13.

The Market Structure of Operating Inputs

OPERATING inputs perhaps are more closely associated with the rising total output, output per man hour and output per unit of all resources in agriculture than any other particular class of inputs. Operating inputs, sometimes called working capital, include materials representing new biological and chemical innovations, fuel and other items representing mechanical innovations. Operating inputs increased by approximately 200 percent between 1926 to 1960, a period in which total farm employment declined by 43 percent, machinery inventories increased by nearly 80 percent and farm output increased by 70 percent. Accompanying these changes was an increase of 280 percent of productivity per man hour and 60 percent in output per unit of all inputs.

Current operating inputs are here defined as purchased, capital inputs which are consumed and transformed into products in a single year. These nondurable resources generally are not stored on farms for extended periods, but are purchased by farmers in quantities considered appropriate for the needs of the forthcoming production period. The profitability of these items depends on prices and output in the current year, thus less judgment has to be made of economic conditions in future years. They do not ordinarily give rise to a fixed plant, although the productivity of this working capital partly is a function of the durable resource with which they are used. Because of divisibility, expendability and other characteristics listed above, operating inputs are the most flexible of the major farm resources.

The following inputs are included in the category of current operating inputs: (a) fertilizer and lime, (b) seed, (c) machinery supplies, including fuel, lubrication and repairs, (d) building repairs, (e) feed, (f) livestock and (g) miscellaneous inputs such as dairy supplies, hand tools, twine, etc.[1] Inter-farm sales of feed, seed and livestock are excluded. These several inputs are considered as a single aggregate in this chapter. A previous chapter included a detailed analysis of

[1] Sources of data and aggregation procedures and criteria are in Tweeten, Luther G. An Economic Analysis of the Resource Structure of United States Agriculture. Unpublished Ph.D. Thesis. Library, Iowa State University. Ames. 1962. Chap. 5. Only the nonfarm share of livestock, feed and seed sales are included. The portion for livestock, for example, includes mainly marketing charges and is only a small proportion of total farm expenditures for livestock in the current year.

fertilizer demand. Demand structure for five additional component categories are included in the following chapter.

Several hypotheses potentially explaining the growth in use of operating inputs are: (a) relative prices of operating inputs have fallen, encouraging greater input of these resources for agricultural production and causing substitution of them for other resources, (b) growing inventories of durable assets such as machinery have increased demand for operating inputs because of strong complementarity between the resources and (c) introduction of new and improved operating inputs have increased their marginal productivity, causing demand to grow because of higher transformation rates. This last condition includes not only new discoveries of their existence and productivity but also greater farmer knowledge of them. As mentioned in Chapters 2 and 4, economic development provides conditions for joint occurrence of these hypotheses. A decline in the relative price may be due to technological changes or decreasing costs in nonfarm industries which supply operating items. A fall in the price of operating inputs may encourage their use and further research on their discovery and productivity. Also a declining real price (hypothesis a) may encourage investment in durable assets and indirectly increase demand for operating inputs through complementarity (hypothesis b). Because all the above conditions influence purchase of operating items, no attempt is made to select one hypothesis from among the set for particular verification. Instead, we attempt a quantitative measure of the existence of all of them.

Demand for operating inputs in aggregate at the farm level is estimated by least-squares and limited information techniques. The supply function for operating inputs is also estimated by limited information. Conditions suggesting that major criteria for aggregation are met in use of the category as a single resource include: Trends in prices of the several components of operating inputs are similar.[2] With the exception of building repairs, trends in purchases of individual categories are somewhat similar over the time period. Since there are, however, obvious advantages in considering demand relationships for separate operating inputs, demand functions are estimated individually for five categories of operating inputs in the following chapter.

TRENDS IN PRICES AND QUANTITIES

Current operating inputs serve as substitutes for some categories of resources and as technical complements for others. Thus, decline in relative prices and growth in knowledge of productivity of various operating inputs have caused divergent trends in their use relative to other categories of farm resources. These variations might be grounds for arguing that demand for current inputs should be considered only in less aggregate categories. However, because certain sectors of the

[2] Ibid., Chap. 4.

economy have interest in the more aggregate category, we attempt to estimate economic relationships surrounding it.

To better visualize patterns of interrelationships between aggregate operating inputs and other broad categories of farm resources, detailed analysis is made of historic trends in this chapter. Figures 13.1 through 13.4 trace trends in the ratio of price and use for operating inputs as compared to three other resources and to output. Each figure contains graphs of P_O/P_i and Q_O/Q_i where P_O and Q_O are respectively the price and quantity of operating inputs and P_i and Q_i are the respective price and quantity of other major farm resources (or farm output). Substitution is expected as a result of price trends since generally P_O has fallen relative to other prices, P_i (i.e. the ratio of Q_O to Q_i is expected to rise). If a decline in P_O/P_i is not accompanied by a rise in Q_O/Q_i, a complementary effect prevails or price effects may be obscured by more fundamental technological or other phenomena.

Figure 13.1 includes comparison in the ratios of (a) operating inputs, Q'_O, to machinery inputs, Q'_M, and (b) operating input price, P_O, to machinery price, P_M, for 1910-59.[3] Prices of operating inputs have declined relative to machinery prices since the late 1920's. The quantity ratio, however, remained quite stable, except for the war periods. Increases in the ratio for 1917-19 and 1942-48 were due mainly to machinery shortages. Farmers substituted operating inputs for machinery by working the old tractors, for example, longer hours. Because motor supplies in general are complements of machinery and are an important component of Q'_O, a tendency exists for complementarity between Q'_O and Q'_M. Other components of Q'_O, such as weedicides, allow crop production with fewer tillage operations; hence a tendency also

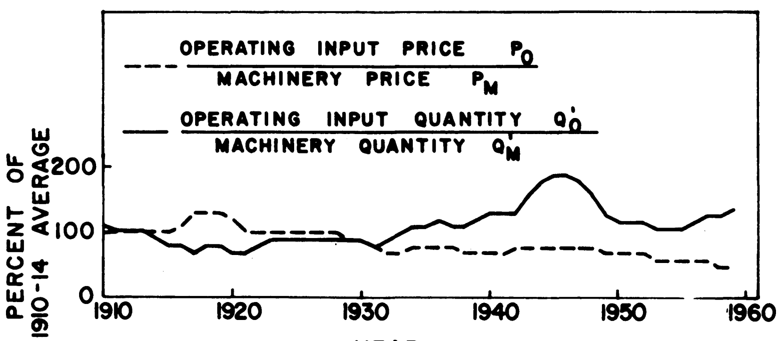

Figure 13.1. Ratios of farm operating input and machinery prices and quantities from 1910 to 1959 (1910-14=100).

[3] Machinery inputs Q'_M are valued as services required to maintain farm equipment and motor vehicles used for productive purposes. Q'_M includes depreciation, license fees, insurance and interest on inventory.

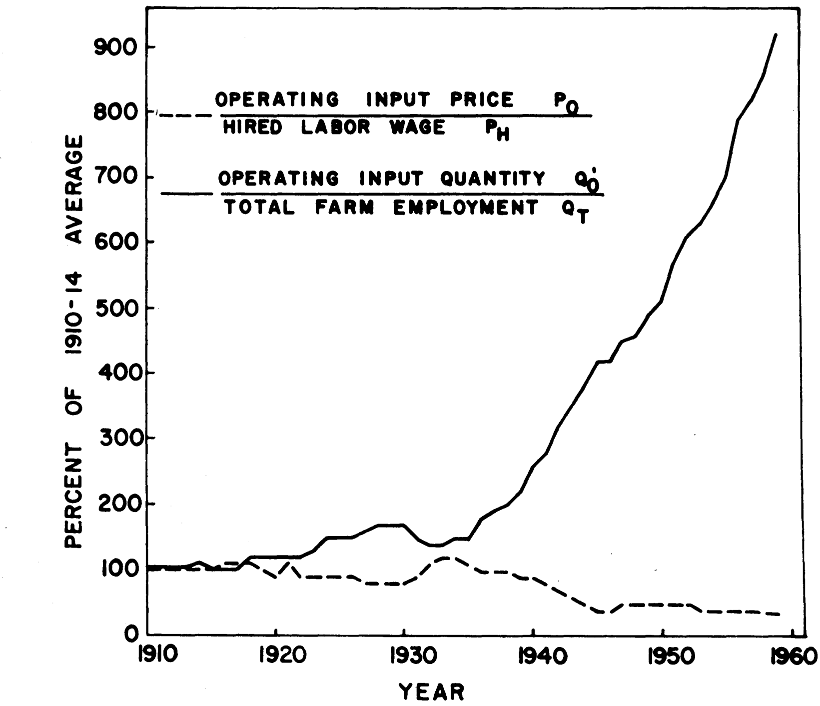

Figure 13.2. Ratios of farm operating input and labor prices and quantities from 1910 to 1959 (1910-14=100).

exists for substitution of Q_O' for Q_M'. These forces influencing the ratio of operating to machinery inputs to a large extent have offset each other over the period 1910-60.

Figure 13.2 includes similar comparisons for operating inputs and labor prices and quantities from 1910 to 1959. Increase in operating inputs was associated with a sharp decrease in labor after 1935; the substitution was at a slower rate before 1935. Substitution is consistent with trends in relative prices of the two inputs over the 50-year period.

While the price of operating inputs relative to labor price declined by 60 percent in the period 1910-59, the quantity ratio increased 800 percent. This suggests a "gross" price elasticity of substitution of approximately -13. (It is "gross" since other forces not included also influenced the ratio of Q_O' to Q_T.) Machinery, for example, is a principal and direct substitute for labor. Since Q_O' and Q_M' are complements, the ratio of Q_O' to Q_T increases concurrently with the ratio of Q_M' to Q_T. Figure 13.2 illustrates, however, the indirect substitution of operating inputs for labor in a developing agriculture. Commercial fertilizer, for example, permits the same or more output with fewer labor resources.

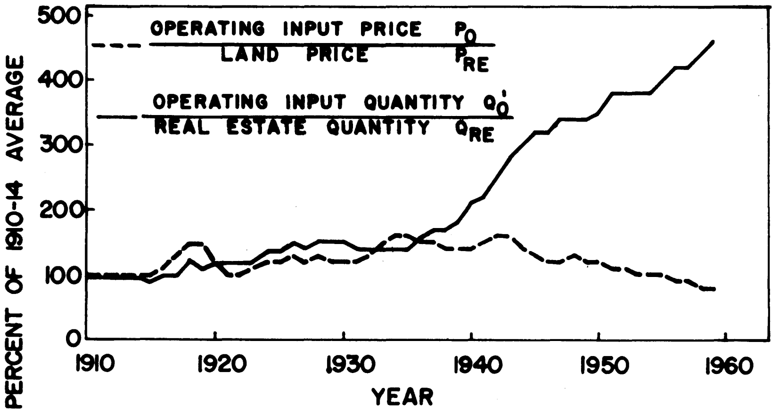

Figure 13.3. Ratios of farm operating input and real estate prices and quantities, 1910-59 (1910-14=100).

Figure 13.3 compares similar ratios of price and input quantity for operating inputs and real estate. Real estate input, Q_{RE}, is measured as interest on investment and other costs necessary to maintain the real estate investment. A tendency to substitute Q'_O for real estate inputs is prominent after the mid-1930's when operating inputs such as hybrid corn and fertilizer were becoming widely accepted. These inputs allow more output without a corresponding increase in the land resource. The price of operating inputs declined 20 percent relative to real estate prices over the 50 years, and the quantity ratio Q'_O/Q_{RE} increased 350 percent. The "gross" price substitution elasticity, -17, exaggerates the actual substitution rate because of confounding with other technological changes and price factors.

Figure 13.4 shows quantity and price ratios for operating inputs and farm output, O. P_R is prices received by farmers for crops and

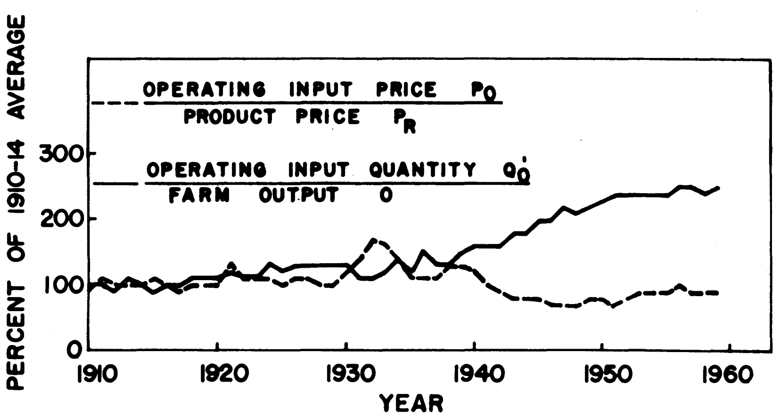

Figure 13.4. Ratios of farm operating input and farm output prices and quantities from 1910 to 1959 (1910-14=100).

livestock. The price ratio P_O/P_R increased during the depression years, remained relatively uniform until 1940, and then declined slightly. Inputs of Q'_O relative to O increased accordingly, rising approximately 120 percent from 1910 to 1959.

The above figures particularly emphasize the gross substitution of operating items for labor and real estate. The ratio of Q_O to other major classes of inputs has been associated with a decline in P_O relative to other prices. The substitution is also consistent with a more rapid increase in the marginal product of operating inputs than of other resources. Remaining sections include attempts at quantification of parameters of structures which determine the use of operating inputs.

THE DEMAND FOR OPERATING INPUTS

The demand function for operating inputs at the farm level is specified as

$$(13.1) \quad Q_O = f[(P_O/P_R)_t, (P_O/P_R)_{t-1}, (P_O/P'_P)_t, (P_O/P'_P)_{t-1}, S_{pt}, W_t, G_t, T]$$

where the demand quantity, Q_O, is a function of operating input prices, P_O, prices received for crops and livestock, P_R, and prices paid for hired labor and machinery, P'_P.[4] S_p is the January 1 stock of productive assets, W is a measure of the influence of weather, G is an institutional variable indicating the existence of acreage controls and price supports and T is time. In the model, t refers to the current year, t-1 to the past year.

[4] It is useful to note that the ratio form (a) below, indicated in equation (13.1) and used in this study, differs somewhat from the form (b) suggested by static economic theory. The two alternative least-squares input demand forms with input price P_i, other input prices P_P and prices received P_R are:

$$\text{(a)} \qquad Q_i = a + b\frac{P_i}{P_R} + c\frac{P_i}{P_P} + e$$

as in equation (13.1) above, and

$$\text{(b)} \qquad Q'_i = a' + b'\frac{P_i}{P_R} + c'\frac{P_P}{P_R} + e'$$

as in the static theory model. If the data are transformed into logarithms, the price elasticities of demand E with respect to prices in the above forms (a) and (b) are:

$$E(P_i) = b + c \text{ in (a); } b' \text{ in (b)}$$
$$E(P_P) = -c \text{ in (a); } c' \text{ in (b)}$$
$$E(P_R) = -b \text{ in (a); } -b' - c' \text{ in (b).}$$

Since input prices P_i and P_P often are highly correlated, the matrix of price variables in form (b) may tend to be singular; the coefficients b′ and c′ unstable and none of the elasticities estimated accurately. In form (a), the standard error of c is likely to be large and c insignificant. This does not necessarily preclude obtaining a realistic estimate of b. Hence, there appears to be some advantage in using form (a).

The Variables

The variables are defined specifically as:

Q_{Ot} = the weighted national aggregate of fertilizer, seed, motor supplies, building repairs, feed, livestock and miscellaneous inputs. Quantities are aggregated by 1935-39 prices prior to 1940, and by 1947-49 prices after 1940. Overlapping values for 1940 are used to value the final aggregated series in 1947-49 million dollars. Inter-farm sales are excluded; hence only a small portion of total livestock purchases are included.

$(P_O/P_R)_t$ = the current year index of the ratio of operating input prices to prices received by farmers for crops and livestock. The past year index is also included. Prices are weighted by quantities using the above procedure.

$(P_O/P'_P)_{t-1}$ = the past year index of the ratio of operating input prices to prices paid by farmers for machinery and hired labor.

S_{pt} = the stock of productive assets on January 1 of the current year. The variable includes real estate, machinery, livestock, feed and cash inventories held for productive purposes, in billions of 1947-49 dollars.

G_t = a current year index of the role of government policies. Years of acreage allotments production controls are given the value -1. Years when farm prices are supported are assigned the value +1. If supports are fixed, an additional +1 is added. These values are summed to form G.

W_t = Stallings' index of the influence of weather on farm output in the current year.[5] Indices for 1958 and 1959 are not computed by Stalling, but are constructed from an index of deviations from a linear trend of crop yields.

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

All price indices are adjusted to a base 1947-49 = 100. The variables are annual data from 1926 to 1959, omitting 1942 to 1945.[6]

Equation 13.1 is a single-equation model of demand and assumes a monocausal structure based on the nature of the supply for operating inputs. Short-run changes in Q_O are not expected appreciably to influence P_O, P_R or other input prices. Also, purchases of Q_O probably have little influence on the stock of productive assets S_p in the short run. We assume that explanatory variables influence Q_O, but are not influenced by it, in the short run. Because logic and empirical data do not entirely support this assumption, it also is desirable to estimate the operating input demand in an interdependent economic system.

[5] Stallings, James L. Weather indexes. Journal of Farm Economics. 42:180-86. 1960.
[6] See Tweeten, op. cit., pp. 128, 129.

Hence, a simultaneous model of demand for operating inputs also is presented later. The variable specification is similar except that while a price ratio form is used in equation (13.1), prices of labor and machinery are included separately in the simultaneous model.

A more complete demand specification might include: (a) a farm income variable, (b) a farm size variable and (c) several categories of prices received and prices paid by farmers. Prices rather than income appear to be the relevant farmer decision variable in the demand function for operating inputs. Furthermore, income tends to be a function of prices, weather and technology variables already specified.

As farm size expands, a tendency exists to substitute additional motor supplies, fertilizer and other operating inputs for labor. Unfortunately, the very high correlation between farm size (cropland acres per farm) and the stock of productive assets, S_p, precludes including both variables in the statistical demand function. The coefficient of S_p must be interpreted as reflecting the influence of farm size as well as other scale effects.

It would be desirable to specify several categories of prices received for products and prices paid for inputs by farmers. High intercorrelations among prices over time prohibit such refinements. In fact, the high intercorrelations among input prices required the exclusion of the current year price ratio $(P_O / P'_P)_t$. The coefficient of the included past year ratio tends to reflect both current and past influences of P_O / P'_P on Q_O because of the high correlation in the time series.

The process by which farmers formulate price expectations and adjust input purchases to uncertain conditions may result in a demand pattern discussed extensively in the literature on the theory of distributed lags (see Chapter 3). Because of the time required for production, farmers maximizing profit must base input purchases on expected prices formulated from knowledge of past prices. It may be argued that prices lagged no more than one or two years provide a satisfactory estimate of farmers' price expectations in operating input demand functions. Input prices are determined primarily by slowly changing variables such as the nonfarm wage rate. Hence, prices of nonfarm produced inputs display very small annual variation and are free of cyclical fluctuations so characteristic of many farm product prices. Since input prices are known with considerable certainty when production plans are made, the principal expectation variable is output price. The nondurable production inputs are consumed in the forthcoming production period; hence their expected profitability is not a function of prices in several future production periods. It seems reasonable to assume that farmer decisions regarding the immediate future are based on the immediate past. Thus, inclusion of product price variables for only one or two past production periods appears adequate.

A second source of a distributed lag model of demand is a lagged adjustment to the equilibrium level of input, given prices and other predetermined variables. That is, a farmer who is subjectively certain of prices may adjust slowly to a profit maximizing level of resource use because of inertia of past decisions, institutional restraints, large investment requirements or indivisibility of inputs (see Chapter 3). The most logical source of the lagged adjustment to the desired Q_O level likely arises from incomplete knowledge or skepticism by farmers of the increased profitability, convenience and other advantages of using more operating inputs.

The inclusion of the productive assets, S_p, in the demand function adjusts for changes in scale of the farm plant. Hence, equation (13.1) is the short-run demand for Q_O, i.e., the demand for operating inputs given the plant size. The influence of S_p on the demand quantity depends on the interaction between Q_O and S_p and on the fixed level of productive assets. Higher levels of S_p might be expected to increase marginal productivity (and demand) for Q_O.

Least-Squares Demand Equations for Operating Inputs

Economic theory, introspection and logic do not dictate an exact demand function. The appropriateness of a given set of variables or form of the distributed lag cannot be determined solely from a priori considerations. To demonstrate the effect of alternative specifications several empirical forms are presented. The procedure in this section is to estimate (a) conventional models with short-run lags and (b) distributed lag models of the Koyck-Nerlove type. The functions include different sets of explanatory variables, beginning with models as completely specified as practical limitations of data and estimational procedures permit. Variables considered inappropriate because of low significance or high intercorrelation with other variables are deleted in subsequent regressions. All equations are estimated in original data (O) and in data transformed to logarithms (L). The two dummy variables, time, T, and government policies, G, are not well suited for logarithmic transformation. Hence, equations containing both variables are estimated in original data only. Where the Durbin-Watson test indicates probable autocorrelation in residuals, the equation also is run in first differences.

Single-equation least-squares estimates of the demand for Q_O as a function of price and other variables are presented in Table 13.1. The seven independent variables in equation (13.2) "explain" over 99 percent of the annual variation about the mean of Q_O.[7] The unusually high R^2 is

[7] The term "explain" is a somewhat inexact generalization of the statistical multiple coefficient of determination R^2. R^2 is the ratio of the sum of squares of the estimated values of the dependent variable to the sum of squares of the actual values of the dependent variable. The R^2 may also be considered the square of the multiple correlation coefficient R between the dependent variable and a linear function of the independent variables. The R^2 may be made equal to 1 by including one less explanatory variable than the number of observations. The adjusted multiple coefficient of determination $\bar{R}^2$ is corrected for the influence of the number of explanatory variables.

Table 13.1. Demand Functions for Operating Inputs Q_O Estimated by Least Squares With Annual 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_O/P_R t	P_O/P_R t-1	P_O/P'_P t	P_O/P'_P t-1	S_P t	G t	W t	T	Q_O t-1
(13.2-O)	.997	1.42	-5939.07	-7.64	-1.89		-10.32	117.98	6.47	6.57	53.81	
				(1.94)	(2.19)		(4.89)	(9.58)	(5.30)	(2.64)	(14.60)	
(13.3-O)	.996	1.21	-4557.10	-7.61	-2.77		-13.93	113.03		6.37	46.78	
				(1.96)	(2.09)		(3.94)	(8.77)		(2.67)	(13.55)	
(13.3-L)	.991	.73	2.25	-.29	-.23		-.17	1.18		.115	.0086	
				(.10)	(.10)		(.19)	(.31)		(.079)	(.0018)	
(13.3-F)	.507	1.51	-§	-5.87	-2.35		-13.65	72.81		1.89	82.82	
				(1.98)	(2.02)		(6.39)	(27.15)		(2.05)	-§	
(13.4-O)	.994	1.04	-4511.47		-9.06		-13.41	105.93		5.23	57.56	
					(1.66)		(4.95)	(10.80)		(3.33)	(16.69)	
(13.4-L)	.988	.80	2.73		-.465		-.24	.94		.103	.0091	
					(.076)		(.21)	(.34)		(.090)	(.0021)	
(13.4-F)	.309	1.65	-§		-4.79		-9.95	61.40		1.21	98.86	
					(2.14)		(7.25)	(31.11)		(2.35)	-§	
(13.5-O)	.997	1.60	-488.55	-4.58		3.16					34.65	.879
				(1.13)		(4.30)					(11.87)	(.054)
(13.5-L)	.996	1.49	.75	-.237		.17					.0050	.780
				(.041)		(.15)					(.0012)	(.083)
(13.6-O)	.997	1.60	230.18	-4.28							28.74	.857
				(1.05)							(8.63)	(.045)
(13.6-L)	.996	1.40	1.39	-.233							.00417	.711
				(.041)							(.00091)	(.056)

*The dependent variable Q_O and the indicated independent variables are defined in the text.

†Equations are estimated in the transformations indicated: original values, O, logarithms, L (T is in original value 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.

caused by the tendency for aggregation to average out the error in Q_O. Also, a large proportion of the variability is due to the highly predictable trend variables S_p and T. The R^2 falls considerably when the functions are estimated in first differences of original values.

The coefficient of the institutional variable G is nonsignificant in the first equation and is deleted for the next one. There exists a high probability that the variable G used to represent the effect of government programs has no influence on Q_O. However, our inability to construct a better index of government policy does not necessarily mean that government programs lack influence on Q_O.

The Durbin-Watson test of the null hypothesis that the true residuals are uncorrelated is inconclusive in equation (13.3-O) and is rejected in equation (13.3-L). Hence, the equation is estimated in first differences of original values. After the first-difference transformation, the test for autocorrelation is still inconclusive.

The signs of the coefficients in all transformations of equation (13.3) are consistent with a priori theory, but the magnitudes of the coefficients differ among transformations. The influence of $(P_O/P_R)_{t-1}$ is stronger and the influence of $(P_O/P'_P)_{t-1}$ is weaker in (13.3-L) than in (13.3-O) and (13.3-F).

Some components of Q_O are expected to be influenced by current prices. These prices may not be available when needed by the economic forecaster, hence it may be necessary to base predictions on past values. The least-squares algorithm will result in a more efficient, though perhaps slightly biased, estimate of Q_O from equation (13.4), omitting $(P_O/P_R)_t$, than from equation (13.3) if only past values of the explanatory variables are known. Based on the sum of the price coefficients in (13.3), it appears that the coefficient of lagged price P_O/P_R in (13.4) tends to absorb the influence of current price. Failure to include the current price variable may not seriously bias the estimate if current and lagged values are sufficiently correlated. While we cannot accurately impute the entire price response to the lagged price variable, (13.4) explains a large portion of the variance in Q_O and is a useful predictive equation.

On the basis of equations (13.2), (13.3) and (13.4), it may be argued that the distributed lag model is not appropriate. A large proportion of the variance about the mean of Q_O is explained by the current and past year explanatory variables in these equations (untransformed data). It is also a fact that the current and past values of Q_O display a high serial correlation. The implication is that, from a statistical standpoint, the lagged quantity is likely to be highly correlated with a linear combination of the explanatory variables. In such instances, the matrix of predetermined variables tends to be singular and, statistically, we are unable to differentiate the influence of individual predetermined variables. The coefficients tend to be unstable, and statistical inference becomes difficult or impossible. The economic interpretation is that influence of past values of explanatory variables, represented in the demand equation by Q_{Ot-1}, on current quantity Q_{Ot} is expected to be small. Current demand quantity essentially is determined by exogenous variables of the current and past year. As an empirical test of this hypothesis, equations (13.3-O) and (13.3-L) were estimated with the addition of the predetermined variable Q_{Ot-1}. In the resulting equations (not included in the table) the coefficients of Q_{Ot-1} were highly nonsignificant. The implication is that farmers adjust operating input purchases to prices, scale of plant and technology in the short run. The adjustment coefficient is unitary according to these results, given the scale of plant.

This conclusion may be too restrictive since (13.5) and (13.6) indicate that if S_p is excluded, the coefficient of lagged quantity in the adjustment equations becomes highly significant. If it is not necessary to include S_p in the demand function (its significant coefficient reflects the lagged adjustment and technology effects that logically belong with variables T and Q_{Ot-1}), (13.5) and (13.6) are appropriate. Furthermore, the time variable could be removed and the price and lagged quantities could explain current demand for Q_O. The increase in demand quantity then would be entirely attributed to lagged adjustment to the secular price decline. While the preceding statements suggest the empirical results to be consistent with several alternative hypotheses, we cannot adequately distinguish the influence of adjustment to price changes, technology and scale of plant on purchases of Q_O. Variables reflecting these influences are too highly correlated through time and are subject to large error. Because of these limitations and the small sample size, two alternative methods of estimating long-run demand for operating inputs are considered. In the first, S_p is omitted and Q_{Ot-1} is included as an indication of long-run influences. From the resulting distributed lag equations, estimates of long-run and short-run elasticities and adjustment rates can be computed.

A second approach considers the long-run demand for Q_O to be a recursive process. Empirical results indicate there are no long-run influences of prices on Q_O, given the scale of plant indicated by S_p and technology indicated by T. But in the long run, prices do influence plant size. In equation (12.23), investment S_p is estimated as a function of farm income Y_F, but also can be expressed as a function of prices. Equation (12.23), estimated with original annual data from 1913 to 1959, omitting 1942 to 1947, may be written as

$$(13.7) \quad S_{pt} = K + .00017Y_{Ft-1} + .00011Y_{Ft-2} + .000056Y_{Ft-3}$$

where K represents the influence of time, weather and carryover of stock. Net income, Y_F, in millions of 1947-49 dollars, is translated to prices by a definitional equation:

$$(13.8) \qquad Y_{Ft} = K' + 209.46\ (P_R / P_P)_t$$

where P_R is prices received by farmers and P_P is prices paid by farmers for items used in production, including interest, taxes and wage rates. Equation (13.8) was estimated by least squares with annual data from 1910 to 1959, omitting 1942-45, but the price variable is the index of the ratio of P_R to P_P (1947-49 = 100) from 1946 to 1959 only.[8] The coefficient indicates that from 1946 to 1959 an increase of the parity index by one unit increased net farm income an average of slightly over 200 million 1947-49 dollars. K′ represents other influences such as weather, technology, etc., on farm income. The right side of (13.7) is substituted into (13.6) to define investment in terms of prices. This expression is then inserted into equation (13.3) to form the approximate "long-run" demand function:

$$(13.9) \qquad Q_O = K'' - 7.61(P_O/P_R)_t - 2.77(P_O/P_R)_{t-1} - 13.93(P_O/P'_P)_{t-1} + 4.01(P_R/P_P)_{t-1} + 2.67(P_R/P_P)_{t-2} + 1.33(P_R/P_P)_{t-3}$$

where K″ is the sum of the influences of weather, technology and errors in predicting Q_O. Equation (13.9) is included to demonstrate the methodology for deriving long-run demand. Because (13.7) contains a distributed lag and up to 20 years are required to adjust stocks to prices, (13.8) is still not the "full" long-run demand function for operating inputs.[9] Use of further lags, however, make the equation cumbersome.

Demand for Operating Inputs Estimated by Limited Information

The demand for Q_O also is estimated in an equation allowing prices and quantities of farm products and resources and farm numbers to be determined simultaneously. The limited information estimates of demand for operating inputs, computed with national aggregates of annual data from 1926 to 1959, excluding 1942 to 1945, are included in (13.10).

$$(13.10) \quad Q_O = -14 - \underset{[-2.23]}{110P_{Ot}} + \underset{[.51]}{25P_{Mt}} - \underset{[-.63]}{41P_{Ht}} + \underset{[1.12]}{112P_{Rt}} - \underset{[-.56]}{47N_t} - \underset{[-.078]}{2.9(P_O/P_R)_{t-i}} + \underset{[3.07]}{171S_{pt}} + \underset{[.0075]}{7.5G_t} + \underset{[.074]}{7.4W_t} - .40C_t$$

where P_M is farm machinery price, P_H is the wage rate of hired labor, N is farm numbers and C is a structural variable with values of zero in prewar years, 100 in postwar years. Other variables are discussed

[8] For the complete equation and others relating income and prices see Tweeten, op. cit., Appendix B.

[9] The nature of this lagged adjustment is not discussed in this chapter, but provision is made for the total long-run response of investment stock to prices in the later sections on price elasticities (see Model I, Chapter 10).

earlier in the chapter. Prices are deflated by the general price deflator of the Gross National Product (1947-49 = 100). The first six variables are endogenous; the remaining five are predetermined. Elasticities computed at the 1926-59 mean level of quantities are included in brackets below the coefficients. Standard errors were not computed.

With two exceptions, the signs of the coefficients are consistent with economic theory and with the results of past empirical studies. The equation indicates that the demand quantity Q_O increases as farm numbers decrease. Because total acreage is quite stable, the implication is that an increase in farm size is accompanied by an increase in demand for current operating inputs. The result may be due to the substitution of operating inputs for hired labor and machinery in the short run as additional land is purchased. A farmer who expands his operation by buying a contiguous unit of land tends to farm it with little additional machinery in the short run. In the long run, as his financial condition improves and his desire to reduce family labor requirements increases, he purchases additional large, more efficient machines.

Equation (13.10) approximately is homogeneous of degree zero with respect to prices. The equation is consistent with equations (13.2-O) and (13.4-O) in indicating the importance of current prices in the demand function. The signs of the P_O and P_R coefficients are as anticipated, but the magnitudes of the bracketed elasticities, unusually large, may be due to specification bias or to certain properties of limited information estimators. The coefficients of P_M and P_H indicate that operating inputs are short-run substitutes for machinery and complements of hired labor. The opposite relationship might have been expected, but a priori evidence on the nature of short-run substitutions is meager.

The coefficients of S_p, W and G are somewhat similar to those in equation (13.3). The coefficient of the structural variable, C, is very small, indicating that there has been little change in the demand structure not attributable to the other variables in equation (13.10).

PRICE ELASTICITIES OF DEMAND

This discussion of price elasticities rests particularly on short-run demand equation (13.2) and long-run equation (13.9). Considering first the elasticity with respect to P_O, some instability exists in the coefficients of the current and past year prices. Hence, the responses for these years are added and referred to as "short-run" price elasticity. The short-run price elasticity of demand for Q_O with respect to P_O/P_R is -.28, -.52 and -.22 computed from (13.2-O), (13.2-L) and (13.2-F), respectively. The elasticity of Q_O with respect to P_O/P_P' is -.36 from equation (13.2-O), -.17 from equation (13.2-L) and -.35 from equation (13.2-F). Thus, the total short-run elasticity with respect to P_O is -.64, -.69 and -.57 from the respective transformations. A 1 percent decrease in the price of operating items is expected to increase purchases by approximately .6 percent in the short run. The operating input price, P_O, does not explicitly occur in variables beyond the short run according to the long-run equation (13.9). A literal interpretation is that -.6 is also the long-run elasticity of Q_O with respect to P_O. P_O is a component of P_P, however, and for this reason the long-run elasticity is somewhat greater than -.6 due to the long-run influence of P_P on Q_O through the productive assets variable.

It is interesting to compare the estimate of the demand elasticity -.6 computed from equation (13.2) with the elasticities obtained from other estimational techniques: (a) a weighted average of the elasticities computed for the components of Q_O from the demand equations for five operating inputs estimated in the following chapter and the comparable demand equation for fertilizer in Chapter 7, (b) from the Koyck-Nerlove equation (13.5) and (c) from the limited information demand equation (13.10). The elasticity with respect to P_O estimated as a weighted average from the six components of Q_O discussed in Chapters 7 and 14 is -.66 and agrees closely with the single-aggregate estimate from equation (13.3).[10] The estimate of elasticity from the distributed lag equation (13.6-L) is -.2 in the short run, -.8 in the long run. This result is not necessarily in conflict with the -.6 estimate from (13.2). The lower estimate, -.2, is for the current year only and is expected to be small. The larger estimate, -.8, is for the long run, and if the component of P_O in P_P were included in the estimate from equation (13.2), the elasticity estimates for the long run from equations (13.2) and (13.6) might be very similar. The elasticity of Q_O with respect to P_O computed from the limited information demand equation (13.10) is -2.3. The estimate from the limited information technique may be too large because of specification errors or properties of the estimational technique. On the basis of statistical properties of the functions and past empirical studies, the results from the least-squares demand equations in Table 13.1 appear to be most realistic.

Thus far we have discussed the elasticity with respect to P_O. From a policy standpoint and for other reasons, the elasticity with respect to P_R is very important. The elasticity with respect to P_R computed from equation (13.3-O) is .28, from equation (13.6-L) is .22 in the short run. In the long run, an increase in P_R also increases Q_O through the investment process. Equation (13.9) suggests that after three or four years a 1 percent increase in P_R increases Q_O about .13 percent through S_p alone. The total intermediate-run (three or four years) elasticity with respect to P_R is estimated approximately at .28 plus .13, or .41. After several years a 1 percent increase in P_R may

[10] The weighted estimate of short-run demand elasticity -.66 computed from individual demand equations and the estimate -.6 from (13.2) differ somewhat in concept. First, inter-farm sales are excluded in Q_O but are included in the individual quantities (dependent variables) used in Chapter 14. However, the weights for the component demand elasticities are averages of constant dollar purchases from 1926 to 1959, omitting the war years, and excluding inter-farm sales. Second, the livestock component is included in Q_O but not in the component estimates from Chapters 7 and 14.

increase S_p as much as 1 percent. Since a 1 percent increase in S_p tends to increase Q_O approximately 2 percent according to equation (13.3), the long-run elasticity of Q_O with respect to P_R potentially is more than 2.0.[11] Purchases of operating inputs can be very responsive to prices received by farmers in the very long run.

DEMAND AND ECONOMIC DEVELOPMENT

Forces of economic development mentioned previously which might explain the increased use of operating inputs are: (a) falling relative prices of operating inputs, (b) increases in the level of durable assets which are complementary with operating inputs, (c) technological innovations, resulting in new inputs and increasing marginal productivities of existing inputs (including greater knowledge by farmers).

The first developmental force is represented by the variables P_O/P_R and P_O/P_P', the second by S_p and the third by T. The several forces are not unrelated in a developmental complex. Equation (13.4) suggests that all three forces have contributed significantly to growth in demand for operating inputs in the period 1926-59. Relative influences of these explanatory variables in the equation on demand quantity is suggested in the standard partial regression coefficients: -.13 for $(P_O/P_R)_{t-i}$, -.22 for $(P_O/P_P)_{t-1}$, .03 for W_t, .42 for S_p and .27 for T.[12] The results suggest little influence of weather on Q_O. The most important variable relating to change in demand quantity, from our formulation in (13.4), evidently is S_p, the stock of productive assets.

Aside from statistical significance and relative magnitudes of coefficients, the importance of a given variable in explaining the 216 percent

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[11] Elasticity derived from equations estimated in original observations are not strictly additive. That is, it is not completely accurate to multiply the elasticity of S_p with respect to P_R times the elasticity of Q_O with respect to S_p to find the elasticity of Q_O with respect to P_R. The correct procedure is to compute the coefficient of the influence of P_R on Q_O by the recursive process indicated in (13.9). This latter method is laborious, and it is sometimes more desirable from a computation and expository standpoint simply to multiply elasticities. Elasticities often are multiplied in this study for this reason, and in most instances the error is very small in relation to other possible sources of discrepancies.

[12] The standard partial regression coefficient b′ is computed as

$$\text{(a)} \qquad b_i' = b_i \sqrt{\frac{\sum x_i^2}{\sum y^2}}$$

where b_i is the multiple correlation coefficient, $\sum x_i^2$ is the corrected sum of squares for independent variable X_i, and $\sum y^2$ is the corrected sum of squares for the dependent variable. The standard partial regression coefficients are corrected for the estimated differences in variance and are intended to reflect the relative influence of the independent variables on Y. They are somewhat comparable to the usual estimates of elasticities E_i, of Y with respect to X_i, computed at the means, i.e.

$$\text{(b)} \qquad E_i = b_i \frac{\bar{X}_i}{\bar{Y}}$$

The elasticities are corrected by the ratio of the means; standard partial regressions by the square root of the ratio of estimated variances.

increase in Q_O from 1926 to 1959 also depends on trends in the explanatory variable over the period. P_O/P_R and P_O/P_P fell 17 and 60 percent respectively during the period. Equation (13.3-O) suggests that the falling real price of operating inputs might explain a third of the total Q_O increase. That is, if the short-run price variables in the equation are set at the 1959 level, with other variables left at the 1926 level, the predicted value of Q_O is 67 percent above the 1926 predicted value.[13] The stock of productive assets, S_p, rose 31 percent from 1926 to 1959. *Ceteris paribus*, the predicted demand for Q_O would have increased 112 percent alone because of complementarity with S_p. Setting the time variable at the 1959 value, to reflect "gross technical trends," and other variables at the 1926 values, equation (13.3) predicts an increase of 61 percent in Q_O. The sum of the three sources suggests a 240 percent increase. Hence, together the hypotheses "overexplain" the actual 216 percent increase in purchases of Q_O. While discrepancy arises from statistical error, the results indicate that the major source of increase in demand for operating inputs arises from the growth of productive assets. However, this conclusion must be qualified since S_p is one of several trend variables moving similarly through time.

Because of the high correlation between these trend variables reflecting the growth of productive assets, technological conditions, knowledge, managerial ability and long-run price effects, it is not possible to estimate the exact relative influence of each on Q_O from time series. Perhaps a more realistic statement is that about one-third of the total increase in purchases of Q_O from 1926 to 1959 is due to *short-run* price influences. The remaining two-thirds of the total increase is ascribed to interrelated technological and managerial influences, to complementarity with the growing agricultural plant, and to long-term adjustments to price. The variables other than short-run prices have moved similarly through time and have not registered observable individual effects. The increase in demand substantially can be "explained" in terms of any one of several correlated variables simply by inserting the "proper" trend variables in the demand function.

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[13] The estimated demand equation may be used as an approximate device to determine the sources of increasing demand from year 1 to year k. A least-squares demand equation with time subscripts for year i is of the form

(a) $$Q_i = a + bP_i + CT_i \qquad (i = 1,2, \cdots n)$$

where Q is predicted quantity, P is price and T is the demand shifter. Assuming the error in prediction is negligible, then the percentage change in Q from year 1 to year k due to P is

(b) $$\%\ \text{change} = \frac{b(P_k - P_1)}{Q_1} \cdot 100$$

and due to T is

(c) $$\%\ \text{change} = \frac{c(T_k - T_1)}{Q_1} \cdot 100.$$

TRENDS AND PROJECTIONS

Figure 13.5 compares actual and predicted values from (13.4-O) of Q_O from 1926 to 1959. Purchases fell sharply in the depression years of the early 1930's, but recovered quickly. Thereafter, inputs of Q_O tended to increase at a uniform rate except for interruptions in 1938 and 1953. The trend in the postwar era has continued upward and is nearly linear with no signs of saturation in demand growth. Predicted values of Q_O provide reasonably accurate ex post predictions of the actual data. The extrapolated value for 1960 underestimates the actual value by only 1.5 percent. However, even a linear trend fitted to the period 1946-59 also would provide predictions conforming closely with actual purchases.

The value of Q_O is projected to 1965 assuming prices at 1955-59

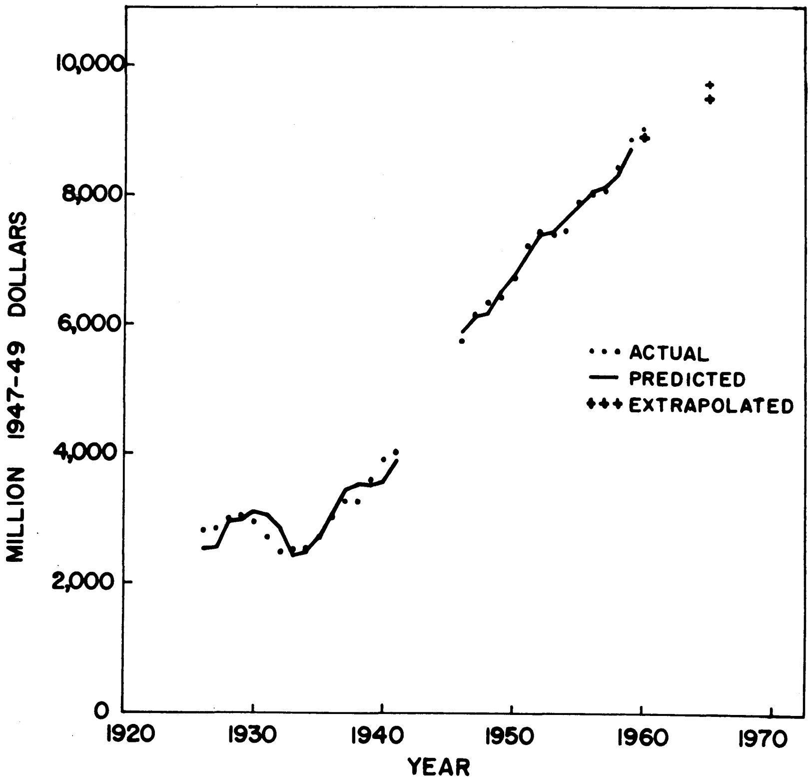

Figure 13.5. Trends in purchases of operating inputs Q_O from 1926 to 1960 (predicted and projected estimates from equation 13.3-0).

levels and that equation (13.4-O) is the appropriate demand relation.[14] Two estimates of S_p are used. The first is based on a USDA projection of 112.4 billion 1947-49 dollars by 1965. This projection agrees with the projected stocks from (13.7) assuming net farm income will remain at the 1955-59 level. A second estimate of S_p of 114.4 billion 1947-49 dollars by 1965 is based on an investment function (12.28) which contains an accelerator.[15] Stocks are estimated from this investment equation assuming farm output will increase 8 percent by 1965. The demand quantities so projected by equation (13.4-O) for 1965 are 7 and 10 percent above predicted 1960 levels if S_p is 112.4 or 114.4 billion dollars, respectively. Unless important changes in the demand structure occur, purchases of Q_O are expected to increase considerably by 1965. The standard error and confidence limits of the projected quantity are not computed, but are expected to be large for extrapolations several years ahead.

SUPPLY OF OPERATING INPUTS ESTIMATED BY LIMITED INFORMATION

We now consider the supply functions paralleling the demand function (13.10) in an interdependent model of market structure for operating inputs. A supply function for operating inputs, estimated by limited information techniques, is

$$P_{Ot} = 83.10 - \underset{(.064)}{.024Q_{Ot}} + \underset{(.46)}{1.37P_{Nt}} + \underset{(.10)}{.34C_t} \tag{13.11}$$

where P_N is the price of nonfarm labor, C is a structural variable with value zero in the prewar years, 100 in the postwar years. P_O and Q_O, the endogenous variables, were defined earlier. P_N and C are considered to be exogenous. The equation was estimated as part of an interdependent system of supply and demand equations for factor and product markets in agriculture from annual time series from 1926 to 1959, omitting 1942 to 1946.[16]

The standard error (in parentheses) of the coefficient of Q_O is more than twice as large as the coefficient. This evidence supports the hypothesis that the coefficient is zero and also supports our hypotheses that (a) the supply elasticity is very large in the short run and

[14] Values of the dependent variables are predicted only for years when values of the independent variables are known. If Q_O is a function of past year variables, the quantity of Q_O can be predicted for 1960 from known 1959 values of the explanatory variables. Estimates of the dependent variable outside the range of data to which the equation is fitted are called extrapolations. When the extrapolation involves arbitrary assumptions about the level of prices and other explanatory variables as for the year 1965, the estimates of the dependent variable are called projections.

[15] These projections should not be confused with those made for S_p in Chapter 12 where we project S_p to the end of 1965, in this section of the beginning of 1965.

[16] The entire interdependent model of agriculture is found in Tweeten, op. cit., Chap. 2.

(b) the price of operating inputs is determined largely in the nonfarm sector. The results are consistent with our previous assumption; namely, that the price, P_O , can be considered an exogenous variable in the least-squares demand functions for Q_O.

Equation (13.11) indicates that a 1 percent increase in nonfarm labor price is associated with a 1.2 percent increase in P_O , an important interrelation of economic forces in the farm and nonfarm sectors.

In a second limited information model, estimated with slight modifications, machinery purchases were adjusted to reflect the latent demand in 1946 and 1947. Also the weather variable, W, and government program variable, G, were omitted from the matrix of predetermined variables in the reduced-form equations. (All the equations except (13.11) of the limited information empirical equations included in this study are from the <u>second</u> formulation.) The changes in the coefficients of the supply equation (13.12), estimated from the second model, are a manifestation of the sensitivity of the model to a change in specification.

$$P_{Ot} = 63.89 - \underset{(.011)}{.034Q_{Ot}} + \underset{(.78)}{2.03P_{Nt}} + \underset{(.17)}{.47C_t} \tag{13.12}$$

The same variables are included as in equation (13.11); however, the magnitudes of the coefficients are somewhat larger in (13.12). The coefficient of Q_O is negative and large relative to the standard error. The positive coefficient of C would indicate that the real supply price (the price of operating inputs relative to the implicit price deflator of the Gross National Product) of operating inputs has increased in the postwar period. Equation (13.12) also might suggest the hypothesis that the real price of operating inputs has declined because of a negatively sloped supply curve rather than because of technological changes that would be indicated by a negative coefficient of C. However, because of the incomplete specification of the supply function and the particular characteristics of the limited information method, we rest no conclusions on equation (13.12).

SUMMARY OF EMPIRICAL RESULTS

The increase in annual purchases of operating inputs by more than 200 percent from 1926 to 1959 has been a particular reflection of economic development in agriculture. Nearly all operating inputs represent new capital forms. Some have increased in demand since they are complements with other innovations such as farm machinery. Others serve directly as substitutes for old capital forms, as in the case of new seed varieties and insecticides. On aggregate effect, operating inputs are strong substitutes for both land and labor. The great increase in their use unquestionably stems from both their favorable real price and increase in productivity.

Based on a priori considerations and the results of our statistical analysis, least-squares equations tended to give the most realistic and meaningful estimates of demand for operating inputs. Whether estimated from data in original values, logarithms or first differences, the several sets of least-squares estimates gave quite comparable results. However, logarithm equations explained slightly less of the annual variation in Q_O and displayed more evidence of autocorrelation in the residuals than the single equations in original values. The demand elasticity with respect to operating input price was estimated as -.6 in the short run. Since operating input prices lagged more than one year were not significant, the elasticity with respect to P_O appears to be not much greater in the long run than in the short run. According to the results in Table 13.1, the short-run demand elasticity with respect to farm prices received, P_R, is approximately .3. The long-run elasticity potentially is greater than 2.0 because of the influence of product prices on the scale of plant. The equations suggest that an increase of 1 percent in the scale of the agricultural plant S_p may increase demand for operating inputs 2 percent after several years. These estimates of elasticity are considered "gross" and need further verification. The following chapter treats individual items with more detail.