926 to 1960. After 1935 a general upward trend in purchases is apparent, despite occasional short-term reversals. There are no signs of a reversal of the strong upward trend in recent years.

Equation (14.17-O) is used for prediction although some doubt exists

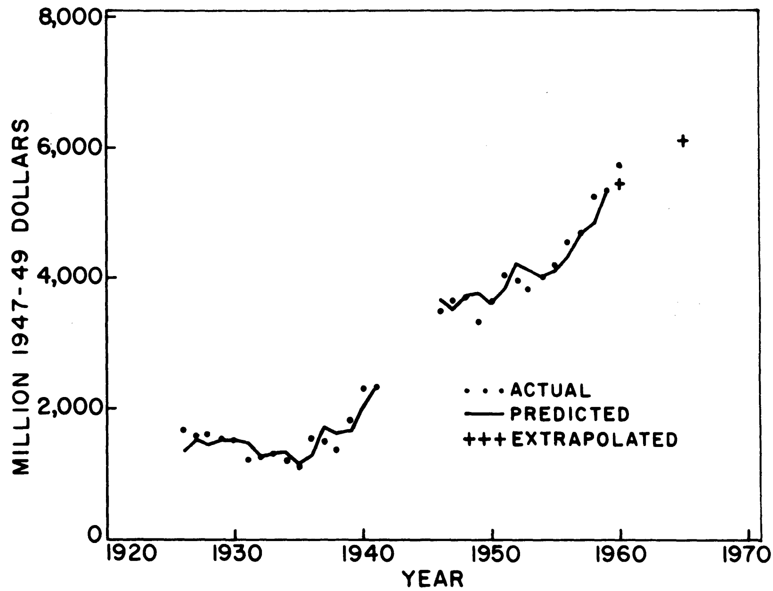

Figure 14.3. Trends in feed purchases Q_{Fd} from 1926 to 1960 (predicted and projected estimates from equation 14.17-O).

about the structural pertinence of this distributed lag equation. Its high predictive power (R^2=.98) and absence of current price, however, encourage use of it for predictive purposes. Some autocorrelation in the residuals of the conventional equations seems to be absorbed into the coefficients of the distributed lag equation. This autocorrelation may be due to systematic errors in the data or failure to specify variables which account for the cattle cycle. Predictive users of the equation, however, can be less concerned about the structural validity of the coefficients. The fit of the equation to the actual observations becomes a sufficient basis for its use in projections. While equation (14.17-O) predicts well for gradual year-to-year changes, it does not accurately indicate more violent changes such as occurred in the early 1950's.

The extrapolated estimate of feed purchases for 1960 is 6 percent below actual purchases. Projections from the equation for 1965 indicate purchases 12 percent above predicted 1960 values. Feed purchases are expected to increase approximately 2 percent per year, under the assumption of prices at 1955-59 levels, assuming that the structural relationships indicated by (14.17-O) remains appropriate. A linear extension of the trend in feed purchases from 1955 to 1960 would result in a much larger projected increase. Hence the estimate from equation (14.17-O) may be conservative.[6]

[6]It also should be emphasized that the analysis is highly aggregative, and purchases of some individual feed resources, within the aggregate category of purchased feed resources, are expected to increase at greater rates.

DEMAND FOR BUILDING REPAIRS

This category includes a highly miscellaneous collection of resources, some relating to crops and some to livestock. On the other hand, some, such as repairs on machine sheds, are technical complements with machinery. Hence, it is not expected that highly efficient demand equations can be predicted from time series on expenditures for building repairs.

The USDA classifies expenditures on fences, windmills, wells and buildings other than the operator's dwelling under two categories — repairs and improvements. Building improvements include new construction, additions and major improvements and are classified as durable goods or investment in this study. Building repairs, inputs necessary to maintain the usefulness and productivity of buildings, fences, etc., have certain characteristics relating to the definition of operating inputs. A large number of these repairs is a function of the level of farm output. Hence, building repairs are classified as operating inputs, although some components of repairs undoubtedly do not fall into this classification.

Purchases of building repairs, measured in 1947-49 dollars, dropped from $424 million in 1926 to $345 million in 1959. This decrease in building repairs amounted to 19 percent during the 33-year period, a compound decline of .6 percent per year. The declining trend in purchases of building repairs is in contrast with the growth in purchases of aggregate operating inputs at an average annual rate of 3.6 percent.

Specification of the Demand Function

The demand quantity of building repairs is specified as a function of prices of building and fence materials, prices received by farmers, prices paid by farmers, beginning year stocks of buildings, beginning year stocks of productive assets, government programs, weather and slowly changing forces represented by the time variable. Stocks of buildings were not available when the statistical demand equations were computed. Later, an approximate estimate of building inventories was constructed. Since this estimate correlates highly (r=.92) with stocks of productive assets, only the latter is included in the demand functions. The variables are defined in more detail as follows:

Q_{BRt} = the purchases of building repairs by U.S. farmers during the current calendar year in millions of 1947-49 dollars. The estimate includes repairs on fences, windmills, wells and farm buildings other than the operator's dwelling.

$(P_B / P_R)_t$ = the current year index of the ratio of prices paid by farmers for building materials to the ratio of prices received by farmers for crops and livestock. Current and past year prices are included in the demand function.

$(P_B/P_P)_{t-1}$ = the past year index of the ratio of prices paid by farmers for building materials to prices paid by farmers for items used in production, including interest, taxes and wage rates. The simple correlation between current and past year values is 0.92, hence, only past year values are included in the demand function.

In addition to these price variables, the demand quantity is specified as a function of the beginning year stocks of productive assets, S_p, the index of government programs, G, weather, W, and time, T. All functions are estimated from aggregate annual data for the years 1926 to 1959, omitting 1942 to 1945.

The Estimated Demand Equations

In Table 14.4 the demand quantity of building repairs, Q_{BR}, is depicted as a function of the variables indicated. The coefficient of G is not significant in (14.18); therefore, the variable is omitted in (14.19). The coefficient of the current price, P_B/P_R, is low and nonsignificant in equation (14.19) where the past price ratio dominates. Beginning year stocks of productive assets appear to have little influence on Q_{BR}. The insignificant coefficient could be caused by conflicting effects on Q_{BR} of variables correlated with S_p. Examples of these variables are: (a) inventories of buildings, (b) stocks of cash and other assets held for production, (c) farm size and (d) structural changes in product demand, specialization and production techniques. Greater investment in buildings may tend to increase demand for repairs, but if the new investment replaces old buildings, repair costs are reduced. Cash for productive purposes and other assets may increase demand for building repairs, but shifts in demand from butter to margarine and improved methods of storing hay (bales) may decrease demand. The influence of each of these correlated variables may be significant, but the collective effect is zero in S_p. Undoubtedly, some of these influences are reflected in the significant coefficient of the time variable. Weather, at least in the form indicated by W, does not influence significantly the demand quantity. Only the variables with significant coefficients in (14.19) are retained to form (14.20).

Although all coefficients are significant in equation (14.20), the three variables explain only one-half of the variation about the mean of Q_{BR}. A linear time trend in purchases of building repairs is not as apparent as the time trend in purchases of other inputs previously discussed. Much of the R^2 in previous demand equations resulted from the time trend, and exaggerated the ability of the equations to predict annual variations in data.

The d statistic indicates significant autocorrelation of the residuals at the 95 percent probability level in equations (14.20-O) and (14.20-L). The Durbin-Watson test suggests that the first-difference transformation successfully eliminates the significant autocorrelation. The

Table 14.4. Demand Functions for Building Repairs Q_{BR} Estimated by Least Squares With Annual Data From 1926 to 1959, Omitting 1942 to 1945 (Including Coefficients, Standard Errors, in Parentheses, and Related Statistics)*

Equation and Transformation†	R^2	d‡	Constant	P_B/P_R t	P_B/P_R t-1	P_B/P_P t-1	S_P t	G t	W t	T	Q_{BR} t-1
(14.18-O)	.57	1.00	237.90	-.42	-2.89	7.56	.20	-.62	.37	-5.75	
				(.87)	(1.06)	(3.22)	(3.37)	(1.99)	(.98)	(4.48)	
(14.19-O)	.56	1.20	169.57	-.37	-2.84	8.28	.52		.40	-6.91	
				(.85)	(1.03)	(2.67)	(3.22)		(.95)	(3.43)	
(14.19-L)	.56	1.01	-.81	-.21	-.98	2.49	.53		.15	-.0098	
				(.31)	(.37)	(.76)	(.88)		(.25)	(.0046)	
(14.20-O)	.56	1.03	213.49		-3.23	8.56				-6.55	
					(.59)	(2.36)				(1.76)	
(14.20-L)	.54	1.00	.42		-1.16	2.46				-.0075	
					(.22)	(.67)				(.0022)	
(14.20-F)	.30	2.42	--§		-2.48	4.16				2.61	
					(.78)	(2.83)				--§	
(14.21-O)	.70	1.91	79.21		-2.35	6.51				-4.69	.40
					(.56)	(2.09)				(1.59)	(.12)
(14.21-L)	.68	1.95	-.097		-.88	1.90				-.0055	.37
					(.20)	(.59)				(.0019)	(.11)

*For sources and composition of the dependent variable, Q_{BR}, and the indicated independent variables, see Table 14.1.

†Equations are estimated in the transformations indicated: original values, O, logarithms, L (T is in original values in L equations), and first differences of original values, F.

‡The Durbin-Watson autocorrelation statistic d.

§The intercept or constant coefficient in the first-difference equation is comparable to the coefficient of T in the O and L equations. The standard error of the coefficient was not computed.

coefficient of P_B/P_R after the transformation, which is expected to provide a more accurate estimate of the significance of the coefficients, is not significant. This casts some doubt on the validity of the complementarity of building repairs with other inputs inplied by the significant positive coefficients of P_B/P_P in these equations. The coefficient of T is 2.61 in equation (14.20-F) and indicates that after adjustments for prices, the demand for building repairs has increased during the years 1926 to 1959. Although the coefficient was not tested statistically, it is probably not significantly different from zero. In this respect, the coefficient of time in equation (14.20-F) agrees with the results of (14.18) and (14.19-O), i.e., the coefficients of time are not significant.

The statistical fit is improved considerably by including the lagged quantity as an independent variable (14.21). Although the magnitudes of the price coefficients are reduced from (14.20), all coefficients in (14.21) are significant. The variables explain 63 percent or more of the annual variation about the mean of Q_{BR}. Autocorrelation is insignificant in the equation. (However, the d statistic tends to underestimate the degree of autocorrelation in such equations.) Although equation (14.20) may be structurally deficient, because of failure to account for building and other inventories, the equation is useful for predictive purposes.

Price Elasticity of Demand

The price elasticities of demand for building repairs with respect to $(P_B/P_R)_{t-1}$ in (14.20-O) and (14.20-L), respectively, are -1.02 and -1.16, indicating that a 1 percent increase in prices received by farmers is associated with approximately a 1 percent increase in purchases of building repairs in the short run. Equation (14.21-L) suggests that a major portion, approximately 60 percent, of the adjustment of purchases to price changes is made in the short run. The long-run elasticity computed with respect to $(P_B/P_R)_{t-1}$ is -1.23 from equation (14.21-O) and -1.40 from equation (14.21-L). The long-run elasticities are not much larger than the short-run elasticities. This result is substantiated by the insignificance of the coefficients of S_p in (14.18) and (14.19).

The price elasticity of demand with respect to $(P_B/P_P)_{t-1}$, estimated from (14.20-O), is 2.18; from equation (14.20-L), is 2.46. The results suggest building repairs to be complements with other inputs; a 1 percent drop in the prices paid for agricultural inputs is associated with an increase in building repair purchases of approximately 2 percent. But as indicated previously, the magnitude of the elasticity of demand with respect to $(P_B/P_P)_{t-1}$ is not defined precisely here. The total elasticity of demand with respect to P_B from equation (14.20-L) is 1.3 (-1.16 due to the change in price relative to P_R plus 2.46 due to the change in price relative to P_P). If the complementarity effect is considered negligible, as indicated by (14.20-F), then the elasticity of demand with respect to P_B is approximately -1.0.

Shifts in Demand

Forces influencing demand have not remained constant, even for building repairs, and the relatively stable demand indicated by the equations results from opposing forces. We would expect the increasing output of agriculture directly to require more operating inputs. But more efficient use of resources, shifts in consumer demand and other structural changes reduce requirements for some resources.

Purchase of repairs was not commensurate with the 30 percent increased investment in farm buildings from 1926 to 1959. The necessity for repair of these buildings may be offset by other forces reducing demand for building repairs. Because of shifts in consumer demand for butter, a large investment in dairy barns and equipment is obsolete. Decreases in the number of farms, development of more durable and flexible construction materials, and adoption of certain farm practices also reduce building repair needs. Consolidation of farm units often makes the second set of buildings of little use; the marginal value product of obsolete buildings sometimes is greatest when used as repairs for other buildings. Such repairs are not included in Q_{BR}, the measure used in this report. The substitution of durable items such as bricks or blocks for wood in construction also lessens the need for repairs. Finally, bailing hay, storing shelled corn in steel bins, and other changes in farm practices tend to reduce demand for building repairs.

Trends and Projections

A highly volatile trend in purchases of building repairs is depicted in Figure 14.4. Inputs of building repairs fell sharply during the depression years but after 1936 recovered to the high pre-depression level. Sales made a rapid recovery after World War II until 1948, then leveled off and finally began a gradual, somewhat regular decline after 1952. A secular trend is not apparent except perhaps after 1948. The large fluctuations suggested during the early years may partially be because of measurement errors in available data.

Quantities estimated by the distributed lag equation (14.21-O) fit the observed values reasonably well in the postwar period. The extrapolated value, Q_{BR}, from the equation for 1960 is 317 million 1947-49 dollars. The actual 1960 purchases, 311 million 1947-49 dollars, are overestimated by only 2 percent. Assuming average 1955-59 prices, and that the structural relationship embodied in equation (14.21-O) is relevant until 1965, the projected 1965 quantity is 277 million 1947-49 dollars. The projected quantity is approximately 12 percent below the predicted 1960 quantity. Examination of the recent tendency for the

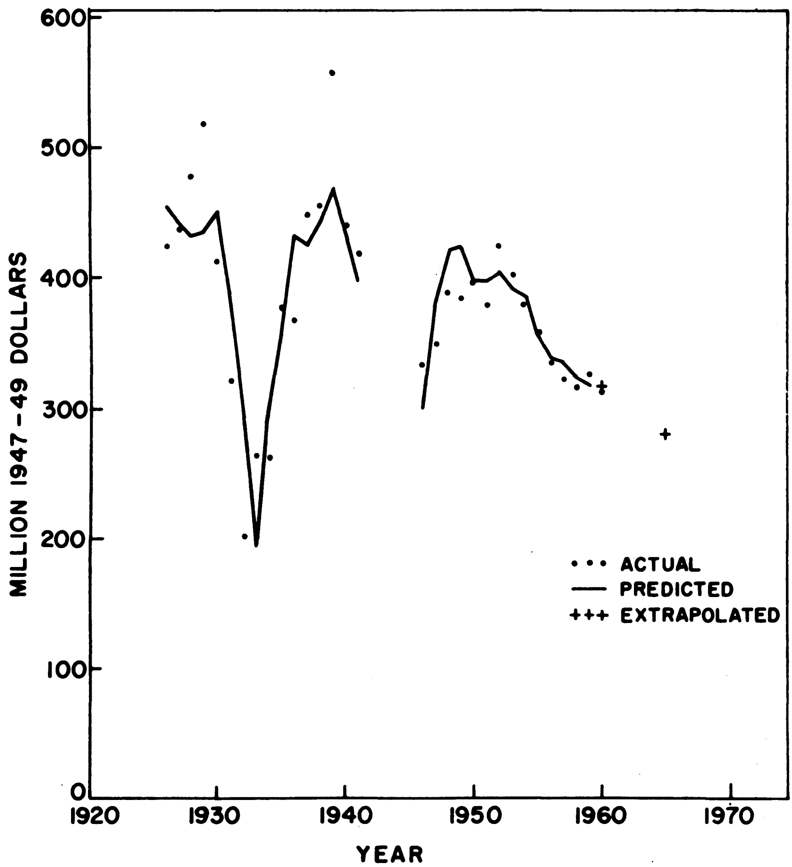

Figure 14.4. Trends in building repair purchases Q_{BR} from 1926 to 1960 (predicted and projected estimates from equation 14.21-O).

decline beginning in 1948 to level off, suggests that this projection may be overly pessimistic. Recent structural changes causing demand to fall less sharply may not be adequately represented in (14.21) because of the limited number of observations for the latest years.

DEMAND FOR MISCELLANEOUS OPERATING INPUTS

Minor operating inputs not included in the previous categories are classified as miscellaneous inputs. The category contains such heterogenous items as repairs by blacksmiths, expenditures for small hand tools and other hardware items, fire, crop and hail insurance, greenhouse and nursery supplies, binding materials, veterinary services and medicine, telephone, dairy supplies, livestock marketing services and milk hauling. Some of the items are not closely related to output but

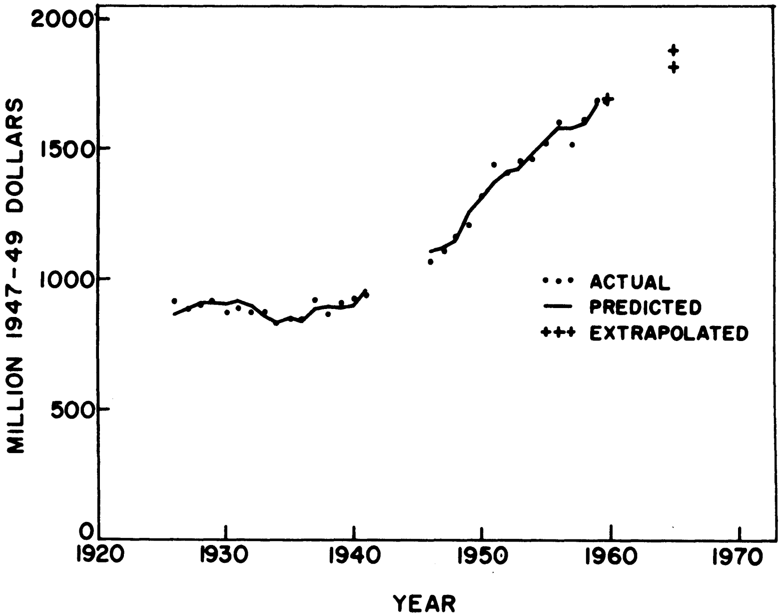

Figure 14.5. Trends in miscellaneous input purchases Q_{MI} from 1926 to 1960 (predicted and projected estimates from equation 14.24-O).

are fixed expenses or investments in minor durable items. The major portion of these inputs, however, falls within the definition of operating inputs discussed earlier. Since expenditures are not available by individual items, the entire grouping conveniently is classified and discussed within the framework of operating inputs.

Inputs of miscellaneous items increased 85 percent from 1926 to 1959, or at an average compound rate of 1.8 percent per year. During the same period, inputs of all agricultural resources increased only at the rate of .2 percent per year, or a total of only 5.5 percent. Hence, there was a net substitution of miscellaneous inputs for other inputs in the production process.

Specification of the Demand Function

In the following specification of the demand function, the quantity purchased is represented as a function of current and past prices of miscellaneous items, prices received and prices paid by farmers, inventories of productive assets, weather, government programs and slowly changing forces reflected by a time variable. Decisions to buy miscellaneous inputs are assumed to depend on both current and past year prices. Many of the items contained in the aggregate are a function of fixed resource levels as well as prices. Thus, the stock of productive assets is specified in the demand function to reflect changes in scale or plant size. Complementarity is anticipated between asset levels and purchases of miscellaneous items. The variables in the demand function are as follows:

Q_{MIt} = purchases of miscellaneous operating inputs by U.S. farmers during the current calendar year in millions of 1947-49 dollars.

$(P_{MI}/P_R)_t$ = the current year index of the ratio of prices paid by farmers for miscellaneous operating inputs (farm supplies) to the ratio of prices received by farmers for crops and livestock. Current and past year prices are included in the demand function.

$(P_{MI}/P_P)_{t-1}$ = the past year index of the ratio of prices paid by farmers for miscellaneous inputs to prices paid by farmers for items used in production including interest, taxes and wage rates. Since the simple correlation between current and past prices is high (r=.93), only past prices are included in the demand function.

Additional variables specified in the demand function are those explained earlier: the stock of productive assets, S_p, an index of government programs, G, the weather variable, W, and time, T. All variables are aggregate estimates for the United States from 1926 to 1959, 1942 to 1945 omitted.

The Estimated Demand Equations

Table 14.5 includes the five empirical demand functions estimated by least squares. The institutional variable as defined has little influence on demand, and is dropped from (14.22) to form (14.23). The coefficients of past year prices in (14.23) are of low significance. The past year prices may be important, but the current year price, P_{MI}/P_R, seems to be a "stronger" variable and absorbs the influence of the former. For predictive purposes, and to observe the influence of dropping the current price variable, (14.24) is estimated with lagged P_{MI}/P_R, S_p, W and T. The coefficients of lagged price and weather are significant at the 90 percent level in the logarithm equation. Since 99 percent of the annual variation about the mean of Q_{MI} is explained by the four independent variables in (14.24), it is used for predictive purposes. However, the coefficients of current price in (14.25) are larger in absolute terms and are significant at a higher probability level than those in equation (14.24). Coefficients of all variables, except T in (14.24), are significant at the 95 percent level. The d statistic indicates that autocorrelation is insignificant in the first two equations of (14.25).

Equation (14.25-F), a first-difference transformation, is included to aid in interpreting the price coefficients. The magnitudes of the

Table 14.5. Demand Functions for Miscellaneous Operating Inputs Q_{MI} Estimated by Least Squares With Annual Data From 1926 to 1959, Omitting 1942 to 1945 (Including Coefficients, Standard Errors in Parentheses, and Related Statistics)*

Equation and Transformation†	R^2	d‡	Constant	P_{MI}/P_R t	P_{MI}/P_R t-1	P_{MI}/P_P t-1	S_P t	G t	W t	T	Q_{MI} t-1
(14.22-O)	.99	1.90	-1689.76	-.44	.056	.13	29.96	-.59	1.16	.81	
				(.36)	(.557)	(2.43)	(2.99)	(.84)	(.59)	(1.81)	
(14.23-O)	.99	1.88	-1731.77	-.45	.16	.19	30.32		1.20	.44	
				(.35)	(.53)	(2.40)	(2.91)		(.58)	(1.71)	
(14.23-L)	.99	1.85	-1.62	-.067	-.018	.070	2.30		.097	.00043	
				(.050)	(.081)	(.265)	(.26)		(.046)	(.00063)	
(14.24-O)	.99	1.98	-1686.99		-.17		29.70		1.07	1.10	
					(.21)		(1.80)		(.56)	(1.53)	
(14.24-L)	.99	2.03	-1.34		-.057		2.20		.090	.00077	
					(.028)		(.15)		(.046)	(.00059)	
(14.25-O)	.99	1.93	-1674.40	-.30			29.93		1.11	.64	
				(.21)			(1.74)		(.53)	(1.53)	
(14.25-L)	.99	1.82	-1.41	-.070			2.24		.097	.00050	
				(.027)			(.14)		(.043)	(.00059)	
(14.25-F)	.37	2.53	-- §	-.62			28.01		1.29	2.51	
				(.43)			(8.12)		(.59)	-- §	
(14.26-O)	.98	2.55	46.59	-.43						3.71	.892
				(.29)						(2.03)	(.075)
(14.26-L)	.98	2.73	.52	-.074						.00140	.864
				(.037)						(.00076)	(.076)

*For sources and composition of the dependent variable, Q_{MI}, and the indicated independent variables, see text and Table 14.1.

†Equations are estimated in the transformations indicated: original values, O, logarithms, L (T is in original values in L equations), and first differences of original values, F.

‡The Durbin-Watson autocorrelation statistic d.

§The intercept or constant coefficient in the first-difference equation is comparable to the coefficient of T in the O and L equations. The standard error of the coefficient was not computed.

price coefficients in (14.25-F) and (14.25-L) are comparable with respective estimates -.08 and -.07 for price elasticities of demand.

The coefficient of the stock of productive assets, S_p, is highly significant in all equations. The trend in this variable is somewhat related to the time variable and may tend to reflect some of the influences usually associated with the latter, since the coefficient of T is not significant. The inclusion of S_p is intended to make the equations short run. As with other operating inputs, the coefficient of a lagged dependent variable added to equation (14.25) was not significant. (Equations including both S_p and Q_{MIt-1} are not included in Table 14.5.) The implication is that there is little influence of lagged prices, Q_{MIt-1}, and other past influences represented by Q_{MIt-1} on current demand quantities, if the scale of plant is fixed.

Equation (14.26-O) is estimated with S_p excluded as an approximate indication of demand when the agricultural plant size is allowed to vary. Weather, which appeared to be of some importance in explaining demand for Q_{MI} in equations (14.24) to (14.25), is not included. The short-run price coefficients in the equation are similar in magnitude to those estimated in (14.25). The distributed lag equation (14.26-L) indicates that adjustments of purchases to price changes occur slowly, approximately 13 percent in the short run.

Price Elasticity of Demand

The point estimate and 95 percent confidence interval of the short-run price elasticity of demand for Q_{MI} with respect to P_{MI} computed from (14.25-L) is $-.07 \pm .056$. The short-run elasticity with respect to P_R is of the same magnitude but positive in sign. The results indicate that the short-run demand for miscellaneous inputs is highly inelastic. A 10 percent fall in P_{MI} could be expected to increase purchases less than 1 percent. The low price elasticity of demand for miscellaneous inputs may be explained by: (a) the minor importance of the individual components of the inputs in the farm budget, (b) the fact that some components of Q_{MI} are related to family living as well as production and (c) a strong complementarity of miscellaneous inputs with fixed assets which are relatively unresponsive to short-run price changes. Electricity and the telephone, for example, are closely related to family living expenses as well as production, and their use is often unresponsive to price changes. Insurance also tends to remain a relatively stable "quantity" in the short run despite changes in the price of insurance. Particular repairs and operating supplies are necessary to keep major machines and equipment in use, and expenditures for such items tend to remain at fixed levels if any production takes place.

The long-run elasticity of miscellaneous inputs with respect to P_R is found from the relationship between Q_{MI} and S_p in demand equation (14.25). Each of the three forms of the equation indicates that a 1 percent increase in S_p is associated with a 2.2 to 2.4 percent increase in

Q_{MI}. (The function for plant and equipment in Chapter 12 estimates the elasticity of S_p with respect to P_R to be approximately unity in the long run.) The implication above is that a sustained 1 percent rise in farm product prices potentially may increase demand for miscellaneous inputs by more than 2 percent. This arises from the strong complementarity of miscellaneous inputs with farm productive assets. Despite the inelastic response of miscellaneous inputs to short-run prices, the response in the long run may be large.[7] (The long run probably is more than 20 years away, according to results in Chapter 12.)

Shifts in Demand

Only a small portion (about 3 percent) of the 83 percent increase in purchases of miscellaneous operating inputs from 1926 to 1959 is explained by short-term price changes. Interpreted literally, the nonsignificant coefficient for T in equation (14.25) would indicate that there have been no shifts in demand for Q_{MI} that cannot be explained by the requirement to service the growing agricultural plant S_p. Technological changes which occur and are adopted at a slow rate may correlate more closely with S_p than T. Innovations decrease demand for certain inputs, and this tendency is evident in several components of Q_{MI}. Examples are blacksmith repairs, binder twine and dairy supplies used for butterfat production.

Trends and Projections

The general trend in purchases of miscellaneous inputs has been similar to that found previously for other categories of operating inputs. Purchases dropped slightly during the depression. Following the depression, purchases began an upward trend which persisted except for some short-run interruptions until 1960. Equation (14.24-O) predicts the actual observations quite well throughout the 33 year period, and the extrapolation to 1960 overestimates the actual observation by less than 1 percent. Since this equation does not contain current prices, the prediction is made from past values of P_{MI}/P_R, S_p and from T. Projections of Q_{MI} for 1965 are made assuming prices at 1955-59 levels and that the structure of demand indicated by the equation will remain applicable. Projections are based on two levels of S_p. The lower level is based on USDA estimates and agrees with projections from (12.23). The higher estimate of S_p is found from an investment equation containing an accelerator coefficient (Cf. equation (12.28)). Under the above assumptions, equation (14.24-O) projects the 1965 demand quantity to be 7 or 11 percent above the 1960 predicted quantity, depending on whether the higher or lower estimate of S_p is used.

[7]The correlation of S_p with technological and other gradual changes in farming may impart positive bias to the coefficient of S_p.

SUMMARY OF EMPIRICAL RESULTS

The demand structures for five individual operating inputs have been estimated in this chapter. The generalized results, based on the "most reasonable equations" of each section, are summarized in Table 14.6. Despite similar trends in prices and quantities of several of the indicated operating inputs, the estimates of price effects and projected quantities often are dissimilar. The empirical results suggest that the short-run price elasticity of motor supplies, building repairs and feed is approximately unity. Seed and miscellaneous inputs evidently are unresponsive to short-run price changes.

The equations including a variable S_p for the scale of the agricultural plant generally provided the most meaningful structural demand functions. The coefficients of lagged dependent variable, introduced as a predetermined variable in equations containing S_p, were generally nonsignificant. This finding suggests that there are no long-run adjustments of operating input purchases, given the agricultural plant size. In the long run, the stock of productive assets is responsive to prices, and input of complementarity operating inputs is determined accordingly. The long-run elasticity of operating inputs with respect to product prices P_R thus is large because the latter variable has a strong influence on S_p.

Table 14.6. Summary of the Analysis of Demand Structure for Five Operating Inputs, including Short-run Demand Elasticities, Structural Changes and Projections of Quantities*

	Input				
	Q_S	Q_{MS}	Q_{Fd}	Q_{BR}	Q_{MI}
Approximate short-run demand elasticity estimates with respect to:					
P_i (own price)	0.0	-1.0	-1.0	-1.0	-0.1
P_R	0.0	0.3	1.0†	1.0	0.1
Estimated percentage change in demand quantity from 1926 to 1959 due to short-run price changes ‡	-15	119	12	15	3
Actual percentage change in demand quantity, 1926 to 1959 ‡	212	365	218	-19	83
Projected percentage change in demand quantity from all sources, 1960 to 1965 §	12	10	12	-12	9

*See the respective sections for input codes, sources of data, type of analysis, qualifications of findings and other information.

†Elasticity with respect to P_{Lk} rather than P_R.

‡The difference between changes due to price and actual changes is explained by lagged adjustment to price, changes in investment in durable assets, farm size, technology, education and improved management.

§When projections were made from two estimates of S_p, the table contains only an average of the separate estimates.

Purchases of operating inputs are projected to increase from 9 percent (Q_{MI}) to 12 percent (Q_{Sd} and Q_{Fd}), except for building repairs. Their purchases are expected to decrease from 1960 to 1965 in constant dollars. The above findings are conditioned, of course, by limitations of the data and by other inadequacies of the models employed.