6.

Static Fertilizer Demand and Corn Supply

THIS CHAPTER examines short-run static demand functions for a particular resource fertilizer. The demand functions are static relationships derived from technical production functions, hence the demand parameters do not measure or reflect the actual behavior of farmers. The term "static" is used since the functions are derived to indicate demand quantities for various commodity and factor prices when it is supposed that these prices and the production function are known with certainty. That is, factor demand is derived in the manner of the algebraic illustrations and theory in Chapter 3.

Useful information about the level and elasticity of factor demand has important implications for farm policy proposals. One policy question posed is: How far would a return to free market prices or lower support prices reduce farm output, particularly that of feed grains? Adjustment to lower factor prices could come from either or both a shift in land out of the specified crops and less intensive production of the same crops on land remaining in production. The less intensive production would result as fewer inputs such as fertilizer are used on each acre.[1] Of course, a counterpart question is: Would further decreases in the real price of a resource such as fertilizer add as much to economic development (the use of more capital with given or less land and labor, with an extension of relative commodity supply) as it has in the decades of 1940-60? The answers to both questions depend on the elasticity of demand for the specified resource with respect to its own price, and its cross elasticity of demand with respect to commodity price. The commodity will be similarly related to the supply elasticity with respect to its own price, and the cross elasticity with respect to factor price. Accordingly, commodity supply functions, paralleling the factor demand functions, also are derived in this chapter.

The static demand and supply functions are not derived for national

[1] We are aware that most farmers do not use a resource such as fertilizer to a point where marginal cost equals marginal revenue. Hence, a decline in commodity price need not give rise to per acre adjustment of resource use in the magnitude suggested by short-run static demand functions of the nature derived in this chapter. On the other hand, we believe that if our static demand functions prove to have low elasticity in relevant ranges, the actual farm demand functions will equally have low elasticity.

or regional or state aggregates. Rather they are functions derived for a single acre, if input-output and price ratios are known and the objective were actually that of maximizing profits. The writers are well aware of the difference between these functions and those which arise from behavioral relations of farmers, and between these functions and the ones derived in later chapters.[2] They are aware of the fact that not all farmers are in a position to maximize profits and that many of them maximize other objectives. It also is known that, in fact, resources other than fertilizer are involved and that the production functions used in this study do not represent a random sample from the "population" of production units. Other cautions could be voiced. Yet, we consider the empirical derivations to be useful. No previous estimates have been derived, showing the possible relation of factor demand and product supply to physical production functions. They provide some unique insights into factor demand, not obtainable from later chapters based on time series data. Similarly, we believe that these functions are not, and will not be, unrelated to farmers' decisions and resource use. The functions derived are extremely <u>micro</u>, <u>short-run</u>, <u>normative</u>, <u>physically oriented</u>, or whatever else the reader may wish to call them. Still, they do show the potential structure of fertilizer demand and corn supply for the particular locations and environmental conditions under which the basic production functions were derived. The terms "long run" and "short run" as used in this chapter have an entirely different meaning from the same terms used in later chapters.

This chapter relates agricultural technology, as expressed in production functions estimated from experimental data, to the market phenomena of factor demand and product supply. The objective is to examine the nature of corn supply and fertilizer demand functions for a within-season period. The functions specify the yield component of demand or supply elasticity, or the supply elasticity assuming corn acreage is fixed and fertilizer is the variable resource. The analysis may be termed normative since the functions indicate what the supply and demand would be, based on production functions derived from fertilizer experiments, if farmers maximized profits under conditions where capital, institutional and behavioral restraints are unimportant. Such normative concepts are referred to simply as "static supply" and "static demand." Because farmers operate in a dynamic world in which prices and input-output relationships are not known with certainty and because the physical conditions on farms do not entirely parallel experimental conditions, the static supply and demand elasticities estimated in this study do not entirely parallel quantities expressed in the market and estimated in later chapters as aggregate behavior relations. Analysis of these differences suggests that the elasticity estimates in this study represent the upper boundary of the

[2] These and other considerations are discussed in Tweeten, Luther G., and Heady, Earl O. Short-run corn supply and fertilizer demand based on production functions derived from experimental data; a static analysis. Iowa Agr. Exp. Sta. Res. Bul. 507. June 1962.

actual short-run supply and demand elasticities. As such, the estimates indicate the maximum short-run production response which might be expected from farmers to changes in price for a given range of factor/commodity price ratios.

Ten production functions fitted to experimental data obtained in Iowa, Kansas, Michigan, North Carolina and Tennessee provide the basis for inferences about static supply and demand curves and elasticities. Because the sample of physical production functions is small, no attempt is made to aggregate functions and to infer quantitative results for U.S. agriculture. Instead, the procedure in the empirical section is to examine the degree of consistency of the estimated quantities with certain hypotheses suggested by economic and agronomic theory. The results of the analysis are consistent with the possible hypothesis that short-run static fertilizer demand and corn supply, in the framework of this chapter, are highly inelastic for farmers using average or profit-maximizing quantities of fertilizer. For all soil and weather conditions, and for all prices considered later, static corn supply elasticity is low. Without exception, supply is inelastic for corn prices over 40 cents per bushel and current fertilizer prices. The supply elasticity ranges from zero to less than .3 for corn prices above $1 and from zero to less than .2 for corn prices above $1.20 per bushel. Supply tends to be most elastic in situations where the soil is low in fertility but is otherwise satisfactory for corn production, i.e., adequate rainfall, good soil structure, etc. The analysis supports the hypothesis that considerable variation in supply elasticity exists among soil types and years within a given area such as Iowa.

The study shows that static corn supply and fertilizer demand elasticities increase as the price of corn falls or fertilizer increases. Because of limited data, demand and supply elasticities estimated for historic results of actual response by farmers to price changes generally consider the elasticity to be single valued. Thus, normative models of the type used in this study, which provide information on supply outside the range of historic data, are a useful supplement to descriptive or positive supply analysis which follows later. Static factor demand tends to be more elastic than static product supply as derived in this chapter. The price elasticity of short-run demand for nitrogen, for example, lies between .2 and 1.7, with the exception of one soil, when the price of nitrogen is .13 per pound. The demand for K_2O is more elastic than the demand for P_2O_5 which, in turn, is more elastic than the demand for nitrogen.

FRAMEWORK OF ESTIMATES

This chapter deals with supply and demand relationships for an extremely short-run period and for a single product and a restricted set of resources. More specifically, it provides estimates for normative supply functions for corn and normative demand functions for fertilizer as these are expressed in controlled experiments. The "length of run" considered supposes land and other resources to be fixed while only fertilizer is considered to be variable. Product supply functions and factor demand functions then are derived from the physical production functions estimated under experimental conditions. The general purpose of this approach is to determine whether potential response in production of a particular crop and use of a particular resource might be large or small, per acre, in relation to price changes.

Empirical supply and demand functions are derived separately for each year and location of the experiments explained later. No attempt is made to aggregate the functions or generalize the results for U.S. agriculture. Only corn-fertilizer production functions estimated under dryland conditions are used in this study for several reasons. First, a number of such functions have been fitted which represent various soil, moisture and other conditions influencing parameters of product supply and factor demand. These functions provide a more meaningful foundation for analysis of supply and demand than do the very limited number of functions fitted for other farm products and factors. Second, fertilizer inputs primarily determine the short-run (fixed acreage) corn supply response within the control of farmers. Agronomic experiments indicate that it is possible to increase corn yields by as much as 50 percent or more by application of fertilizer.[3] The opportunity within a year for farmers to adjust corn output per acre depends largely on fertilizer application. A third reason for selection of corn-fertilizer production functions is the importance of corn supply in the feed-grain surplus and the possible effect that various price policies might have on feed input and quantity of resources used. Although corn output is potentially responsive to fertilizer, farmers do not base production decision on physical possibilities alone. Their action is determined by a complex of conditions including input-output and price ratios, behavioral and institutional factors. For purposes of this chapter, we define short-run supply of a farm product as the various quantities which farmers would produce at all possible prices (a) if they maximized profits, given the production function and prices of inputs and outputs and (b) all factors but fertilizer (and its technical complements) were fixed. In subsequent sections of this chapter, this concept of short-run supply of a farm product is called "static supply."

A distribution of production functions exists for the various soil, technological and weather conditions found on farms throughout the country. The production functions contained in this study were estimated under experimental conditions where the variety, soil type and weather were "fixed." That is, each production function was estimated with various levels of fertilizer, but with given moisture, soil, seed variety, etc. These fixed conditions were probably more favorable for use of fertilizer than conditions found on most farms because:

[3] Heady, Earl O., Pesek, John T., and Brown, William G. Crop response surfaces and economic optima in fertilizer use. Iowa Agr. Exp. Sta. Res. Bul. 424. 1955. p. 304.

(1) experiments are likely to take place on soils where yields are responsive to fertilizer and (2) experimental data showing little or no yield response from fertilizer are often not published. Hence, the production functions cited in this study probably represent an above-average response to fertilizer (above-average marginal product of fertilizer) in terms of the total distribution of functions on farms.

There appears to be little clear a priori basis for expecting demand and supply elasticities computed from data showing above-average yield response to overestimate or underestimate static supply elasticity on farms. The elasticity is influenced by experimental conditions through a base effect and a slope effect. The base effect is due to the position of the static supply or demand curve, given the slope. If static supply is estimated under more favorable moisture or other conditions than found on farms, the actual demand and supply curves are likely to "lie further to the left" than are the static curves. Assuming the slopes are the same, the elasticity of the farm static supply or demand curve is underestimated. That is, the absolute change in supply quantity (slope effect) will be the same, but the percentage change in quantity computed from experimentally derived functions will be smaller because it is computed from a larger base.

The slope of the static supply curve relates to the production function through the slope of the marginal physical product. If the marginal product falls sharply to the right, the slope of the supply curve is steep. If resources other than fertilizer are not as limiting under experimental conditions as those found on farms, the marginal productivity of fertilizer may not fall as sharply, and therefore the supply curves may rise less steeply. The result of this condition is a tendency for the slope effect to overestimate the static supply elasticity on farms. In summary, if experimental conditions are more favorable for fertilizer response than those found on farms, the result may be underestimation of static supply elasticity on farms through the base effect and overestimation through the slope effect. These effects may offset one another to some extent.

Failure to specify all relevant economic factors in the production function which are variable in the short run may cause static supply elasticity on farms to differ from supply elasticity estimated from production functions. "Relevant" economic factors are those which potentially influence production, can be controlled by farmers and have a price. In this chapter static supply is estimated from production functions with only one, two, and in one instance, three variable factors, all of which are fertilizer nutrients. In general, only those fertilizer nutrients which gave no response were excluded. But other inputs, including measures to control weeds and insects, are relevant economic inputs in the short run on farms. Farmers can exhibit greater responsiveness to price changes when more inputs are variable. Hence, failure to specify inputs in the production function may cause underestimation of static supply elasticity on farms.

Production functions do not specify the effect of competing and complementing crops on corn output. The functions do not indicate how corn production would change in response to legume or soybean production through physical effects on corn yield. Also, the extent of residual response from fertilizer application is not specified. Although some fertilizer remains in the soil for longer periods, the production functions indicate only the corn yield response the same year the fertilizer is applied. Individual static demand and supply curves exist for the second and subsequent years of residual response. The "total" of static curves can be considered the sum of these annual curves. The "single year" curve necessarily would lie to the left of the total supply or demand curve, if response in all years were considered. Due to the base effect, the first-year curve likely would be more elastic than the total static supply or demand curve. The estimation of static supply and demand also depends on the adequacy of the algebraic forms used to express the physical relationships found in nature and the economic relationships in the market. The algebraic forms of the supply and demand relationships assume that corn and fertilizer are independent of other outputs and inputs in the market.

The marginal value product relates to static demand in the same way that marginal cost relates to static supply. Marginal cost and marginal value product are expressions of respective costs and returns which may be derived with knowledge of the production function and prices. These concepts do not indicate what farmers will do, but only describe quantities existing in nature. When the assumptions of profit maximization, etc., are made, these concepts form the basis for projected behavior of farmers. Defined as static supply and static demand, these concepts form an expository link between physical relationships and market prices.

PRODUCTION FUNCTIONS USED FOR ESTIMATES

The production functions used in this chapter represent broad soil, weather and other conditions which influence yield response and also supply and demand parameters. The production functions do not represent all of the corn-fertilizer functions which have been fitted to data and which are available. Some were considered inappropriate, due to an insufficient range of fertilizer application in the experimental treatments and were omitted. The analysis was restricted to published functions. In some instances it was necessary to select the most appropriate function from several acceptable functions fitted to the same data. Also, it was sometimes necessary to fix the level of factors such as moisture in the production function at "mean levels." Certain details of the functions are important in understanding the nature of the parameters which they estimate. In the following paragraphs the basic production functions used are presented, along with brief comments on the soil, weather and other pertinent conditions. The original sources may be consulted for further details. All functions and quantities are on a per-acre basis. Unless otherwise specified, Y is predicted bushels of corn, N is pounds of nitrogen, P is pounds of P_2O_5 and K is pounds of K_2O.

Equation (6.1), a quadratic form with three independent variables, was fitted to data from a 1954 experiment on Clarion silt loam in Iowa.[4]

$$(6.1) \quad Y = 58.7647 + 0.2088N + 0.1388P + 0.0825K - 0.000511N^2 - 0.000859P^2 - 0.000499K^2$$

Application of P_2O_5 and K_2O ranged up to 160 pounds. Nitrogen application ranged up to 320 pounds. Rainfall was limited, and marginal yields diminished rapidly.

Equation (6.2) was fitted to the data[5] from a 1953 experiment on calcareous variant Webster silty clay loam in Wright County, Iowa.

$$(6.2) \quad Y = 76.9263 - 0.1632N - 0.1430P + 3.6048N^{1/2} + 1.4606P^{1/2} + 0.1803N^{1/2}P^{1/2}$$

Nitrogen, P_2O_5 and K_2O were applied at rates up to 240, 120 and 80 pounds, respectively. None of the K_2O terms were significant and hence were omitted from the equation. Rainfall was adequate during most of the growing season.

Equation (6.3) was derived from a 1953 experiment with nitrogen, P_2O_5 and K_2O variable on Carrington silt loam in Iowa.[6] Nitrogen was applied up to 240 pounds; P_2O_5 and K_2O up to 120 and 80 pounds, respectively. The soil was highly fertile and a large response from fertilizer was not anticipated. P_2O_5 did not have a significant response, except interacting with K_2O, and was dropped from the equation.

$$(6.3) \quad Y = 99.223 - 0.04453N + 0.3162K + 0.9190N^{1/2} - 0.001813K^2$$

Data for equation (6.4) were obtained from a 1955 experiment also on Carrington silt loam.[7]

$$(6.4) \quad Y = 73.67811 + 0.06731P + 0.03000K - 0.000177P^2 - 0.000213K^2 + 0.000080PK$$

[4] Doll, John P., Heady, Earl O., and Pesek, John T. Fertilizer production functions for corn and oats; including an analysis of irrigated and residual response. Iowa Agr. and Home Econ. Exp. Sta. Res. Bul. 463. 1958. p. 367.

[5] Stritzel, Joseph Andrew. Agronomic and Economic Evaluation of Direct and Residual Crop Responses to Various Fertilizer Nutrients. Unpublished Ph.D. thesis. Iowa State University Library. Ames. 1958. p. 33.

[6] Brown, William G., Heady, Earl O., Pesek, John T., and Stritzel, Joseph A. Production functions, isoquants, isoclines and economic optima in corn fertilization for experiments with two and three variable nutrients. Iowa Agr. Exp. Sta. Res. Bul. 441. 1956. p. 809.

[7] Doll, Heady and Pesek, op. cit., p. 390.

Nitrogen was included in the experiment, but none of the direct and interaction effects of nitrogen was significant above the 50 percent level and they were therefore not included in the equation. The low rainfall in 1955 caused the yield response from nitrogen to be more limited than the response from other nutrients. Heaviest application of nitrogen was 240 pounds; P_2O_5 and K_2O, 160 pounds.

Equation (6.5) results from an experiment conducted on Wisner loam soil in the "thumb" area of Michigan in 1956.[8]

$$(6.5) \qquad Y = 104.1 + 0.07370N + 0.05002P - 0.0003316N^2 - 0.00005602P^2 - 0.00002546NP$$

The magnitude of the constant term indicates that the fertility level was probably high without any fertilizer application. The maximum application of nitrogen was: K_2O, 320 pounds and P_2O_5, 640 pounds. The small numerical values of the coefficients of the linear and squared terms suggest very little response to fertilizer. The interaction term, though negative, does not differ significantly from zero. Only 16 percent of the variability in yield was explained by nitrogen and P_2O_5.

In addition to the two-nutrient equations just listed, the square root equation (6.10) fitted to Ida silt loam data was used for this particular soil and year.[9]

An experiment conducted on the coastal plain of North Carolina provided data for equation (6.6).[10]

$$(6.6) \qquad Y = 15.4 + 0.6900N - 0.0029N^2$$

Nitrogen was applied in 20-pound increments up to 180 pounds. Weather was described as "dry."

Equation (6.7) was estimated from a 1955 experiment on Norfolk-like soils in North Carolina.[11]

$$(6.7) \qquad Y = 36.55 + 0.2369N - 0.00094N^2$$

The experiment included nitrogen, P_2O_5 and K_2O, but little response was exhibited to any nutrient except nitrogen. Equation (6.7) is a

[8] Sundquist, W. B., and Robertson, L. S., Jr. An economic analysis of some controlled fertilizer input-output experiments in Michigan. Michigan Agr. Exp. Sta. Tech. Bul. 269. 1959. p. 40.

[9] Heady, Pesek and Brown, op. cit., p. 304.

[10] Johnson, P. R. An Economic Analysis of Corn Fertilization in the Coastal Plains of North Carolina. Unpublished Ph.D. thesis. North Carolina State College Library, Raleigh. 1952.

[11] Hurst, D. C., and Mason, D. D. Some statistical aspects of the TVA North Carolina cooperative project on determination of yield response surfaces for corn. p. 213. In Baum, E. L., Heady, Earl O., Pesek, J. T., and Hildreth, C. C., eds. Economic and Technical Analysis of Fertilizer Innovations and Resource Use. Iowa State University Press, Ames. 1959. pp. 209-16.

simplified decoded form of the three-nutrient equation with P_2O_5 and K_2O fixed at their average level, 75 pounds. The heaviest application of nitrogen was 250 pounds.

Equation (6.8) was estimated from a 1956 experiment on Verdigris soil in eastern Kansas.[12]

$$Y = 69.38 + 0.311N - 0.001379N^2 \tag{6.8}$$

Nitrogen, P_2O_5 and K_2O were applied up to 120, 80 and 40 pounds, respectively. Rainfall was adequate and almost ideal conditions prevailed during most of the growing season. An analysis of variance indicated that nitrogen was significant at the .99 percent level. P_2O_5 and K_2O were nonsignificant and were omitted from the equation.

Equation (6.9) represents a production function derived from Lintonia soil in Tennessee over the years 1954-56.

$$Y = 92.95 + 0.4834N - 0.0010N^2 - 0.5981D - 0.0028ND \tag{6.9}$$

For the lowest moisture level, the drouth index D equals 103.[13] Finally, production function (6.10) is from a 1952 experiment on calcareous Ida silt loam in western Iowa. Rainfall was adequate and the soil was highly deficient in nutrients.

$$Y = -5.68 - .316N - .419P + 6.35N^{1/2} + 8.52P^{1/2} + .341N^{1/2}P^{1/2} \tag{6.10}$$

All of the preceding production functions are for corn.

Short-Run and Long-Run Functions

We now examine the nature of short-run and long-run static fertilizer demand and corn supply derived from the preceding functions. The term "short run" is used to indicate that a single-fertilizer nutrient is variable, a modification of the usual economic conventions in terminology. The term "long run" similarly is used to indicate that more than one nutrient is variable. Both concepts are short run in the usual terminology, since inputs other than fertilizer would be variable in the conventional meaning of long-run supply.

The restraints imposed by algebraic forms of the production function particularly affect the estimates of static supply elasticity at very high or very low prices. To avoid extreme prices, the supply curves and elasticities for corn are illustrated for corn prices ranging from 40 cents to $1.20 per bushel. Nitrogen, P_2O_5 and K_2O prices are 13 cents, 8 cents and 5 cents per pound, respectively, for variations in

[12] Orazem, Frank, and Smith, Floyd W. An economic approach to the use of fertilizer. Kans. Agr. Exp. Sta. Tech. Bul. 94. 1958. p. 9.

[13] Parks, W. L., and Knetsch, J. L. Corn yields as influenced by nitrogen level and drouth intensity. Agronomy Journal 51:363-64. 1959.

corn price over this range. The corn price range of 40 cents to $1.20 appears adequate to illustrate magnitudes of static supply elasticity which are relevant. In examining static fertilizer demand and elasticities, however, we have used a much wider relative range of fertilizer prices.

STATIC FACTOR DEMAND

Both short-run and long-run static demand for fertilizer are estimated in this section, in the framework outlined above. Static demand is derived with the price of corn fixed at $1.10 per bushel. It is possible to generalize for other corn prices by considering the fertilizer/corn price ratio since the demand quantity is a function of this ratio. The demand quantity when corn price is $1.10 per bushel and nitrogen is 11 cents per pound, for example, is the same as when corn is 80 cents per bushel and nitrogen is 8 cents per pound. Throughout the analysis, emphasis is placed on the conditions which influence the level and elasticity of static demand.

Short-Run Demand

A family of short-run static demand curves can be generated from a given production function for different levels of the fixed resource. The data are made manageable in the following presentation by setting the "fixed resource" at the several levels indicated as in the supply analysis. For space conservation we present only the derived demand, supply and elasticity functions which correspond to production function (6.10).[14] The short-run demand function for N so derived is (6.10a) where P_n is the price per pound of nitrogen, corn price is set at $1.10 per bushel and P_2O_5 is fixed at 80 pounds per acre. The elasticity equation of static nitrogen demand function with respect to its own price is (6.10b).

$$N = 26.7289(P_n + .3476)^{-2} \tag{6.10a}$$

$$E_n = -2P_n(P_n + .3476)^{-1} \tag{6.10b}$$

The parallel short-run demand function and elasticity equations for P_2O_5 are (6.10c) and (6.10d), respectively, with nitrogen fixed at 80 pounds per acre.

$$P = 40.4496(P_p + .4587)^{-2} \tag{6.10c}$$

$$E_p = -2P_p(P_p + .4587)^{-1} \tag{6.10d}$$

[14] The algebraic form of the production function used to express the physical experimental data have an important impact on the demand curves and elasticities. For a discussion, see Tweeten and Heady, op. cit.

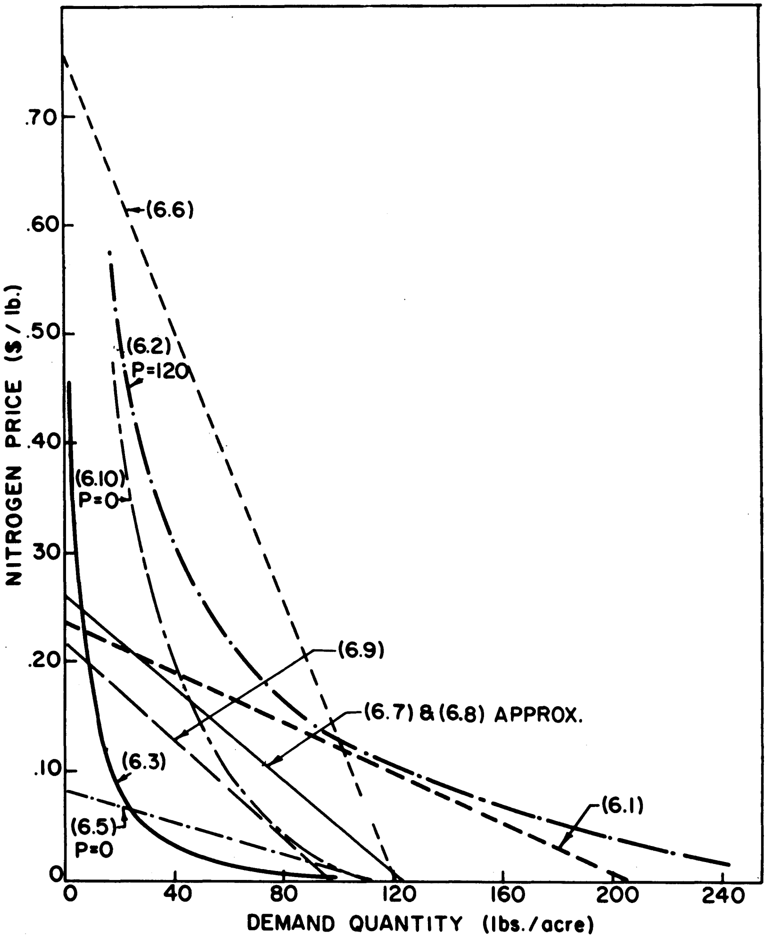

Figure 6.1. Per acre short-run static nitrogen demand curves (corn price = $1.10).

Obviously, the static demand functions have an algebraic form corresponding to their underlying production function. The "fixed resource" is set at the level giving the highest estimate of static demand elasticity for the quadratic and square root forms. Figure 6.1 includes static short-run demand functions for nitrogen derived from the production functions mentioned earlier. The numbers on the demand curves correspond to the number of the production function equations. Where the same number is used for two curves, different demand curves have been estimated for more than one level of the "fixed resource" P_2O_5. The level of the latter is indicated accordingly.

The striking feature of Figure 6.1 is the lack of uniformity in the level of static demand derived from the various production functions.

This is expected, of course, because of the wide geographic spread from which the production functions are derived over the nation, with a large variation in climate and soil productivity. At a price of 13 cents per pound for nitrogen, the demand quantity ranges from zero to 100 pounds of nitrogen per acre when phosphate is at the levels indicated (P). The possible sources of the divergent pattern of static demand are the algebraic form of the function, the moisture pattern, and the initial fertility and other properties of the soil.

The square root production functions consistently give rise to higher demand quantities than the quadratic functions only as the curves approach the price axis. Moving farther to the right from the price axis, no pattern is apparent for either algebraic form.

The computation of static demand is independent of the constant in the production function and is, therefore, not directly affected by the initial nutrient level of the soil. The initial fertility influences the demand quantity indirectly, however. A high level of nitrogen demand reflects a large response of corn yield to additional inputs of nitrogen (marginal physical product). The marginal physical product upon which static demand quantity rests is likely to be large if (a) the soil is not initially satiated with nitrogen and (b) other factors such as P_2O_5, K_2O and moisture are not limiting. The level of demand indicated by each curve in Figure 6.1 may be explained by (a) or (b).

Although rainfall was adequate in 1953, the static curve for function (6.3) depicts a low demand quantity. The yield response to nitrogen was low for (6.3) because the initial fertility level of the Carrington soil was high (i.e., the constant of the production function was 99 bushels). The low demand for nitrogen on Wisner soil (6.5) is also explained by the high fertility level of the soil (104 bushel yield without fertilizer). On such soils, a large response to fertilizer application usually is not anticipated.

Demand curve (6.6), derived under dry conditions on Norfolk-like soil in North Carolina, has relatively large quantities because the soil was initially low in nitrogen but contained adequate amounts of other nutrients. The result was a considerable response to nitrogen despite the low moisture. The demand curve for function (6.2) indicates the lowest level of demand at low nitrogen prices, and was derived under favorable moisture conditions and adequate amounts of P_2O_5 and K_2O (120 pounds) on Webster soil in Iowa.

The slopes of the static demand curves indicate the "intensity" of diminishing fertilizer productivity. If marginal corn production falls off rapidly with additional units of nitrogen, the demand curve for nitrogen drops sharply to the right. The slope and the level of the demand curve (Figure 6.1) determine the elasticity (Figure 6.2 where the numbers again refer to the production functions). The magnitude of elasticity is directly related to the slope and inversely related to the level of demand or the base effect described earlier. Changes in the level of the fixed factor cause compensating changes in the position and slope of the square root form of demand. The static demand elasticity

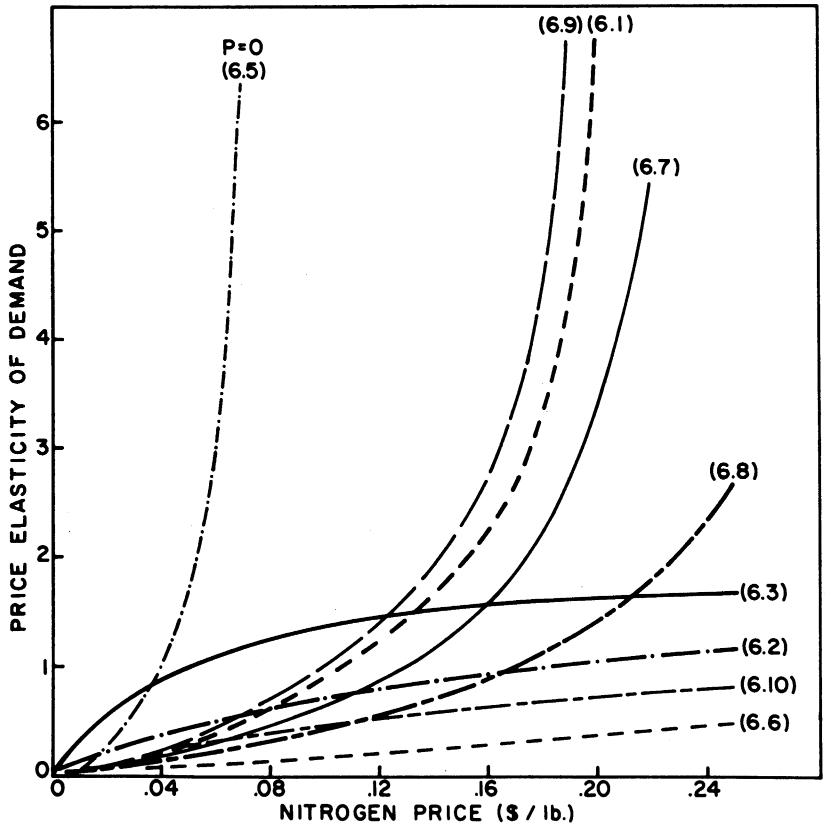

Figure 6.2. Price elasticity of static nitrogen demand curves in Figure 6.1.

consequently is constant at all levels of the fixed factor. If interaction is positive, the quadratic form of the demand curve shifts to the right and the elasticity decreases with higher fixed factor levels.

The elasticities of the static demand curves for nitrogen are quite uniform for low nitrogen prices to about 13 cents per pound. (In Figure 6.2 the horizontal axis is the nitrogen price.) If price of nitrogen is 13 cents, the elasticity ranges from .20 to 1.70 except for function (6.5). Demand becomes considerably more elastic and highly divergent above 13 cents. The divergence is explained by the algebraic forms and by the experimental conditions under which the curves were estimated. The elasticity of the quadratic equations (the linear static demand functions in Figure 6.1) approaches infinity and of the square root functions (the curved lines in Figure 6.1) approaches two at high factor prices. The four curves indicating the highest elasticities in Figure 6.2 are based on quadratic forms of production functions. Three of the four curves indicating the lowest elasticities are based on square root forms of production functions.

The low elasticity for function (6.6) in Figure 6.2 is due to the high level and steep slope of the demand curve in Figure 6.1. The level of demand is high because the soil was initially low in nitrogen; the slope is steep because low moisture restricted the yield response from large applications of nitrogen. The demand curve for function (6.5) is highly elastic when the price of nitrogen is greater than 6 cents. As the nitrogen price approaches the intersection of the demand curve with the price axis at 8 cents in Figure 6.1, the elasticity approaches infinity in Figure 6.2. Wisner loam for function (6.5) is a heavy rich soil, and the yield response to nitrogen was low. Demand curve for function (6.9) also was very elastic at most nitrogen prices. The production function contains a drouth index which was set at a low moisture level to give the demand curve illustrated in Figure 6.1. Had the index been set at a high moisture level, the elasticity would have been lower. We conclude

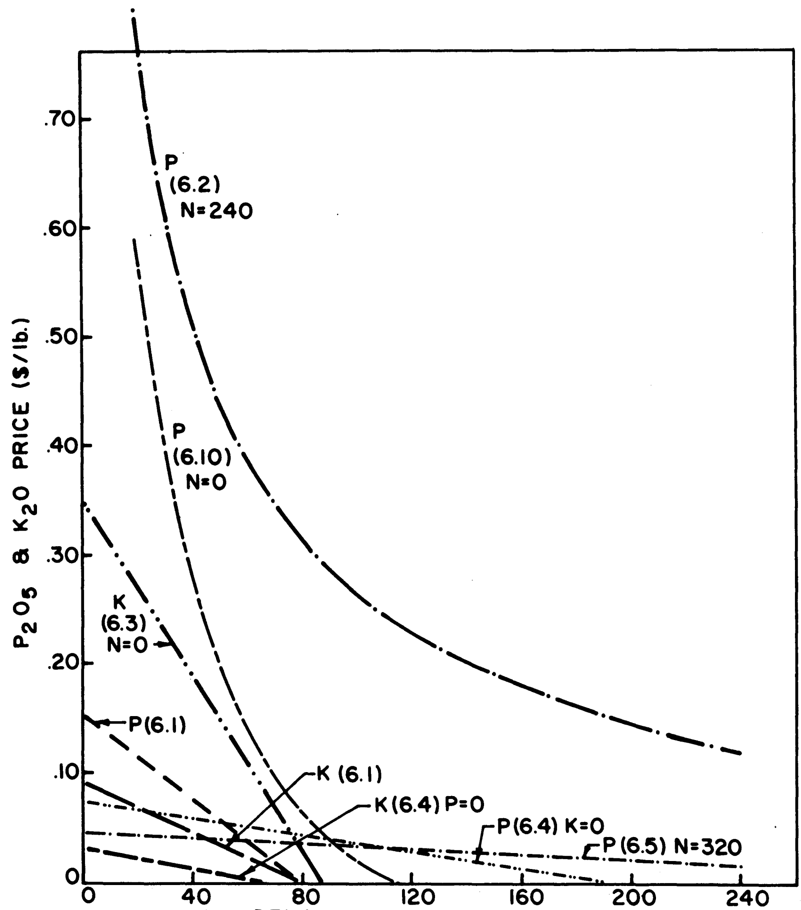

Figure 6.3. Per acre short-run static demand functions for P_2O_5 and K_2O (corn price = $1.10).

that demand is most elastic under conditions where nitrogen fertilizer has little effect on yield because the soil initially contains adequate nitrogen or because the yield response is limited by lack of moisture or other factors.

Considerable variation also is apparent in the levels of short-run static demand for P_2O_5 and K_2O illustrated in Figure 6.3. (P and K on the curves indicate the static demand for P_2O_5 and K_2O, respectively.) The divergent level of demand is explained by the nutrient and moisture conditions of the soils for which the production functions were derived. Curves (6.4) for P_2O_5 and K_2O depict two of the lowest demand levels. Both were estimated from an experiment on Carrington soil in 1955 when the yield response was severely limited by low rainfall. Demand curve (6.2) for P_2O_5 indicates the highest level of demand. It was derived from a 1953 experiment on Webster soil when rainfall was adequate. The high level of nitrogen (N = 240 pounds) also shifted demand curve (6.2) to the right. A high level of demand is also depicted by curve (6.10). It was estimated from a 1953 experiment on Ida soil in Iowa. Moisture generally was sufficient in 1953, and the soil gave a significant yield response to use of nitrogen and P_2O_5.

The curves depicting the highest level of demand had the lowest price elasticity as indicated in Figure 6.4. The static demand curves

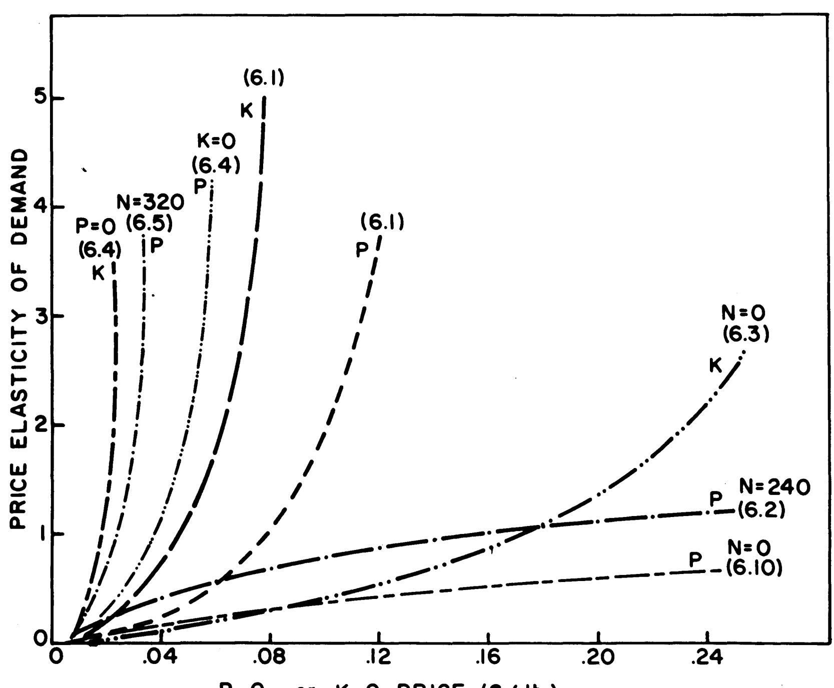

Figure 6.4. Price elasticity of the static demand curves for P_2O_5 and K_2O in Figure 6.3.

of greatest elasticity are those indicating the lowest level of demand, (6.4) and (6.5). The flatter slopes of (6.4) and (6.5) also contributed to the high elasticity. Some of the difference is due to the restraints imposed by the square root form on the elasticities of (6.10) and (6.1). The difference, however, mainly is attributed to the conditions under which the functions were estimated.

The elasticities of the P_2O_5 and K_2O demand curves are greater and more divergent than the elasticities of demand for nitrogen illustrated in Figure 6.2. Much of the difference in the magnitude is due to the lower levels of demand for P_2O_5 and K_2O. For example, five demand curves in Figure 6.3 for P_2O_5 and K_2O intersect the price axis below 20 cents. But only one demand curve (6.5) for nitrogen intersects the price axis below 20 cents.

Long-Run Demand

The long-run static demand functions for N and P_2O_5, corresponding to production function (6.10), are presented in equations (6.10e) and (6.10f).

(6.10e) $$N = 26.5225(P_n + .3494)^{-2}$$

(6.10f) $$P = 36.7236(P_p + .3850)^{-2}$$

Both functions represent demand quantity as a function of the same nutrient's price where we suppose prices for the alternative nutrient are fixed at the levels for (6.10a) and (6.10c), but that the alternative nutrient can be varied to its most profitable level, its price fixed, while the price of the particular nutrient is varied.

Figure 6.5 provides long-run demand curves for nitrogen derived as explained earlier. Factors other than nitrogen, i.e., P_2O_5 and K_2O, are not fixed as in Figures 6.1 and 6.3, but are allowed to vary as the price of nitrogen changes. Figure 6.5 also includes demand curves from production function (6.6) to (6.9) which contain only one variable input. While these curves are termed long-run because all factors in them are variable, they do not differ from the short-run curves in the manner of the other functions.

Figure 6.5 illustrates the effects of moisture and soil type on static long-run demand as defined here. Production functions (6.10), (6.2) and (6.3) were estimated in 1953 in Iowa. Since the rainfall was somewhat uniform among these experiments, the level of demand differs mainly due to soil type. Demand curve (6.10) from Ida soil data depicts one of the highest demands, and curve (6.3) from Carrington data depicts one of the lowest demands. The elasticities of these curves display more uniformity, however, as indicated in Figure 6.6.

The effect of moisture is apparent from production functions (6.3) and (6.4) estimated in 1953 and 1955, respectively, on Carrington soil.

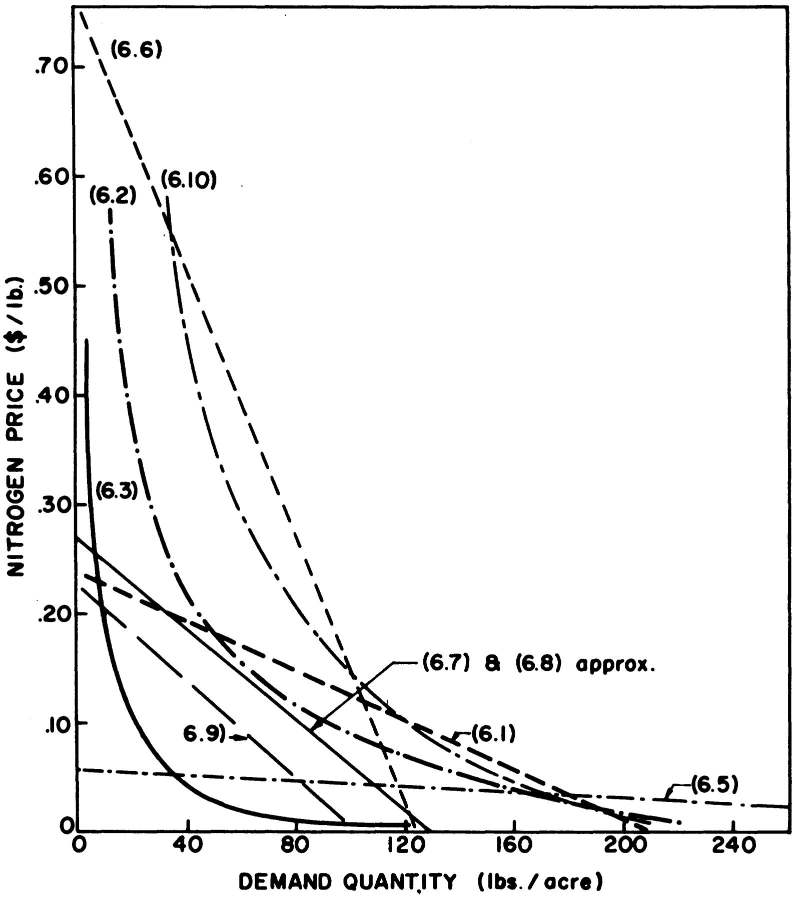

Figure 6.5. Per acre long-run static demand curves for nitrogen; other nutrients variable as in production functions (corn price = $1.10).

The demand curve for nitrogen is indicated in Figure 6.5 for the year 1953 only. In 1955 nitrogen gave no response due to low rainfall. Hence, the demand quantity for nitrogen in 1955 was essentially a zero.

In general, the Iowa functions depict a greater static demand quantity for nitrogen, at a given price, than do the other functions except (6.6). Demand curve (6.3) from Iowa data indicates a very low demand, however. The slope as well as the level of the static demand curve relates to the soil fertility and moisture conditions. The two quadratic forms displaying the greatest and least slopes are (6.6) and (6.5) in Figure 6.5. Demand curve (6.6) was estimated on soil with sufficient nutrients other than nitrogen, but with limited moisture. The first units of nitrogen gave a large yield response but, due to insufficient moisture, the marginal product declined rapidly. The flattest demand curve (6.5) was estimated for heavy Wisner soil. Because the initial

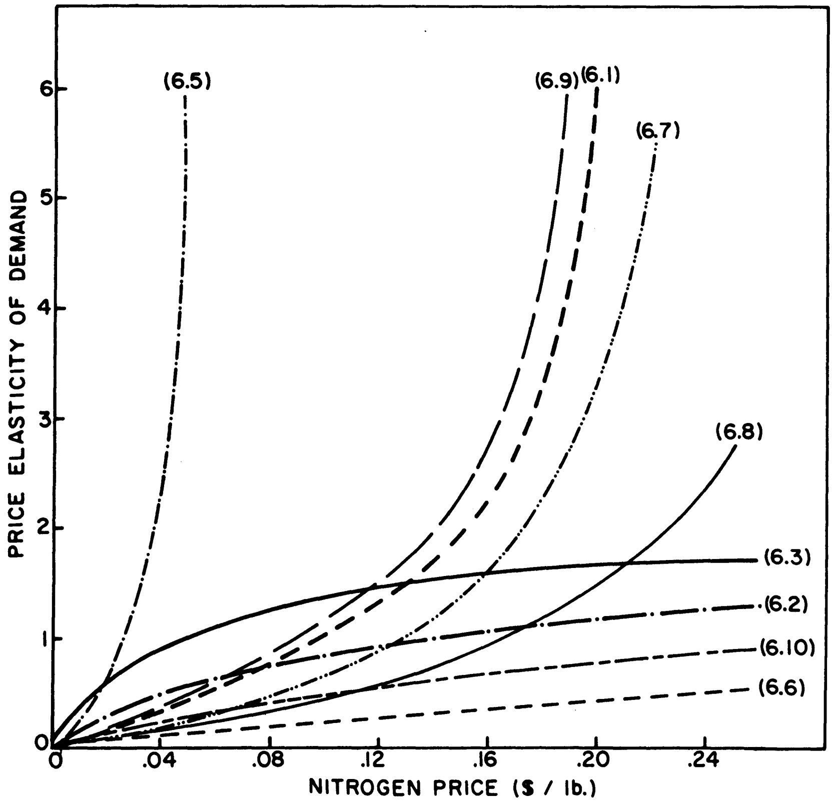

Figure 6.6. Price elasticity for nitrogen static demand curves in Figure 6.5.

nitrogen level in the soil was high in relation to the available moisture, the first units of nitrogen added little to the yield. The marginal product remained almost constant as more nitrogen was applied due to adequate amounts of other nutrients and moisture-holding capacity of the heavy soil. These results conform with the general observation from Figure 6.5 that the demand curves denoting the largest quantity at a given price also decline most rapidly in slope. The possible reason is: fertile soils, such as those represented by (6.1) and (6.5), which do not exhibit a large initial response to nitrogen fertilizer, sustain some response, with application of greater amounts of nitrogen, due to the high levels of other nutrients and moisture-holding capacity of the soil.

The demand curves derived from Iowa data appear to have lower elasticity than those from other areas. Much of the difference is due to the algebraic form and the production elasticity at lower nitrogen inputs. Comparisons are more realistic at the mid-range of nitrogen prices. Considering only the six demand curves with the lowest elasticity, every other one was derived from Iowa data. The differences in

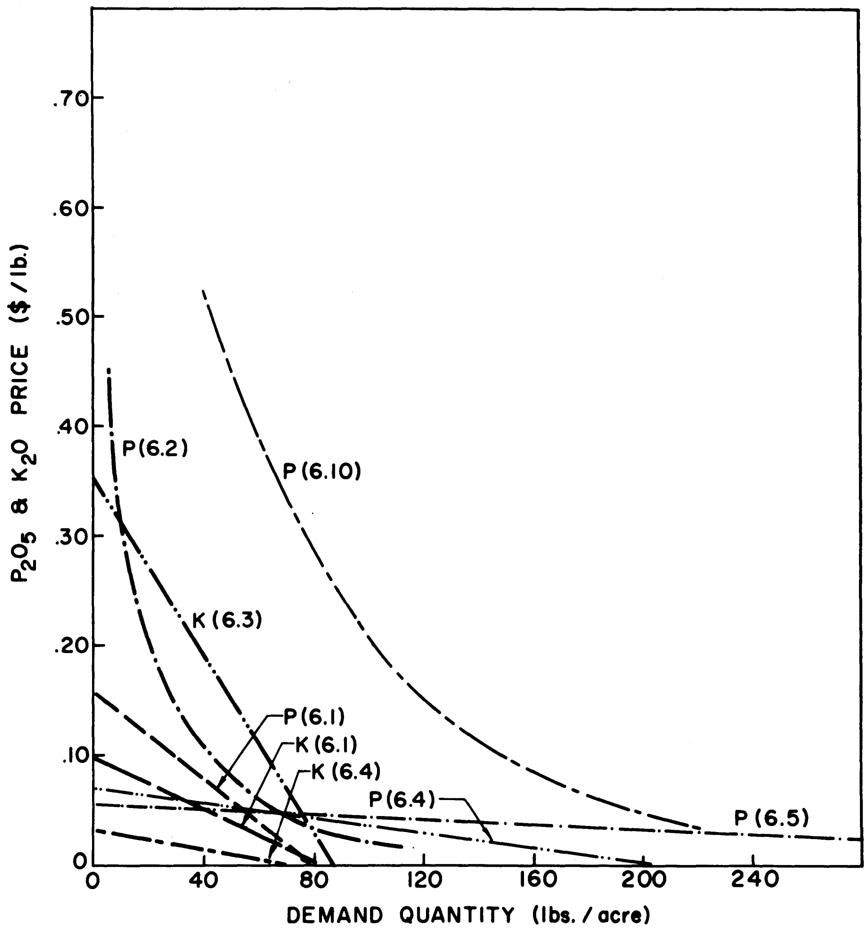

Figure 6.7. Per acre static long-run P_2O_5 and K_2O demand curves (corn price = \$1.10).

elasticities are perhaps better explained by soil and moisture conditions rather than by areas. Demand elasticity tends to be lowest for soils which are low in nitrogen and where rainfall and other fertilizer elements are plentiful.

The level of long-run demand for P_2O_5 and K_2O illustrated in Figure 6.7 is somewhat lower than the long-run demand for nitrogen in Figure 6.5. Figure 6.7 also suggests that, for the particular experimental production functions and environmental conditions, the demand for K_2O is less than the demand for P_2O_5 at a given price. In several instances P_2O_5 and K_2O were included in the controlled experiments from which the production functions were derived but did not give significant responses. The P_2O_5 and K_2O variables omitted from the functions in such instances represent a zero demand for the nutrient.

Demand curve for function (6.1) for Clarion soil in Iowa illustrates the differences in demand levels for the three nutrients in a given year. Demand quantity, at a given price, for nitrogen in Figure 6.5 is greater than for P_2O_5 in Figure 6.7, which in turn is greater than that for K_2O.

All of the static demand curves except (6.5) in Figure 6.7 are from Iowa data. The divergent pattern in Figure 6.7 again suggests the wide variation in demand existing within a given area. Static demand curve (6.3) for K estimated in 1953 indicates much larger quantities than (6.4) for K estimated in 1955 although both are for Carrington soil. Demand curve (6.3) for K is also less elastic than curve (6.4) for K in Figure 6.8. The elasticity of long-run static demand for P_2O_5 and K_2O tends to be high and divergent. The price elasticity is greatest on soils giving little response to fertilizer because of an initially high nutrient level or inadequate moisture. For example, curve (6.5) estimated on a heavy, rich soil gave little response to fertilizer and the elasticity is high. Demand curve (6.10), estimated on a soil with ample moisture and low P_2O_5, gave a large response to fertilizer. The elasticity of demand functions estimated for the data explained earlier for equation

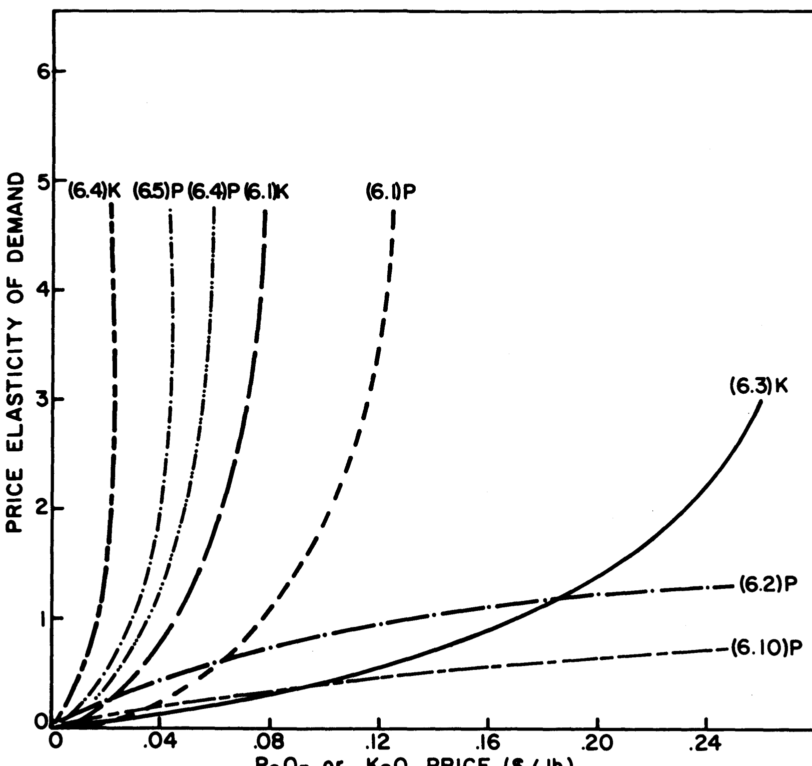

Figure 6.8. Price elasticity for long-run static P_2O_5 and K_2O demand curves in Figure 6.7.

(6.10) was low when either a square root or quadratic production function was used. To the limited extent that it is possible to generalize from the small sample, a change in the price of fertilizer would have the greatest proportional impact in areas such as the Great Plains. The least percentage change in fertilizer consumption would occur in the Corn Belt and Southeast where response to fertilizer is very large. Of course, the largest absolute change in fertilizer consumption likely would occur in areas where fertilizer is being used in the largest amounts. It is useful to consider the impact of fertilizer price changes by soils rather than by areas since the analysis indicates that the demand elasticity varies greatly by soil and year within areas.

The static factor demand functions above provide some insight into the manner in which physical production functions might condition the demand elasticities for a particular resource fertilizer. A change in crop price or fertilizer cost is expected, in terms of the static and physical basis outlined, to cause greatest change in fertilizer demand in the "more marginal areas" of use.

In the foregoing analysis, the demand for K_2O is more elastic than the demand for nitrogen. Fertilizers are often sold in fixed ratios, and it may not be meaningful to consider independently the demand for a single element. Assuming demand to be independent, however, a fertilizer manufacturer of all three elements likely would find the purchase of K_2O more responsive than that of nitrogen to a lowering of both nutrient prices by the same percentage. The demand curve for nitrogen, P_2O_5 and K_2O in fixed ratio would fall to the right of the demand curve for any one element. It follows that the demand for a fixed ratio of the three elements probably would be less elastic than the demand for any one element.

The price elasticity of static demand with respect to the price of fertilizer or with respect to the price of corn is equal but opposite in signs. Inferences about the response of fertilizer purchases to fertilizer prices also apply to corn prices. For example, a fall in the corn price would be expected to reduce fertilizer purchases proportionately more than the decline in corn production. The results of the static analysis are also consistent with the hypothesis that a change in corn price has the greatest percentage impact on fertilizer sales in marginal areas, but the greatest absolute impact in traditional areas of corn production.

The static analysis indicates fertilizer demand is more elastic than corn supply. Because of diminishing returns, successive inputs of fertilizer add smaller and smaller increments to corn output. Thus, fertilizer consumption must increase by a larger percent than corn output in response to a favorable corn price. The reduction in demand to the fertilizer industry, from a decline in corn price and in terms of static analysis, is expected to be greater than the decrement in corn output.

The static analysis provides some basis for forming hypotheses of future trends in the demand for fertilizer. If the price of fertilizer falls relative to the price of corn, the largest proportional increase in fertilizer consumption in the short run is expected in marginal areas of fertilizer use. However, the largest total increase would still likely be in areas where fertilizer is used in large amounts. As the fertility level of the soil declines because of cropping and erosion, the demand curve for fertilizer is expected to shift to the right and probably become less elastic. Although the demand for fertilizer will increase, the relative short-run responsiveness of fertilizer consumption to changes in the price of corn or of fertilizer probably will diminish. Introduction of irrigation and other technological improvements also will influence the demand elasticity of fertilizer. To the extent that these technological changes substitute for fertilizer, the fertilizer demand elasticity will increase. To the extent that innovations such as new crop varieties only shift the demand for fertilizer to the right, the fertilizer demand elasticity will decrease.

STATIC SUPPLY FUNCTIONS

Based on the same production functions, and with the same limitations in illustration and prediction, static corn supply functions are presented in this section. While this book emphasizes resource demand and structure in agriculture, the basic study is made as a step in better explaining agricultural supply and related price and income problems. Some of the possible interrelationships between resource demand and commodity supply are illustrated below, as they stem from the static analysis and physical production functions. The numbers shown on the supply functions which follow, like those for demand, refer to the production functions from which they were derived.

Short-Run Static Supply

Presentation of a complete family of short-run supply curves for many values of the fixed nutrients is impractical when two or more nutrients are included in the production function. The short-run static supply function for corn, corresponding to production function (6.10), is (6.10g) where N is variable, P_2O_5 is fixed at 80 pounds per acre and N is priced at 13 cents per pound and Y is bushels per acre. The corresponding elasticity equation is (6.10h).

(6.10g) $$Y = 37.12 + \frac{22.98P_y + 27.93P_y^2}{.0676 + .329P_y + .399P_y^2}$$

(6.10h) $$E = \frac{5.97P_y}{Y(.26 + .632P_y)^3}$$

As explained earlier, for the analysis which follows, the fixed resource or nutrient is set at the level giving the highest estimate of elasticity within the range of the experimental data for the variable resource. A low level of the fixed resource generally results in the highest elasticity of supply for the variable resource. The low "fixed factor" levels do not affect the slope, but shift the quadratic supply curves to the left, increasing the elasticity. The static supply curve for the quadratic equation (6.5) was an exception since the coefficient for interaction between nutrients was negative. In the square root equations (6.10), (6.2) and (6.3) the level of the fixed factor exerts opposite influences, through the base and slope effects discussed previously, on elasticity. The base effect overshadows the slope effect in (6.10) and (6.3) and results in the highest elasticity of static supply at low "fixed factor" levels.

With nitrogen as the only per acre variable input, the positions of the supply curves are widely dispersed, but the slopes are very "uniform," as shown in Figure 6.9. (The K and P values on the curves indicate the level at which these two factors are fixed.) The level of supply varies as much as 100 bushels per acre. The wide range is explained largely by (a) the soil fertility, (b) moisture conditions and (c) the level of the fixed nutrient. The value of the constants in the production function is the predicted yield level of the soil without application of fertilizer. It reflects the initial fertility level of the soil

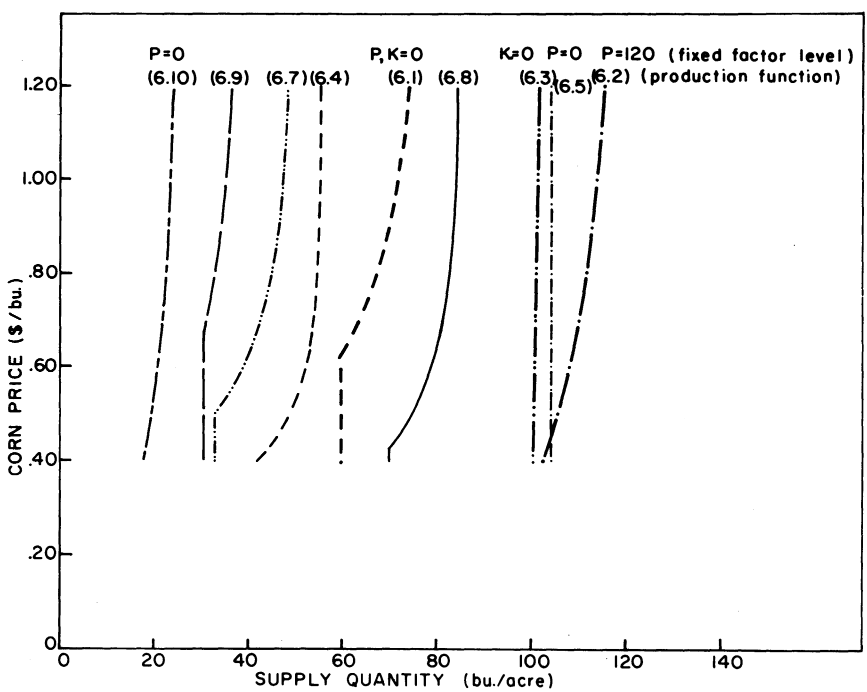

Figure 6.9. Per acre short-run static supply curves for corn (nitrogen price = $.13).

and moisture conditions, or (a) and (b). The supply curves farthest to the right, (6.2), (6.3) and (6.5), represent production functions with high values of the constant (i.e., 77, 99 and 104 bushels per acre, respectively). The initial yield level of the supply curve farthest to the left (6.10) is almost zero. If all curves are adjusted to a common constant and fixed factor level, the range of supply quantities at any price is very small.

The steep slopes of the curves indicate that a change in price would result in but little change in quantity under the conditions for deriving the static supply functions. Supply curve (6.5) for Wisner loam in Michigan is a vertical straight line. Nitrogen would not be used until

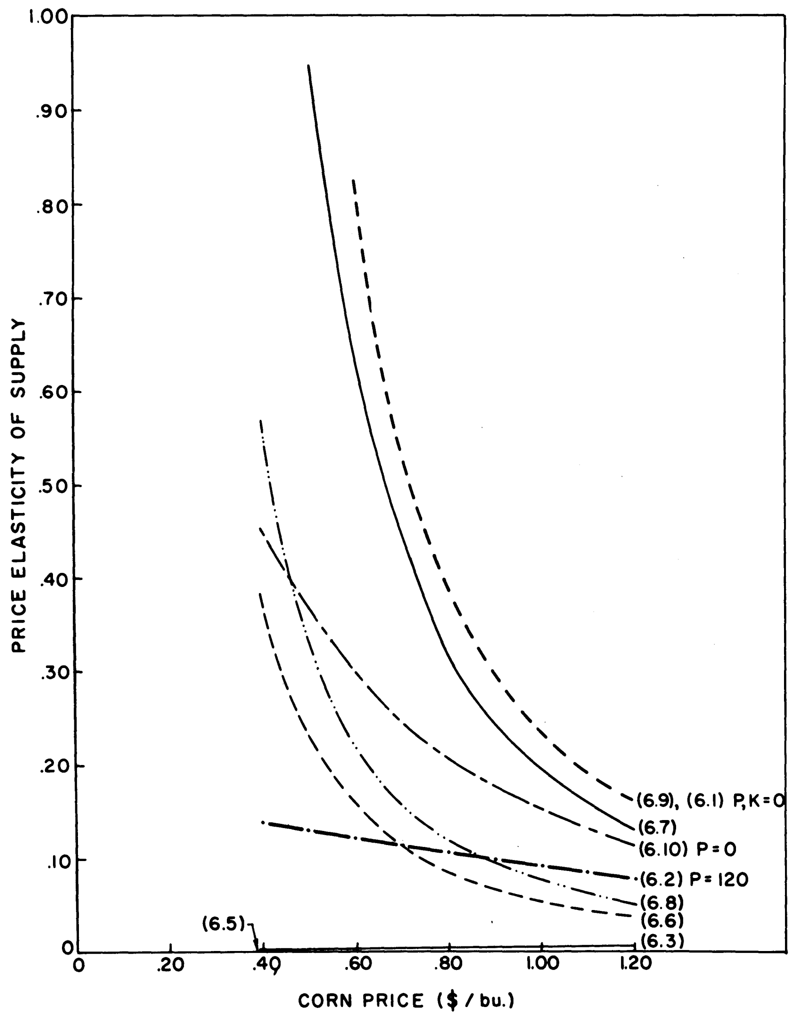

Figure 6.10. Price elasticities for static short-run supply curves in Figure 6.9.

corn reaches $1.80 per bushel. The supply quantity at all indicated prices is the initial yield, 104 bushels. Curves (6.1), (6.7), (6.8) and (6.9) display vertical straight line segments. These segments indicate use of nitrogen to be unprofitable up to the corn price when the static supply curves have slopes less than infinity. The supply quantity in these segments is the initial yield or constant value in the production function equation. (The vertical segments do not extend to the quantity axis since, at some nonzero corn price, harvesting of the initial yield would be unprofitable.) The cost per bushel to harvest corn is well below the 40 cents per bushel minimum of Figure 6.9 and need not concern us.

The steep slopes of the static supply curves in Figure 6.9 reflect their low elasticities as illustrated in Figure 6.10. All supply curves have a price elasticity less than 1.0 when the corn price (horizontal axis) is above 40 cents. Moving from right to left in Figure 6.9, the elasticities of curves (6.1), (6.7) and (6.9) rise sharply. The elasticity of some static supply functions would be greater than unity with a corn price of less than 40 cents, but nitrogen no longer is profitable. Static supply elasticity drops to zero when the corn price is below 62 cents, 50 cents and 67 cents for curves (6.1), (6.7) and (6.9), respectively. The elasticity of all supply curves is less than .5 when corn price is above 80 cents. At a corn price of $1.20, the elasticities range from zero (6.5) to .16 (6.1 and 6.9). We conclude that the elasticity is low for all static supply curves throughout the wide range of prices considered in the analysis.[15]

Figure 6.11 depicts static corn supply curves with either P_2O_5 or K_2O as the only variable factor. (The variable factor is indicated by P or K below each static supply curve.) The curves indicate a considerable range of supply levels. The range would be somewhat less if the border curves (6.10) and (6.2) were estimated with nitrogen fixed at the same level. All curves except (6.5) were derived from Iowa data. Hence, there is little basis for comparisons among regions. Figure 6.11 demonstrates a broad range of static supply by soil types and weather within Iowa. Supply curves (6.3) and (6.4) were estimated

[15]Figures 6.9 and 6.10 have wider application if price ratios, rather than absolute prices, are considered. The price of nitrogen, P_n, used to estimate the supply curves and elasticities was 13 cents per pound, but it is desirable to be able to generalize the supply quantities and the elasticities for other nitrogen prices. The corn price axes may be considered "price ratio" axes. For a corn price, P_c, of 90 cents per bushel, the ratio is $\frac{90\text{ cents}}{13\text{ cents}} = 7$. The supply quantity or the elasticity of supply remains the same for any absolute level of prices providing a price ratio is 7. But if P_n falls to 10 cents and P_c remains at 90 cents, the new price ratio is 9. To find the level of supply from Figure 6.9 or the elasticity from Figure 6.10 for P_n = 10 cents, P_c = 90 cents, we can compute the corn price which gives a price ratio of 9 when P_n = 13 cents; i.e., P_c = $1.17. Then the supply quantities and elasticities from Figures 6.9 and 6.10 for P_c = $1.17 can be determined. This method is limited when supply is computed with two or more variable factors. It is necessary to consider the price ratios among factors as well as between factors and products. The procedure described may be used as an approximate device if interfactor price ratios remain unchanged.

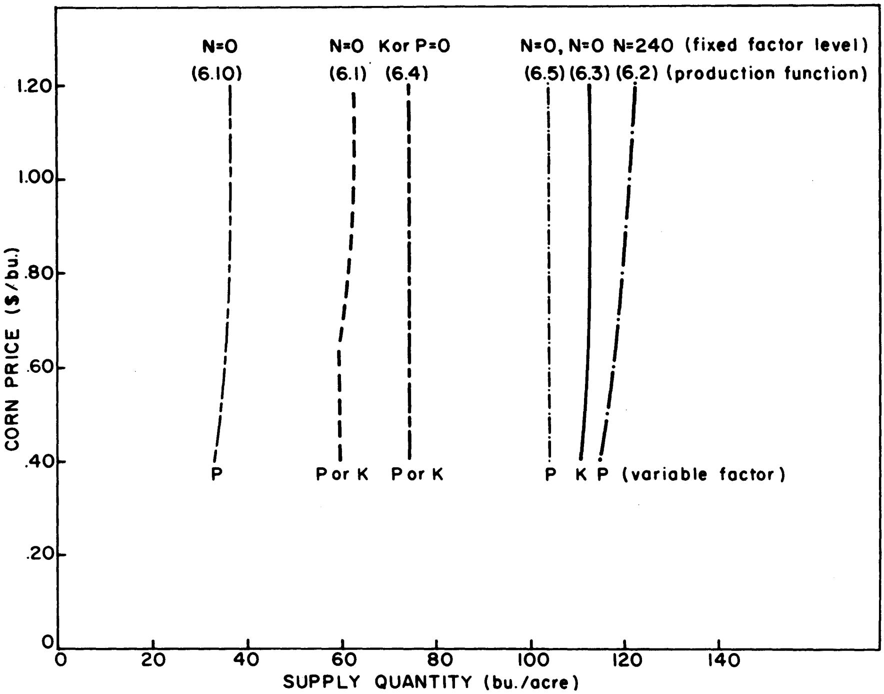

Figure 6.11. Per acre static corn supply (P_2O_5 price = \$.08 or K_2O price = \$.05).

from experiments on Carrington soil in 1953 and 1955, respectively, indicating the wide range in supply level among years for a given soil type.

The slopes are more uniform than the positions of the supply curves. In general, they rise even more steeply than the static supply curves when only nitrogen is variable as in Figure 6.10. Supply curves (6.4) and (6.5) are vertical in Figure 6.11. P_2O_5 is "not used" for (6.4) until the corn price reaches \$1.67 per bushel with nitrogen and K_2O fixed at zero pounds. K_2O is "not used" until the corn price is \$1.19 per bushel. With nitrogen fixed at the zero level in (6.5), P_2O_5 is not profitable until the price of corn reaches \$1.60 per bushel. Only the initial yield level, the constant of the production function, is assumed to be supplied until these prices are reached.

The elasticity of supply curve (6.1) up to 60 cents and of (6.4) and (6.5) is zero (Figure 6.12). All the static supply curves with only P_2O_5 or K_2O variable are highly inelastic. All have elasticities below .20 for a corn price of 40 cents. The elasticity declines with higher prices of corn and is less than .05 for all supply curves when corn is \$1.20 per bushel. Although the magnitude of static supply elasticity with only P_2O_5 or K_2O variable differs by soil type and weather, it is uniformly low over the range of corn prices considered. This conclusion is based primarily on Iowa data. In several other experiments of other states,

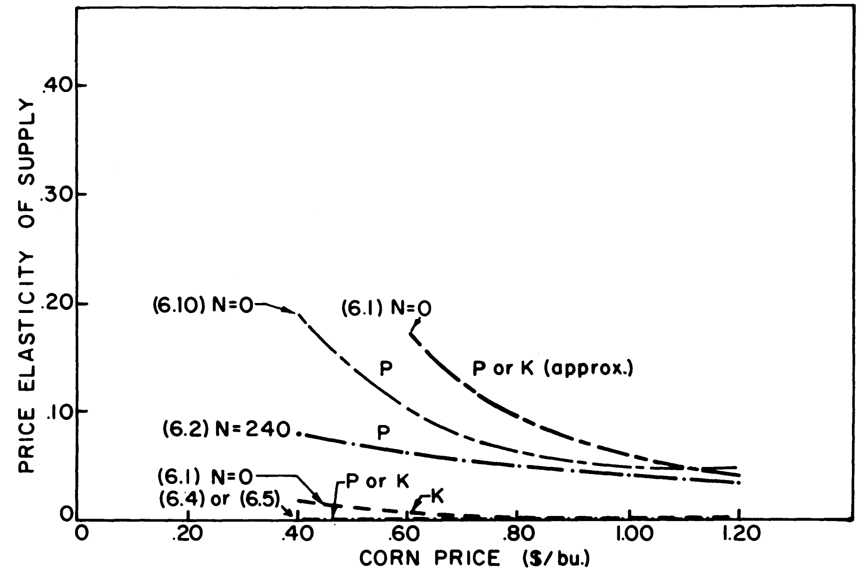

Figure 6.12. Price elasticities for supply curves in Figure 6.11.

P_2O_5 and K_2O were included but did not affect yield significantly. We may generalize that the static supply elasticity with only P_2O_5 and K_2O variable for the production function of the latter soil and weather conditions also is near or at zero.

All the supply curves in Figure 6.11 were derived from production functions which include two or three fertilizer nutrients as inputs. It is unlikely that either P_2O_5 or K_2O would be applied alone. Long-run static supply curves with P_2O_5 and K_2O varying with other nutrients provide a more meaningful estimate of static supply.

Long-Run Supply

As a single example, the long-run supply function where both N and P_2O_5 are variable for production function (6.10) is presented in (6.10i) where C has the value given in the footnote.[16]

(6.10i) $$Y = -5.682 - .316C_n^2 - .417C_p^2 + 6.351C_n + 8.516C_p + .341C_n C_p$$

[16] The value of C is:

$$C_n = \frac{1.016P_y + 8.201P_y^2}{.042 + .318P_y + .411P_y^2}$$

$$C_p = \frac{2.814P_y + 7.548P_y^2}{.042 + .318P_y + .411P_y^2}$$

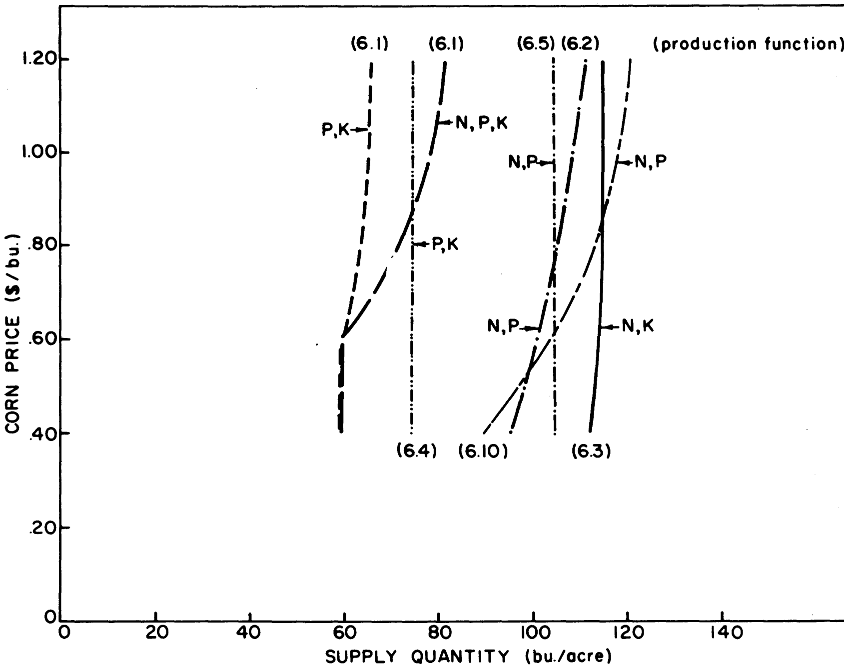

Figure 6.13. Per acre long-run static corn supply (nitrogen price = $.13, P_2O_5 price = $.08 and K_2O price = $.05).

As in the case of other static demand and supply functions presented above, the form depends upon the underlying production function from which it is derived.

The range of supply quantities is not as broad and the curves are not as steep when more than one nutrient is variable for the static supply curves in Figure 6.13. Three fertilizer nutrients are variable in static supply curve (6.1) N, P, K; in the remainder only two nutrients are variable. The static supply curves (6.1) N, P for nitrogen and P_2O_5 variable and (6.1) N, K for nitrogen and K_2O variable are similar to (6.1) N, P, K and, consequently, are not illustrated. Addition of the third nutrient, P_2O_5 or K_2O in either case, causes little change in the supply curve. But adding nitrogen to (6.1) P, K shifted the curve sharply to the right. Obviously, nitrogen was the most limiting resource on the Clarion soil from which function (6.1) was derived.

Supply curve (6.1) N, P, K presents an interesting pattern. Nitrogen, P_2O_5 and K_2O individually become profitable (nonzero quantity) at corn prices of 62 cents, 58 cents and 61 cents, respectively. The slope of (6.1) is vertical until P_2O_5 is profitable at 58 cents. The segment of (6.1) N, P, K from 58 cents to 61 cents is the same as the short-run curve (6.1) P over the same price range in Figure 6.11. At 61 cents K_2O also becomes profitable and (6.1) N, P, K becomes "long-run" with two variable nutrients. It follows the curvature of (6.1) P, K until

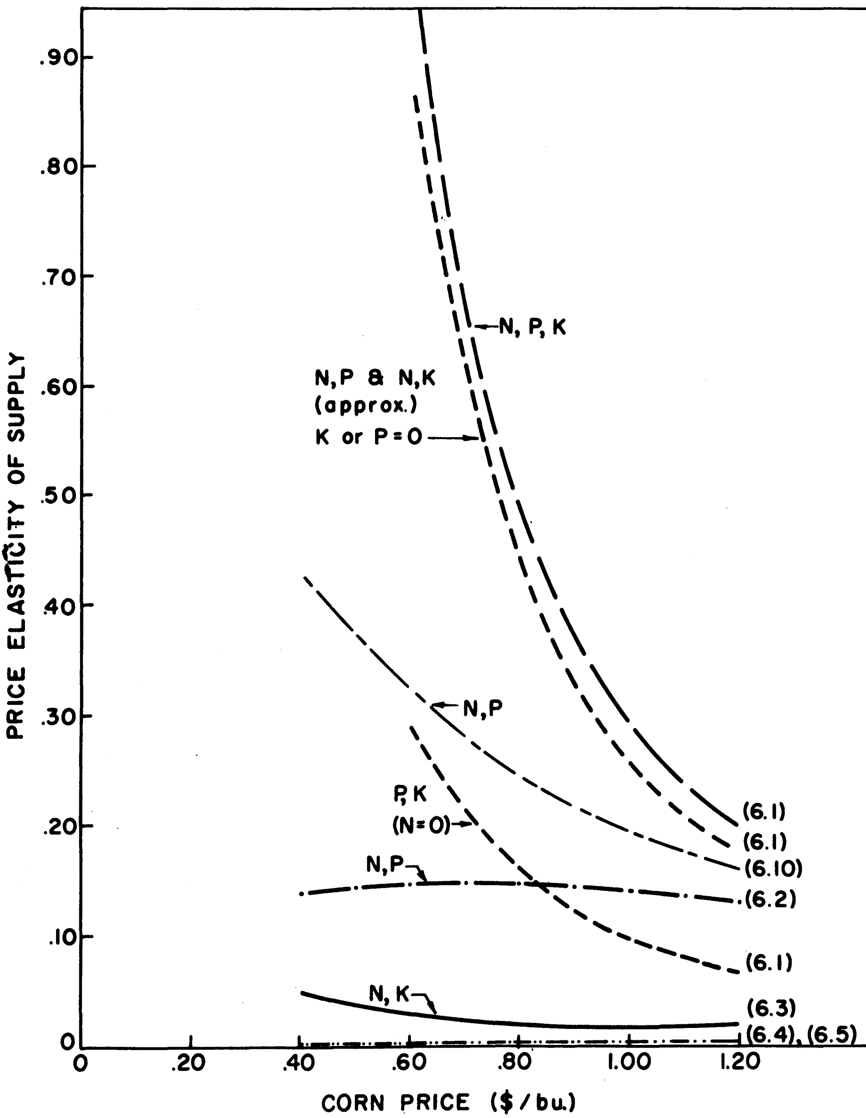

Figure 6.14. Price elasticities for supply curves in Figure 6.13.

nitrogen becomes profitable at 62 cents. When all three nutrients become variable at 62 cents, (6.1) N, P, K becomes separate from other static supply curves for (6.1).

All the static supply curves except (6.5) in Figure 6.13 are from Iowa data. While it is not possible to make interregional comparisons, it is possible to isolate some of the effects of supply of moisture and of soil fertility. Curves (6.3) and (6.4) were derived on Carrington soil

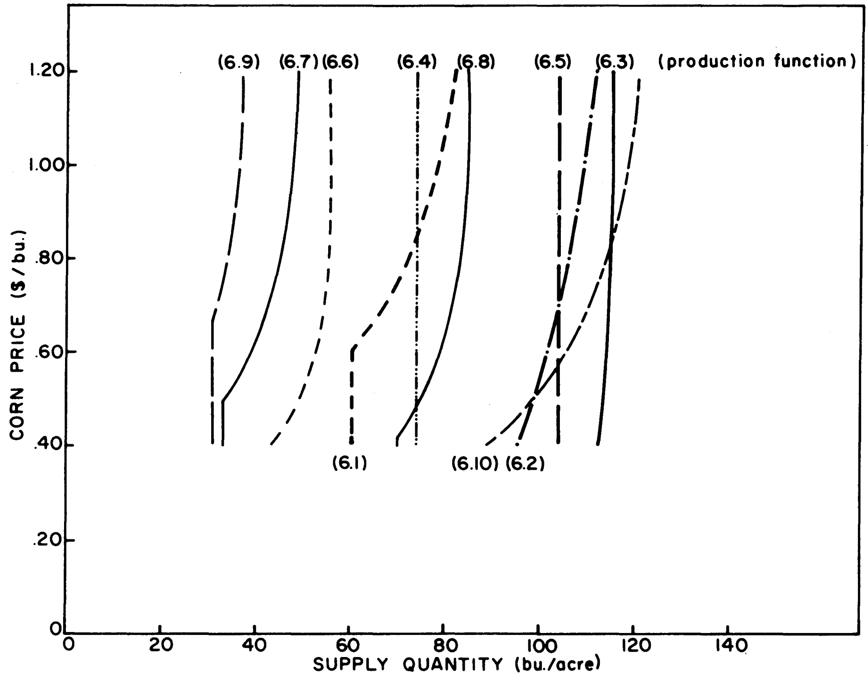

Figure 6.15. Summary of short-run and long-run static corn supply: All fertilizer nutrients included in the production function are variable. The prices of the variable factors, nitrogen, P_2O_5 and K_2O are 13 cents, 8 cents, 5 cents per pound, respectively.

in 1953 and 1955, respectively. Because of more rainfall in 1953, curve (6.3) lies considerably to the right of curve (6.4). Curves (6.10), (6.2) and (6.3) were estimated on different soils in Iowa but under similar moisture conditions in 1953. The curves depict nearly equivalent levels of supply. The results are consistent with the hypothesis that greater divergences in the level of supply arise because of differences in moisture than because of differences in soil type.

The moisture and fertility levels of the soil also explain the curvature of the supply curves. The greatest curvature is found in curves derived on soils low in fertilizer but otherwise favorable for corn production; i.e., with adequate moisture, good soil structure, etc. Curves (6.10) and (6.2), for example, were estimated under favorable moisture conditions. Curve (6.1), though estimated under limited moisture, lacked fertilizer, particularly nitrogen, and hence indicated considerable curvature.

On the other hand, supply curves (6.4) and (6.5) are vertical straight lines. The corn prices at which nutrients become profitable — the slope becomes less than infinite — for supply curve (6.4) are $1.23 and $1.51 for P_2O_5 and K_2O, respectively. For supply curve (6.5) it is profitable to use P_2O_5 when the corn price reaches $1.59 per bushel,

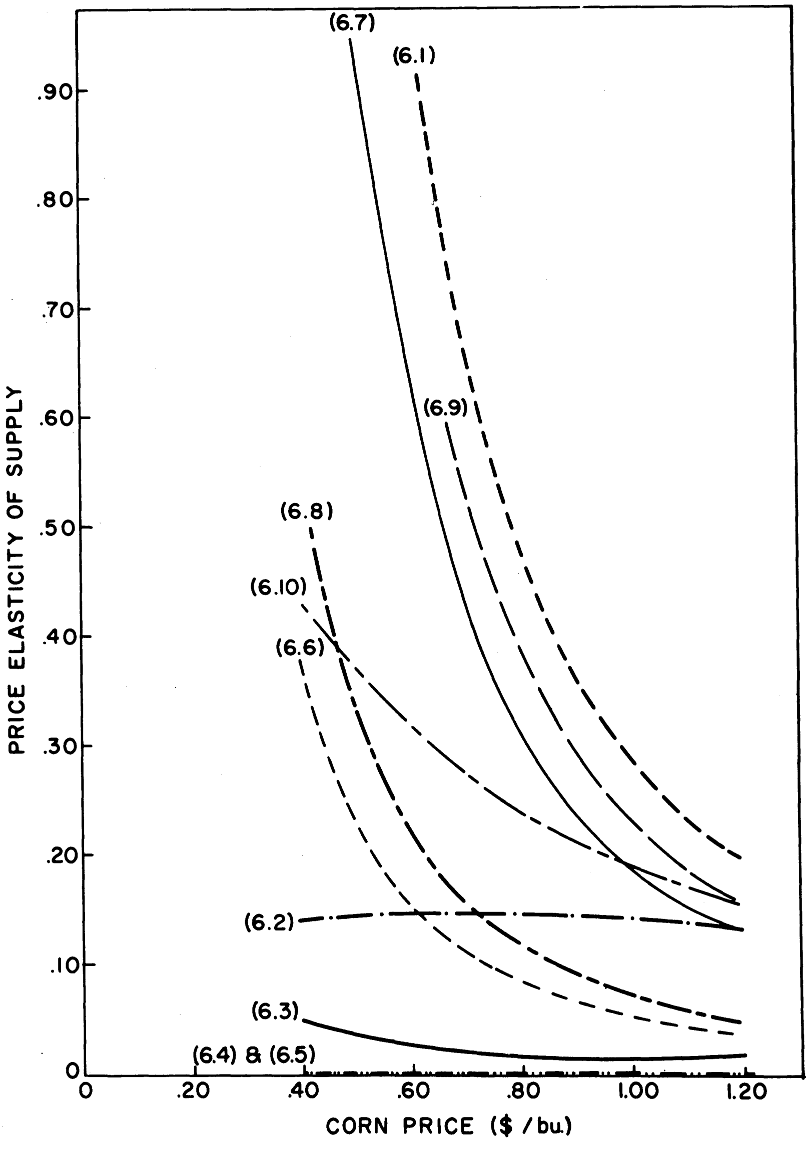

Figure 6.16. Price elasticity of short-run and long-run static supply curves illustrated in Figure 6.15.

but the price of corn must reach $1.79 per bushel before nitrogen becomes profitable. Lack of moisture severely limited the physical response to fertilizer for production function (6.4) in 1955. Wisner loam is a fertile, heavy soil, and the lack of curvature in (6.5) is due as much to the initial fertility of the soils as to limited rainfall.

The long-run static supply curves have higher elasticity (Figure 6.14) than have the short-run supply curves (Figure 6.12). Nevertheless, all the long-run curves are inelastic when corn is over 40 cents per bushel. The elasticity is less than .5 when the price of corn is greater than 80 cents and less than .20 when the corn price is $1.20 or higher. If (6.1) were omitted, the elasticity of the remaining curves would lie below .45 for all corn prices of 40 cents or more. Much of the elasticity of (6.1) is due to nitrogen; the elasticity with only nitrogen variable (Figure 6.10) is nearly as large as with three nutrients variable and is considerably more elastic (less inelastic) than with only P_2O_5 and K_2O variable. Clarion (6.1), a highly productive soil, lacked fertilizer, particularly nitrogen, for the site of the experiment.[17]

Figures 6.15 and 6.16 are included to provide a summary of the static supply curves when all nutrients included in the production functions are allowed to vary.

The elasticities of the static supply curves also do not show any important differences among areas (Figure 6.16). Static supply curves (6.1) and (6.4) from Iowa data rank lowest and highest in elasticity, indicating that greater differences may exist within an area than among areas. Despite differences within and among areas, the elasticities of all the curves are uniformly low. All of the static supply curves have an elasticity of less than unity for a corn price over 40 cents. The elasticity falls with high corn prices. It is less than .3 for a corn price greater than $1 and less than .20 for a corn price greater than $1.20. The elasticity of supply curves (6.3), (6.4) and (6.5) is zero or near zero in the price range of 40 cents to $1.20.

IMPLICATIONS

Figures 6.10 through 6.16 indicate that the elasticity of static supply is low for all soil and weather conditions, prices, short-run and long-run supply curves and algebraic forms considered. Without exception, static supply is less than unity for corn prices over 40 cents per bushel. The elasticity is less than .3 for corn prices above $1.00 and less than .2 for corn prices above $1.20. The "average" elasticity of the curves lies well below these values, since in many instances the elasticity is near zero or zero in the relevant price range. Furthermore, the estimates indicate the elasticity at the beginning of the growing season on a given acreage. As the season progresses, opportunities diminish for increasing yields in response to favorable prices, and the supply elasticity essentially is zero for <u>all</u> production units as the end of the growing season approaches. The results clearly indicate low static supply elasticity.

[17]The long-run supply elasticities of Figure 6.14 give a more realistic estimate of static supply than do the short-run elasticities for the same production functions shown in Figures 6.10 and 6.12. A farmer seldom would use only a single nutrient when other nutrients give a significant yield response and also limit the response of the single nutrient.