4

Elasticity of Demand

A. Elasticity of Demand for Individual Farm Products

In most cases in economics, it is difficult to draw a sharp line between the long run and the short run. In agricultural economics, however, one kind of short run is clearly marked off. Most crops are produced once a year, and the yield per acre is determined chiefly by the weather. Variations in the weather from year to year are almost entirely random in character. A tendency toward cyclic variations has been "discovered" by a number of different investigators, but the length of the cycles differs so much among the different investigators that there is a real question whether there actually are any cycles at all. Crop production series show almost completely random variations from year to year. Each crop is like a flip of a coin or a roll of the dice—a new item, practically independent of the other items in the series. Crop production series, and other series closely associated with them (such as crop price series in times of stable demand, or independent of variations in demand), therefore lend themselves well to statistical analysis.

RELATIONS AMONG PRODUCTION, PRICE, AND INCOME

Each year farmers plant their crops, not knowing whether the weather will be good, bad, or indifferent; their crops accordingly large, small or average; and their prices accordingly low, high, or average.

Large crops bring low prices, and small crops, high prices. But will large crops bring high incomes, or low incomes?

The answer depends upon the extent to which prices vary (inversely) with variations in production. In the case of some crops, an increase in production of 10 per cent decreases price 20 per cent.

The price falls twice as far as the size of the crop increases. In this case, a large crop brings a lower income than an average crop. In other cases, the price falls less than the size of the crop increases; a large crop then is worth more than an average crop.

This relation between the extent of the change in the size of the crop and the extent of the change in price is called the price elasticity of the demand. Each crop has its own price elasticity of demand, differing from the elasticity for other crops. It is important to measure this elasticity for each crop. In a free-market economy, it is important to know how much, and in which direction, variations in the size of the crop affect income as well as price. This knowledge is still more important in a controlled economy or sector of an economy, such as a price or income stabilization program.

MEASUREMENT OF THE ELASTICITY OF DEMAND

The concept of elasticity is basically simple. People will buy more carrots, for example, when they are cheap than when they are high-priced. A reduction in the price of almost anything ordinarily increases the amount of the thing that can be sold. This responsiveness of quantity to price is called the elasticity of the good in question.[1]

With some goods, for example peaches, a change in the price will result in a large change in the amount that can be sold. With other goods, for example, salt, the same change in the price has only a small effect on the amount that can be sold. In practically no case is the quantity of a good completely unresponsive to a change in price; that is, the demand is very seldom completely inelastic. With most goods a change in price has an appreciable effect upon the quantity that can be sold—a small effect in the case of some goods, a large effect in the case of some others.

This definition of elasticity of demand is phrased in terms of the change in quantity per unit change in price. This does not mean that the change in price is regarded as the cause, and the change in quantity as the effect. In many cases the line of causation runs the other way; in agriculture, farmers determine the acreage and the weather determines the yield of the crop, and the quantity produced

[1] The term elasticity is not very clear. Frank Knight believes that the term "responsiveness of consumption" expresses the concept better. (Frank H. Knight, "Demand," *Encyclopaedia of the Social Sciences*, Vol. 5, 1931, p. 70.) It makes clear that elasticity refers to the responsiveness of quantity to price, not vice versa (which Moore has called the "flexibility of prices"). Knight's term, "responsiveness of consumption," is clearer or at least more self-explanatory than "elasticity of demand"; but it has one shortcoming, namely that it cannot, strictly speaking, be applied to the purchases of dealers who do not consume the product, whereas "elasticity of demand" can be thus applied. The term "elasticity of purchases" would meet this objection, but it is not so clear as the other. In any case, "elasticity of demand" has become so well established in use that it probably will remain in use (like the established width of railroad tracks, even though a greater width would be better suited to present needs).

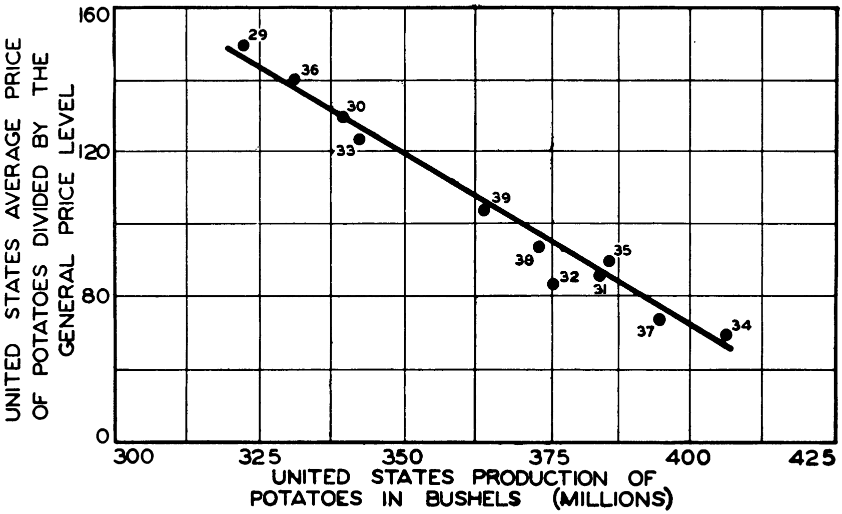

Fig. 4.1 — Potatoes: United States average farm price, December 15, and total production, 1929–39. (Data in the 1950's and 1960's show too much scatter to be handled in one diagram.)

"sets the price." But the term elasticity here as elsewhere refers to the change in quantity, neither causing nor caused by, but *associated with* a given change in price.

The concept of elasticity has been familiar to economists for generations. Gregory King two or three centuries ago attempted to measure the elasticity of the demand for wheat in quantitative terms,[2] but nothing much else was done until Moore in 1914 published his empirical studies of the elasticity of the demand for corn, hay, and potatoes.[3] After World War I, a great increase took place in the quantity of statistical data available concerning production, prices, demand, and supply, and analytical statistical methods were applied to economic data on an extensive scale. Many studies of the elasticities of demand for different products have been published, and one of the first things a student of price analysis

[2] "We take it, that a defect in the harvest may raise the price of corn in the following proportions:

Defect		*Above the Common Rate*
1 Tenth		3 Tenths
2 Tenths	*Raises the*	8 Tenths
3 Tenths	*price*	16 Tenths
4 Tenths		28 Tenths
5 Tenths		45 Tenths

so that when corn rises to treble the common rate, it may be presumed that we want above 1/3rd (one-third) of the common produce; and if we should want 5/10ths, or half the common produce, the price would rise to near five times the common rates." C. D'Avenant, *Political and Commercial Works*, Vol. II, 1771, p. 224, quoted in *Farm Economics*, Cornell Univ., May, 1939, p. 2758.

[3] Henry L. Moore, *Economic Cycles, Their Law and Cause*, Macmillan, 1914.

TABLE 4.1

POTATOES: UNITED STATES PRODUCTION AND AVERAGE FARM PRICE, DECEMBER 15, 1929–39*

Year	(1) Potatoes (000 bushels)	(2) Potatoes Average Price per Bushel December 15 (cents)	(3) Wholesale Price Index, All Commodities Dec. 1926=100	(4) [(3)x1.50−50]	(5) (2) ÷ (4)	Data in (1) and (5) Expressed in Percentages of Average: Production	Deflated Prices
1929	322,204	134.6	93.3	89.95	149.6	88.1	144.5
1930	340,572	89.8	79.6	69.40	129.4	93.1	125.0
1931	384,125	45.0	68.6	52.90	85.1	105.0	82.2
1932	376,425	36.8	62.6	43.90	83.8	102.9	81.0
1933	342,306	69.2	70.8	56.20	123.1	93.6	118.9
1934	406,105	44.9	76.9	65.35	68.7	111.0	66.4
1935	386,380	63.7	80.9	71.35	89.3	105.6	86.2
1936	331,918	106.3	84.0	76.0	139.9	90.7	135.2
1937	395,294	53.0	81.7	72.55	73.1	108.1	70.6
1938	374,163	61.3	77.0	65.5	93.6	102.3	90.4
1939	364,016	70.8	79.0	68.5	103.4	99.5	99.9

* Sources of data: (1) and (2) *Agricultural Statistics*, 1940, pp. 262, 269; *Crops and Markets* (monthly); data from *Wholesale Prices* (monthly). (3) *Mimeo. 4313*, Bureau of Labor Statistics, U. S. Department of Labor.

should be able to do is to measure the elasticity of the demand for a given product and interpret his results properly.

Measuring Elasticity

Let us take a concrete example. The price and production data for potatoes for eleven years are given in Table 4.1. They are plotted in scatter-diagram form in Figure 4.1. The prices are the average United States farm prices December 15 each year, adjusted for changes in the general price level.[4] The production figures show the total production of potatoes in the United States.

The dots in Figure 4.1 fall closely around a sloping line, which can be fitted to the data mathematically by the method of least squares, or simply drawn in freehand. In either case, the investigator must decide whether to use a straight line or a curved line to fit the dots. The decision must be based on (1) the appearance of the data, (2) the investigator's knowledge of the particular product, and (3) his grasp of economic theory. That is, the line chosen should be a reasonable one from all three of these points of view. In Figure 4.1 the dots fall about a straight line, and in the absence of any reason for using a curved line, a straight line is chosen. The line in this case is drawn in freehand. It does not necessarily go through any of the dots, but merely represents the average relationship between production and price shown by the data. The line should not be extrapolated (extended) beyond the dots.

The job now is to measure the elasticity of the demand represented by this line—that is, to measure the change in quantity associated with a unit change in price.[5] Inspection of the chart

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[4] These actual production and market price data are used so as to show that the concept of elasticity that we measure here is a concept that reflects and arises from what goes on in the world, and not merely from some economist's brain. Data for the pre-war period are used, because the data since that time are affected by additional war and post-war forces that can only be taken into account by complicated methods that still leave the dots with a rather wide scatter about the line.

The adjustment for changes in the general price level here consists in dividing the price data by the corresponding Bureau of Labor Statistics all-commodity wholesale price index inflated by 50 per cent (because the relation between the two is not 1 to 1 but 1 to 1.5). This procedure, probably not clear to the reader at this point, is explained in detail in Chapter 8, along with a general discussion of the adjustment of prices to take care of the effect of changes in demand.

The simple analytical methods used have resulted in the straight-line demand curve shown. More complicated and accurate analyses show that the demand curve has a concave curvature at the lower end.

[5] The computation of the elasticity of the demand should be based upon two points on the line rather than upon two actual data dots, because a line joining any two dots (1938 and 1939, for example, or still more obviously, 1931 and 1932) may have a different slope from the line representing the average relationship of all the dots, and it is the average relationship that is being measured. Furthermore, two points at the ends of the line shown in Figure 4.1 should be

shows that a change in quantity from 325 million bushels to 400 million bushels (using round numbers near the ends of the line) is associated with a change in price in the opposite direction, from 144 to 70 cents per bushel. That is, a change in quantity of 75 million bushels is associated with an opposite change in price of 74 cents; the change in quantity per unit change in price is $\frac{75}{-74} = -1.01$.

But this is not the elasticity of the demand for potatoes, for it is evident that the result is determined largely by the particular units in which the quantity and price changes are measured. If the quantity had been measured in bushels, for example, instead of millions of bushels, the answer obtained by the formula above would have been —1,013,389, clearly an absurd answer. Or if the price had been measured in English money, the change in price would have been about 3 shillings instead of 75 cents; and this again would have given a different answer. The basic situation remains unchanged when different units of computation are used, but the numerical results obtained above are quite different. This is not as it should be. What is needed is a measure of elasticity that will be unaffected by the units of measurement chosen—a coefficient of elasticity.

The Coefficient of Elasticity

One good way to compute such a coefficient of elasticity is to divide the observed change in quantity by the average of the two quantities, i.e., divide 75 by 367.5 ($400-325$ by $\frac{400+325}{2}$).

The same thing can be done with the prices. The formula thus becomes a complex fraction,

$$\frac{\dfrac{\textit{change in quantity}}{\textit{average quantity}}}{\dfrac{\textit{change in price}}{\textit{average price}}}$$

used, rather than two anywhere along the line, since it is the elasticity of the line as a whole that is to be measured, not just the elasticity of a part of it.

This concept of the elasticity of the line as a whole, or of a part of it, may be referred to as the average elasticity in much the same way that reference is made to one's average speed, say 50 miles an hour, on a trip. It is contrasted with point elasticity, as in physics the empirical concept of average speed is contrasted with the limiting concept of velocity. Point elasticity is taken up in the next chapter.

Now the average is simply the total sum divided by the number of items. The number of quantity items is the same as the number of price items (in this case two) so the result will be the same if the sum of the quantities and the sum of the prices is used instead of the average prices and quantities (the 2's in the numerator and denominator cancel out). This will save some computation. The formula may then be expressed:

$$\frac{\dfrac{q_1 - q_2}{q_1 + q_2}}{\dfrac{p_1 - p_2}{p_1 + p_2}}$$

The same formula can also be written in the form

$$\frac{q_1 - q_2}{p_1 - p_2} \cdot \frac{p_1 + p_2}{q_1 + q_2}$$

This was substantially the form which Marshall used,[6] although he restricted the concept to infinitesimally small changes, in which case the change is represented by "*d*," and there is no need to use the average or the sum of the quantities and prices. His formula was merely $\frac{dq}{dp} \cdot \frac{p}{q}$. The complex-fraction formula is clumsier in appearance than the Marshallian form of the formula; it is superior to the other form for introductory expository purposes, because it shows more clearly just what elasticity is, but Marshall's form of the formula is standard and we will use it henceforth.

The data for potatoes substituted in this formula yield the following coefficient of elasticity:

$$\frac{400 - 325}{70 - 144} \cdot \frac{70 + 144}{400 + 325} = \frac{75}{-74} \cdot \frac{214}{725} = \frac{1605}{-5365} = -0.299$$

Exactly the same result is obtained when the original quantity data are expressed in tons instead of bushels. The figures then become

$$\frac{12 - 9.75}{70 - 144} \cdot \frac{70 + 144}{12 + 9.75} = \frac{2.25}{-74} \cdot \frac{214}{21.75} = \frac{481.5}{-1609.5} = -0.299$$

The same thing is obviously true if the prices are expressed in some other units.

We can now refine our definition of elasticity and make it more

[6] Alfred Marshall, *Principles of Economics,* 8th American edition, Macmillan, Mathematical Appendix, Note III, p. 103 n.

precise and definite, thus: *Elasticity is the proportional change in quantity associated with a proportional change in price.* The strict mathematical definition runs in terms of infinitesimals, but for students without mathematical training, the concept can be expressed in terms of percentages. The definition in that case is: *Elasticity is the percentage change in quantity associated with a 1 per cent change in price (other things remaining constant).* The computation for potatoes given above shows that a change in quantity of 0.299 per cent (roughly, 0.3 per cent) is associated with a 1 per cent change in price. That is, the elasticity of the demand for potatoes is — 0.3.

EFFECT OF CROP SIZE ON TOTAL INCOME

The chart discussed in the preceding pages shows the effect of the size of the potato crop upon the price of potatoes. Another question now arises. What is the effect of the size of the potato crop upon the *total revenue* from the crop? Does a large crop depress prices so much that the low price per bushel more than offsets the large number of bushels sold, or not?

It takes only a moment to answer this question. The smallest crop shown in Figure 4.1 was 322 million bushels; it sold at a price of \$1.50 per bushel; the total revenue, therefore, was 322 million × \$1.50, or *\$483 million.* The largest crop was 406 million bushels; it sold at a price of 69 cents per bushel; the total revenue therefore was 406 million × \$.69, or *\$289 million.* The small crop was worth more than the large crop. The larger the crop, the smaller the total income. The demand in this case is said to be inelastic. In the case of some goods, a small reduction in price results in a larger increase, proportionally, in sales, and the larger the crop, the *larger* the total revenue. The demand in this case is referred to as elastic.

What these terms elastic and inelastic really mean is "relatively elastic" and "relatively inelastic." The term "relatively" is dropped only for brevity; it really belongs in. "Relatively" here means relative to *unit elasticity,* the borderline case between relatively elastic and relatively inelastic. If the elasticity of demand for a good were such that any percentage increase in supply depressed the price by an equal percentage, then the total value of a large crop would be the same as that of a small crop.[7] In fact, no matter

[7] Strictly speaking, this is true only when the percentage changes involved are infinitesimally small. Large changes introduce slight arithmetic discrepancies. For example, if the crop increased 10 per cent and the price decreased 10 per cent, the total value would be 90 × 110 = 9,900, not 10,000. This question is discussed fully in the next chapter.

what the size of the crop, it would be offset by an opposite change in price, so that the total value of the crop would be constant no matter what its size. In this case, in the formula presented a few paragraphs back, a 10 per cent (or any other) change would yield the following results:

$$\frac{10}{-10} \cdot \frac{100}{100} = \frac{1000}{-1000} = -1.0$$

This is called unit elasticity. It is the dividing line or borderline case between elastic demand and inelastic demand. If the elasticity is less than 1 it is called inelastic; if it is more than 1 it is called elastic. For technical accuracy, the terms, "relatively inelastic" (that is, less elastic than unity, inelastic relative to unit elasticity) and "relatively elastic" (more elastic than unity) should be used. But the word "relatively" is understood, and may be omitted in ordinary discussion.

In the illustration just given, an increase in quantity, a plus, is associated with a decrease in price, a minus. The measure of elasticity, therefore, carries a minus sign, as shown. Curves of this sort, with minus signs, all slope downward to the right, that is, from northwest to southeast. Practically all demand curves are of this character. If a case were found where increases in quantities were associated with *increases* in prices, the numerical expression of elasticity would have a positive sign and the curve would slope upwards to the right.

ELASTICITY GRAPHICALLY REPRESENTED

Elasticity can be represented graphically, but proper attention must be given to the scales of the charts. One might think that a demand curve of unit elasticity would be the hypotenuse of a right-angled triangle lying on one side, and that the slope of the curve would therefore be 45°; and, further, one might conclude that all curves that were more steeply sloped than 45°—say 50°, 60°, or 70°—would be inelastic, and all curves less steeply sloped than 45° would be elastic.

Reference back to Figure 4.1, however, shows that the demand curve for potatoes shown in that figure has a slope that is definitely less than 45°. It is about 30°. This would seem to place it in the elastic category. Yet the numerical computations a few pages back showed that the elasticity was —0.3°. This is clearly inelastic. Which is wrong, our graphics or our arithmetic?

A moment's reflection shows that it is our graphics that is at fault. The scales in Figure 4.1 are laid out in absolute, not percentage, terms. But elasticity is a proportional concept. The scales in the graph should run in percentage terms, and 10 per cent on the quantity scale should cover as much distance as 10 per cent on the price scale. If this procedure is followed, the chart will show elasticity correctly; the category into which the curve falls—inelastic or elastic—can then be determined directly from the chart by observing whether its slope is steeper or flatter than 45°.

The data, expressed in percentage terms and plotted on a properly scaled chart, are shown in the left-hand section of Figure 4.2. The curve in this chart is much steeper than the one in Figure 4.1. It is clearly in the inelastic category. The proper arrangement of scales for representing elasticity directly is that which is used in Figure 4.2, with the data expressed as percentages and the horizontal and vertical scales equal, so that 10 per cent on one scale equals the same distance as 10 per cent on the other.

It is not the conversion of the original data into percentage form alone that enables elasticity to be read directly from the slope of the line on a chart with arithmetic scales. It is this, plus the setting of the horizontal and vertical scales so that 10 per cent on the one scale is represented by the same distance as 10 per cent on the other scale, that does the trick.

This could be accomplished just as well by plotting the data in their original form, on a chart with the horizontal and vertical scales set so that the average price equals (say) 5 inches on the vertical scale, and the average production equals the same distance, 5 inches, on the horizontal scale. The elasticity could then be read directly from the slope of the line on a chart with arithmetic scales, regardless of what units the original data were expressed in. This sounds easier than converting the data into index form. But, as a matter of fact, it turns out that it is more trouble to do this than to convert the data into index form and plot them in that form. For suppose that the average price comes out to be 77 cents, or some other figure that is not an easy multiple of 5; the resulting scale is very awkward to plot, especially when the production scale is probably awkward too. It is easier after all to convert the data into index form (i. e., into percentages) and set the scales so that 100 per cent equals 5 or 10 inches, or some other easy divisor of 100.

Elasticity can also be shown graphically by plotting the data in their original form on double logarithmic paper, that is, paper in which both the horizontal and vertical scales are logarithmic. No matter what units the original data are expressed in—dollars, francs,

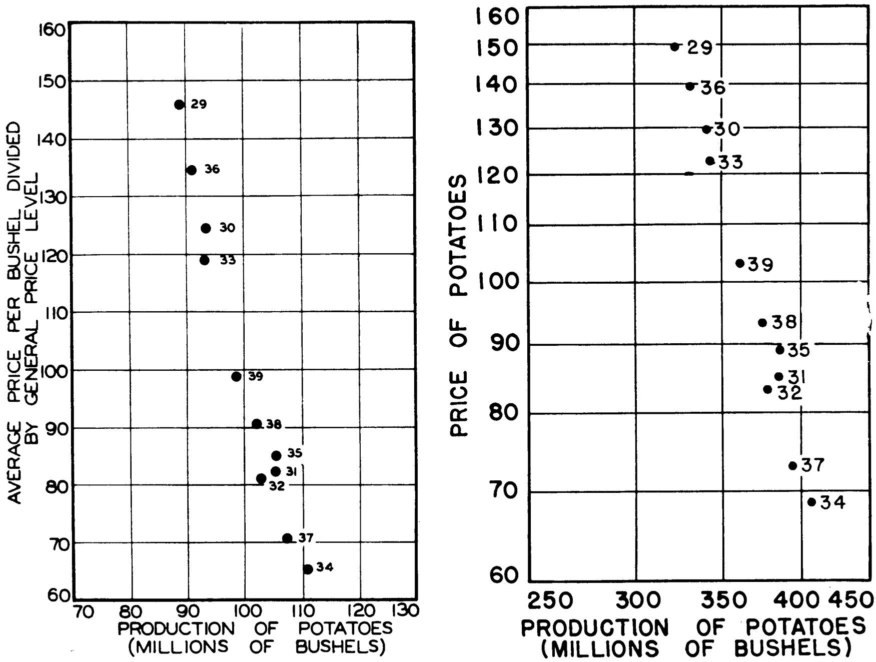

Fig. 4.2 — Potatoes: United States average farm price, December 1, and total production, 1929–39. Chart on left, data in percentage terms, arithmetic scales; on right, data in original form, logarithmetic scales.

pounds, ounces, etc. — when they are plotted on double logarithmic scales, the slope of the line shows the elasticity directly.[8] The data plotted in this manner are shown in the right-hand section of Figure 4.2. The slope of the curve here is identical with the slope of the curve in the left-hand section of Figure 4.2. This is really the simplest way to show the relation between price and production data; but most people are not familiar with logarithmic scales, so for purposes of presentation it is better to plot the data in percentage terms on ordinary arithmetic paper.

Considerations similar to those which hold for ordinary arithmetic paper rule here. It is not the plotting of the data on logarithmic scales that enables elasticity to be read directly from the chart; it is the fact that the horizontal and vertical scales are equal that does it.

[8] Technically speaking, the elasticity is not the same as the slope; it is the reciprocal of the slope. For the slope is the number of units that the curve rises per unit of horizontal run; it is $\frac{p}{q}$. But elasticity is $\frac{q}{p}$. The greater (i.e., steeper) the slope the less the elasticity. In addition, elasticity is expressed in proportions, while slope is usually expressed in absolutes, such as feet.

EFFECT OF MIDDLEMAN'S MARGINS ON ELASTICITY

The factors that determine elasticity are discussed in any good textbook on elementary economic theory, and there is no need to repeat the discussion here. But most discussions of this sort deal with the elasticity of demand at the retail store, or wherever the consumer buys the goods. The elasticity of demand at the farm is affected by still another thing in addition to these—by the size and stability of the middleman's charges, that is, the margins between the prices of goods at the farm and at the retail store.

Middleman's margins remain rather stable through periods of high prices and low prices resulting from fluctuations in supplies. They change from periods of prosperity to periods of depression (fluctuations in general demand) because wages, although comparatively stable, do change to some extent from peak to trough of industrial activity. But during periods of relatively stable industrial activity, the margin between potato prices at the farm and potato prices at the retail store, for example, remains much the same when potato supplies are short and prices high as when supplies are plentiful and prices low.

In that case, if the demand curves for potatoes at retail and for potatoes at the farm were plotted on the same chart with arithmetic scales, the two curves would be parallel, the one lying above the other. The curves would look something like those in Figure 4.3. This figure is based on hypothetical data, that enable the exposition to be made arithmetically simple.

In this chart the average price of potatoes at the retail store is 20 cents a pound, the average price of potatoes at the farm is 10 cents a pound, and the margin between the two prices remains fixed at 10 cents a pound. The elasticity of the demand for potatoes at retail is represented as unity. From the parallelism of the two curves, one might conclude that the elasticity of the demand for potatoes at the farm must be unity also.

But that would be a mistake. Application of the regular elasticity formula to these hypothetical data shows that whereas the elasticity of the demand at retail is unity, that at the farm is only -0.5. The two calculations, based upon figures read off the chart, follow:

For potatoes at retail $\dfrac{12-8}{16-24} \cdot \dfrac{20}{10} = \dfrac{80}{-80} = -1.0$

For potatoes at the farm $\dfrac{12-8}{6-14} \cdot \dfrac{10}{10} = \dfrac{40}{-80} = -0.5$

Looking at the two sets of calculations, we see that they are identical in all respects except the average price. For potatoes at retail, the average price is 20; for potatoes at the farm it is 10.

It is clear from this formula that if you halve the average price, other things being the same, you halve the elasticity. It shows that the width and fixity of the margin between farm prices and retail prices affects the elasticity of the demand at the farm. The wider and more stable the margin, the less elastic is the demand at the farm compared with the demand at the retail store.[9]

OWN-PRICE ELASTICITY AND CROSS-ELASTICITY OF DEMAND

The elasticity of demand means the responsiveness of consumption to changes in price. Since this refers to the price of that product, one type of elasticity is sometimes referred to as the "own-price" elasticity — the responsiveness of consumption of a product to changes in its own price.

There is also a second kind of elasticity — the responsiveness of consumption of a good, say carrots, to changes in the price of a substitute, say beans. This is referred to as the cross-elasticity of demand.

The own-price elasticity and the cross-elasticity of demand for the major farm products have been brought together in a comprehensive and internally consistent table covering four pages.[10] This table is reproduced here as Table 4.2, with thanks to the author for saving a lot of people a lot of trouble.

AN INDIFFERENCE SURFACE FOR BEEF AND PORK

Economic theorists have constructed an objective foundation for the traditional demand curve. This demand curve is based on the subjective concept of diminishing utility. Economic theorists have long wanted a more objective basis for the demand curve, and they have developed for this purpose the concept of the "indifference surface."

This concept can be represented in graphic form by plotting the quantity of one good along the horizontal axis and the quantity of a somewhat similar, readily substitutable good along the vertical axis. A line or curve can then be drawn along a series of points at which the consumer is indifferent whether he buys, for example, 2.5 pounds of beef and 4 pounds of pork, 3 pounds of each, or 4.5 pounds of beef

[9] When a reduction is made in middlemen's margins, who gets the benefit — the producer, or the consumer? This question is answered in G. S. Shepherd, *Marketing Farm Products*, 5th ed., Iowa State Univ. Press, 1969, Chap. 9.

[10] G. E. Brandow, "Interrelations Among Demands for Farm Products and Implications for Control of Market Supply," Pennsylvania State Univ., Agr. Exp. Sta., Bul. 680, Aug. 1961, p. 17.

and 2 pounds of pork. The theorists then go on to show how this can be shown to underlie the demand curve; they start with an assumed indifference curve and deduce what demand function this would imply.

Very few theorists have fleshed out this concept with real empirical data. One economist who has done this, however, is Fred V. Waugh. The rest of this section is quoted verbatim from his "Demand and Price Analysis," USDA Tech. Bul. No. 1316, 1964, pages 53 to 56. Waugh developed this section over a period of several years of discussion with economic theorists, and included it in his last major bulletin before retirement. It shows his clear and refreshing style at its best.

> . . . very few people have attempted to start with market data and find the indifference functions that are implied by the quantities purchased and their prices. Yet, this is just what we need if we are to make any practical use of indifference functions, or even if we are to use such functions to help us understand how the market operates.
>
> I have attempted to derive an indifference surface for beef and pork. It is based on data in table 7.1. The first two columns in the table show per capita consumption of beef and pork in the United States from 1948 through 1962. The third column, q_3, is the per capita consumption of all goods and services other than beef and pork. It is found by starting with the per capita disposable income, subtracting the expenditures for beef and pork, and dividing the remainder by the consumer price index. This gives us the deflated expenditures for everything except beef and pork. In this sense, it represents consumption of all other things. The fourth column, r, is the ratio of retail beef prices to retail pork prices. (The fifth column will be explained a little later.)
>
> The first step in the analysis was to run an ordinary regression equation in logarithms, using log r as the dependent variable, since r is the variable to be explained. It turned out to be

$$(7.5)\quad \log r = -4.788588 - \underset{(0.310)}{0.85546} \log q_1 + \underset{(0.441)}{0.955203} \log q_2 + \underset{(0.398)}{1.452289} \log q_3.$$

> The numbers in parentheses are standard errors of the regression coefficients immediately above. The squared correlation coefficient was 0.800.
>
> Now, we come back to column 5 of table 7.1; r is the price ratio adjusted for variations in q_3. The mean of log q_3 was 3.274239. The formula for the corrected price ratio is given in footnote 3 of the table.
>
> *The adjusted price ratios r' are estimates of what the price ratios would have been with varying amounts of beef and pork (i.e., varying q_1 and q_2, but with expenditures for all other goods and services held constant).* I will use these adjusted price ratios to make inferences about the shape of a *partial* indifference surface for beef and pork—that is, *a set of isoquants connecting various combinations of beef and pork to which the typical consumer would be indifferent* (assuming constant amounts of other things).
>
> This use of indifference curves differs from those found elsewhere. Edgeworth, and many other early writers on indifference, discussed cases in which the consumer spent his entire income for the two goods studied—say, for beef and pork, or for foods and nonfoods. This enabled them to work in only two dimensions. Hicks and some other modern economists make a similar simplification by considering combinations of one commodity and other things grouped together.

TABLE 7.1

DATA FOR INDIFFERENCE SURFACE

Year	Annual per Capita Consumption: Beef (q_1)	Annual per Capita Consumption: Pork (q_2)	Consumer Income[1] (q_3)	Actual Price Ratio[2] (r)	Adjusted Price Ratio[3] (r')
	Pounds	*Pounds*	*Dollars*		
1948	63.1	67.8	1,615	1.226	1.529
1949	63.9	67.7	1,592	1.241	1.584
1950	63.4	69.2	1,703	1.379	1.594
1951	56.1	71.9	1,744	1.485	1.657
1952	62.2	72.4	1,785	1.490	1.607
1953	77.6	63.5	1,847	1.052	1.079
1954	80.1	60.0	1,817	1.006	1.053
1955	82.0	66.8	1,924	1.158	1.120
1956	85.4	67.3	2,003	1.185	1.081
1957	84.6	61.1	2,006	1.095	.997
1958	80.5	60.2	1,960	1.190	1.120
1959	81.4	67.6	2,040	1.388	1.259
1960	85.2	65.2	2,057	1.364	1.197
1961	88.0	62.2	2,083	1.281	1.104
1962	89.1	64.0	2,144	1.319	1.090

[1] Per capita disposable income less expenditures for beef and pork, deflated by the consumer price index.

[2] Ratio of retail beef price to pork price.

[3] The same ratio corrected for the effect of q_3. Specifically,

$$\log r' = \log r - 1.452289 (\log q_3 - 3.274239), \text{ or}$$
$$\log r' = \log r + 4.755141 - 1.452289 \log q_3.$$

I searched for combinations of beef and pork that would apparently have been equally satisfactory to the typical consumer, *always assuming that he could have bought the same amounts of other goods and services.*

These indifference combinations of beef and pork will be inferred from the adjusted price ratios, r'. The price ratios are the "bridge" between objective statistical analysis and the pure theory of subjective indifference.

First, we plot the data for q_1, q_2, and r' for each year, as in figure 7.2. In 1948, for example, q_1 was 63.1, q_2 was 67.8, and r' was 1.529. We locate the point (63.1, 67.8), and label it 48 to identify the year. Through this point we draw a line sloping downward 1.529 units on the x-axis for each unit on the y-axis. A transparent triangle and straight edge are very useful in drawing such lines. Similarly, we locate the (q_1, q_2) points and the price-ratio slopes for all the other years.

What do these lines mean? Take 1948, for example. If the price ratio were 1.529, the typical consumer could have bought any combination of beef and pork lying along the straight line (extended as far as he pleased in either direction). Any of the combinations along that line would have cost the same amount of money and would have left the consumer as much to spend on other things. Actually, the typical consumer bought 63.1 pounds of beef and 67.8 pounds of pork. He did so of his own free will, *because he preferred that combination to the others on the straight line.*

This is the key to indifference analysis. We can infer certain things about preferences from the actual responses of consumers to prices. More precisely, we can infer that there is an indifference curve tangent to the straight line through each observed combination (q_1, q_2), and that each such line is concave downward. We know that no two indifference curves can cross one another.

With these simple principles in mind, it is easy to interpolate a series of graphic curves in a diagram like that in figure 7.2. Like any statistical problem with actual data, the conditions will not be met exactly—the fit will not be perfect. But it will be close enough for practical purposes—that is, the adjusted price ratios, r', will be approximately equal to the slopes of the indifference lines passing through a given (q_1, q_2) combination.

For precise measurement, there is merit in fitting a mathematical surface to the data. The isoquants (contour lines) of such a surface should fit the data in the sense described above. Appendix 5 explains a mathematical equation that I used to fit the surface in figure 7.2. But we need not spend time on the mathematical fit here. The principles are the same, whether the indifference lines in figure 7.2 are interpolated graphically, or are computed on a calculating machine.

I have drawn five indifference curves through figure 7.2. Of course, any number could have been drawn. The five curves are numbered in Roman numerals. The analysis does not indicate which combinations are preferred—only which are indifferent. But the consumer's position is obviously improved as he goes from combinations on curve I to those on II, and to those on the higher curves, since he can get more beef and more pork on the higher curves. But there is no attempt in this analysis to measure the gain, either in total utility or in marginal utility. The satisfactions obtained from combinations of curve II are not necessarily twice as great as those on curve I—they are simply greater. How much greater we do not know. This is no different from measuring how hot it is by a thermometer. We do not necessarily feel twice as warm when the thermometer reads 60° F. as when it reads 30°. We are simply warmer. (Advertising claims of a certain soap making clothes 9.2 percent brighter, 28.6 percent fluffier, or 1.67 percent better smelling may well be considered with some suspicion.)

One final comment should be made on the indifference lines in figure 7.2. These lines are only slightly curved—that is, they are almost straight lines, if they were straight lines, they would indicate that beef and pork were

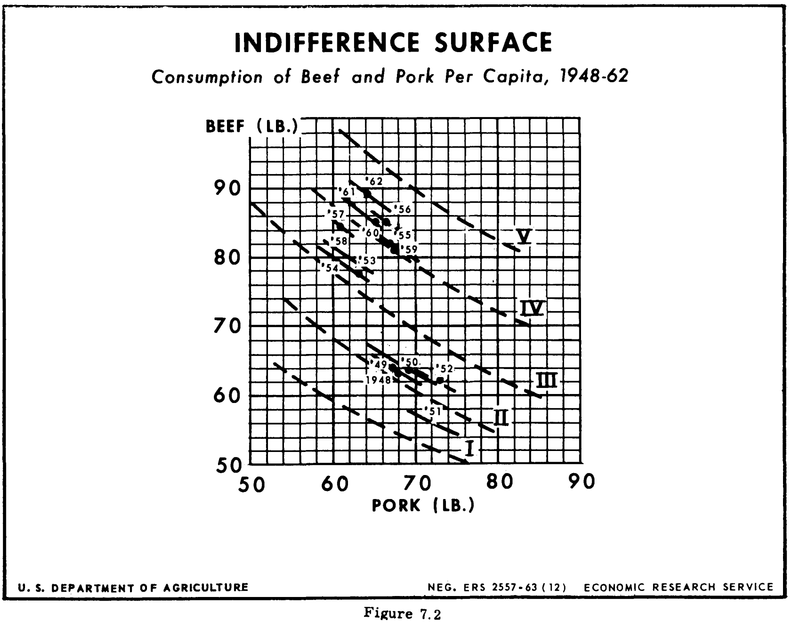

Figure 7.2

perfect substitutes for one another. They obviously are good substitutes—at least for many people. The small degree of curvature indicates, as we would expect, that the typical consumer does not consider them perfect substitutes. He will buy more pork and less beef if, and only if, pork becomes less expensive relative to beef. But the main point is that this analysis indicates that only small changes in price ratios are needed to induce rather substantial adjustments in consumption. Some mathematicians might wonder whether the relative flatness of the indifference lines in figure 7.2 might not be due to the particular mathematical equation that was used. The answer is that any mathematical equation that fits the data would give the same results—as anyone can see by studying the slopes of the actual price ratios in figure 7.2.

B. Effect of Time Upon Elasticity

Economists since at least as far back as Marshall have recognized that it is incorrect to speak of "*the* elasticity" of the demand for a commodity, for the elasticity differs according to the length of time involved. The subject has been given extensive theoretical discussion, with the aid of hypothetical data, but not much has been offered in the way of empirical demonstration. A few studies may be brought together to serve this purpose.

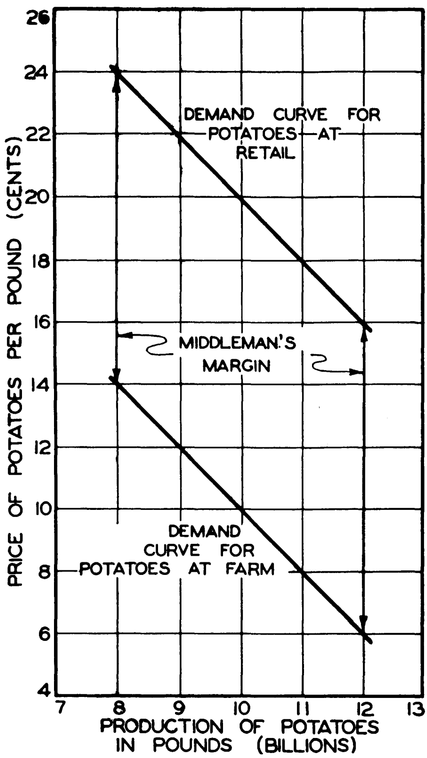

Fig. 4.3 — Hypothetical demand curves for potatoes at the retail store and at the farm.

SHORT-TIME ELASTICITIES

Estimates have been made that "*the* elasticity" of the demand for hogs at the farm is —0.46.[11] But all that this statement means is that the elasticity of the demand for hogs based upon annual data is (or, more accurately, was) —0.46. Other empirical studies have shown that the elasticity of the demand for hogs derived from weekly data is much greater than this, and that the elasticity

[11] *Ibid.*

derived from daily data is still greater. Stover[12] found that over a 7-year period the elasticities of the demand for hogs at Chicago based on daily, weekly, and yearly data were as follows:

Saturday	—5.8
Wednesday	—2.8
Week	—2.5
Year	—1.0

Among the various days of the week, the elasticity was greatest on Saturday and least on Wednesday; the elasticity on Wednesday was almost as high as the elasticity for the week as a whole.[13]

Similarly, the elasticity of the demand for eggs, based upon annual data, is about —0.3,[14] whereas the elasticity based upon monthly data would be higher. Other instances of this sort could be given. It is not surprising that the short-time elasticities differ from the annual-data elasticities; they refer to different demands. The short-time elasticities should be greater than the long-time elasticities, because a large part of the short-time fluctuations in supplies thrown on the market are absorbed by short-time storage operations. Dealers buy eggs, for example, for storage, whenever they believe that the price of eggs some time in the future (within the probable storage life of an egg) will be higher than it is at present — and higher by more than the cost of storage to that future time. The future changes in prices that dealers can predict most confidently are those associated with regular seasonal changes in egg receipts, so that storage is largely a seasonal phenomenon. At the time of large egg receipts and low prices, therefore, the storage dealer's demand for eggs is added to the consumer's demand; this keeps prices from falling as low as they would in the absence of purchases for storage. Later on in the season, when egg receipts are light and prices high, the storage dealer's eggs are added to the current receipts from producers. This keeps prices from rising as high as they would otherwise. Longer-time (annual) fluctuations in supplies, however, cannot be thus absorbed, because the commodity is too perishable to stand storage for more than a few months.

[12] Howard J. Stover, "Relation of Daily Prices to the Marketing of Hogs at Chicago," Cornell Univ. Agr. Sta. Bul. 534, p. 33.

[13] The elasticity he found for the yearly data was higher than that which was found in the more recent study referred to in the preceding footnote, because his data were Chicago (not national) data, and he found the gross regression of receipts on prices, not the net regression.

[14] G. E. Brandow, *op. cit.*, p. 17.

LONG-TIME ELASTICITIES

The elasticities of demand based on daily, weekly, or monthly data are likely to be greater than for annual data. What about the elasticities based on items each of which covers more than a year, perhaps five or ten years?

There are reasons for believing that these elasticities based on long-time data may be greater than the elasticities based on annual data. These reasons are not the same as those which make the elasticities for weekly data greater than for annual data; they are related not to storage, but to the ease of substitution.

If some year the grapefruit crop is short, for example, consumers who have established a place for it on their breakfast table may bid grapefruit prices up to a high point in an attempt to keep it there. They know that grapefruit will probably be plentiful again within another year, and they dislike to change their consuming habits merely for a year only to change them back again when the year is over. But if grapefruit acreages were more or less permanently reduced and grapefruit rose to a place in the luxury price class, many consumers would replace it on their breakfast table with something else, and prices would not be bid so high as for a one-year shortage.

Another example is corn. The demand for corn, based upon annual data, is only about —0.5 at its lower end; but if large supplies and low prices seemed likely to persist for years in the future, power alcohol plants would be set up to use the cheap corn, and would open up a demand that would be very elastic indeed. Similarly, at the upper end of the scale, if scarcity and high prices appeared likely to persist for a decade or more, consumers would have time to cultivate new tastes and manufacturers would have time to bring new substitute products on the market, which would render the upper part of the curve more elastic also.

This boils down to the simple fact that the more time you give people to change their tastes, the more they will change them. This principle operates continuously, from the shortest periods of time, only a few moments long, up to the longest periods, decades and more in length. Within the short periods of time, however, the effect of this principle is more than offset by the opposite effect of storage and subsequent "unstorage" of temporary surpluses. The lowest elasticity of demand for a good, therefore, is that which is based on data each of which represents a period just a little longer than the storage life of that good. For extremely perishable goods like strawberries, this period is only a few days or weeks in length. For many farm products which are semiperishables, such as meat, eggs, and butter, this period is a year. Most analyses of the demand for farm products are based on annual data, and the elasticities found for the semiperishables are likely to be the minimum elasticities; both shorter-period and longer-period data yield higher elasticities than the annual data. For grains, which are stored to some extent for longer periods than one year, the minimum elasticity period is likely to be longer than one year. For cotton, which is stored for still longer periods than grain, the minimum elasticity period is likely to be still longer.

THE MEASUREMENT OF LONG-RUN AND SHORT-RUN ELASTICITY

It is difficult to measure "the" short-run elasticity of supply or demand directly, for through each point on a long-run supply or demand curve passes a fan of short-run curves, each one appropriate to a different interval of time.[15]

Figure 4.4, Section A, illustrates this point. The curve D_LD_L is the long-run demand curve. The point B on D_LD_L represents an equilibrium of demand and supply: At a price OA, the quantity AB is consumed each period. If the supply curve shifts so that the price is now OC, the quantity consumed does not increase immediately to CP, where P is a point on the long-run demand curve, but to CD, where D is a point on one of the short-run demand curves through B. If the price were to remain at OC, the quantity CE would be consumed the following period, then CF, then CG, CH, and so on. Each of the points, D, E, F, G, H, etc. lies on a different short-run demand curve through the point B. As time passes, the points gradually approach the point P which lies on the long-run demand curve.

In most situations, price will be changing constantly; hence, the points observed never lie on the long-run demand curve. Figure 4.4, Section B, illustrates this situation. We start out, as before, from an initial equilibrium point B on the long-run demand curve D_LD_L. Now, however, let supply shift in such a way that the price falls constantly, first to OC, then to OE, OG, OJ, and so on. When the price falls from OA to OC, consumers adjust their consumption

[15] The next few paragraphs, ending with Figure 4.5, are adapted from Marc Nerlove, "Distributed Lags and Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," *Journal of Farm Economics,* Vol. 40, No. 2, May, 1958.

from AB to CD. If the price remained at OC, they would consume CW the following period; but the price falls again to OE. Consequently they move along a new short-run demand curve through the point W to F. They consume slightly more than they would have, had the price remained at OC. Thus, as price falls, we observe a series of points, D, F, H, J, L, etc., which all lie on different short-run demand curves passing through different points on the long-run demand curve.

A curve passing through these points, $D_E D_E$, has neither the average elasticity of the short-run curves nor the elasticity of the long-run curve. The curve $D_E D_E$ is the sort of demand curve that would be estimated were we to neglect the whole problem of short- and long-run demand; i.e., it is the sort of demand curve which has usually been estimated. The position, elasticity, and even the shape of the estimated demand curve, $D_E D_E$, depend on the pattern of assumed price changes: if price had been assumed to fall more slowly, the elasticity of demand would be closer to the long-run elasticity. The measured elasticity could exceed the long-run elasticity or fall short of the shortest of short-run elasticities. The estimated curve is neither a short-run demand curve nor a long-run demand curve. In fact, it is not a demand curve at all.

THE ESTIMATION OF DISTRIBUTED LAGS

Whenever the effects of an economic change are not exerted all at once, but are distributed over time, we have what may be called a distributed lag.

The problem of estimating a distributiton of lag may be attacked in several ways: (1) We may make no assumption as to the form of the distribution. (2) We may assume a general form for the distribution of lag and estimate the parameters which define the exact distribution. (3) Finally, we may develop an explicit dynamic model of producer or consumer behavior which implies a distributed lag only incidentally. These models may be used directly in an analysis designed to estimate the long-run elasticity of demand or supply.

Because of the short length and degree of auto-correlation in most economic time series, the first approach where nothing is assumed is not always feasible. The error term is so large that the investigator gets erratic results if he tries to determine empirically from the data what the nature of the distribution of the lag is. The second approach necessarily contains a somewhat arbitrary assumption concerning the form of the distribution of lag. The investi-

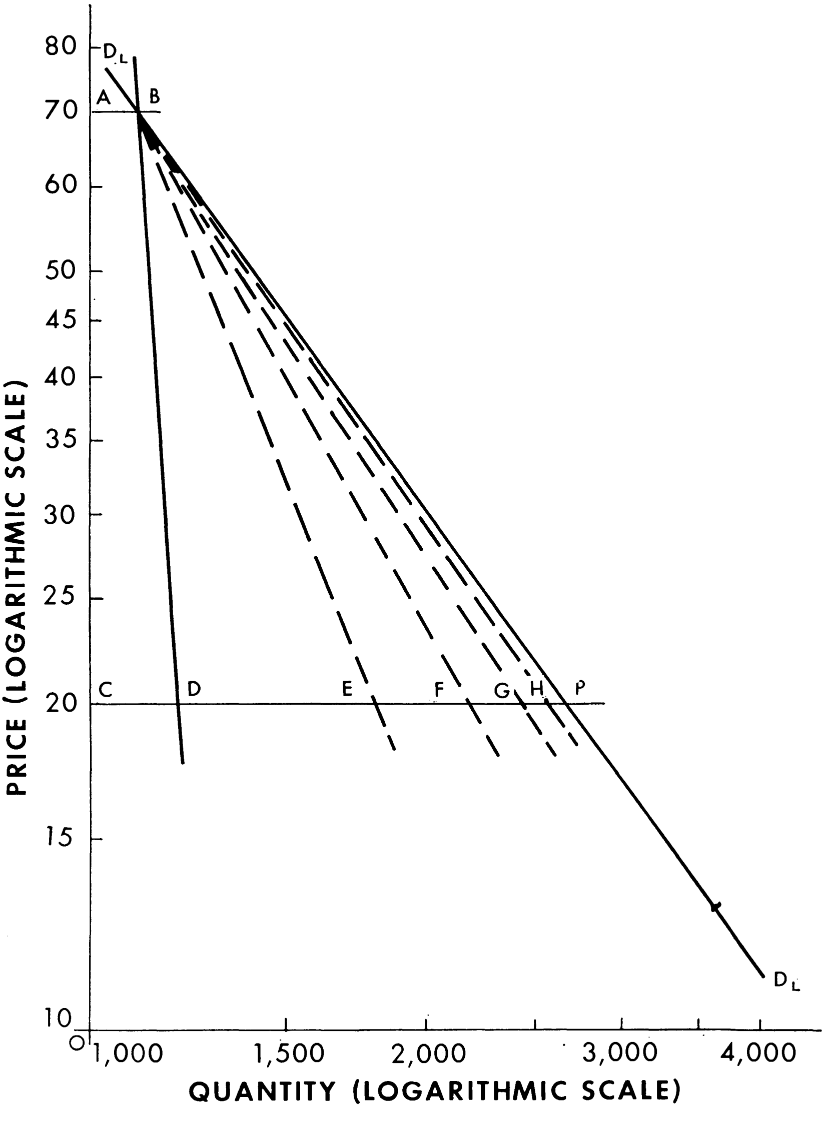

Fig. 4.4A—Adjustment of the quantity demanded to a once-and-for-all change in price.

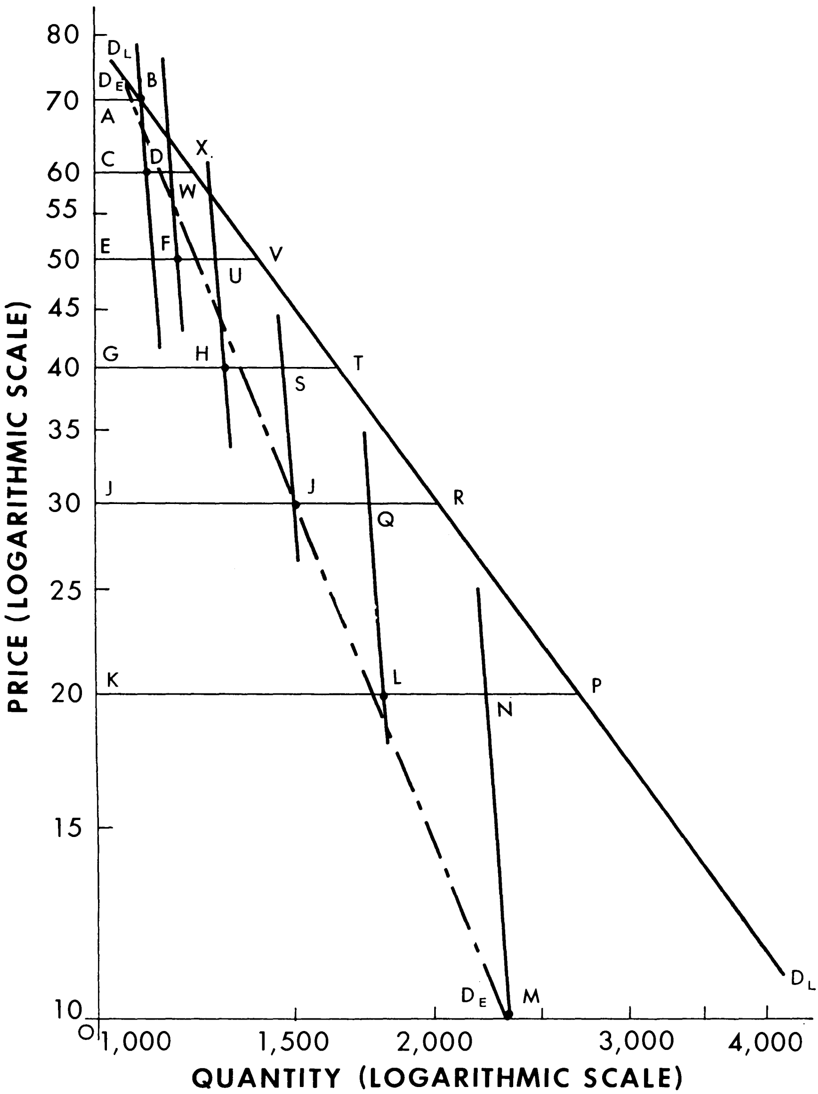

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Fig. 4.4B — Adjustment of the quantity demanded to successive changes in price.

gator must assume in advance what the nature is, and then carry the analysis through on the basis of that assumption.

The second approach can be used with several different assumptions. One is that the lag is distributed like a normal distribution (when time is expressed logarithmically) the effect being small at first, rising to a peak, and then declining. A second assumption is that the effect is at a maximum at first and then declines at a constant rate. The second assumption is shown in graphic form in the upper section of Figure 4.5.

Berger used this second assumption in an empirical study of India's imports of glass from the United Kingdom.[16] He ran the following least squares regressions:

$$x_t = a + b\,\frac{(3p_t + 2p_{t-1} + p_{t-2})}{6} \qquad (1)$$

$$x_t = a + b\,\frac{(4p_t + 3p_{t-1} + 2p_{t-2} + p_{t-3})}{10} \qquad (2)$$

$$x_t = a + b\,\frac{(5p_t + 4p_{t-1} + \cdots + p_{t-4})}{15} \qquad (3)$$

$$x_t = a + b\,\frac{(6p_t + 5p_{t-1} + \cdots + p_{t-5})}{21} \qquad (4)$$

where x_t = the ratio of glass imports from the United Kingdom to total glass imports during period t, and p_t = the ratio of British glass prices to prices of competing glass. The simple correlations between the dependent variable and the weighted average independent variable were 0.858, 0.881, 0.836, and 0.751 for regressions (1), (2), (3), and (4), respectively. Regression (2), with the largest correlation, was selected as showing the "best" distribution of lag.

Working used a different assumption with respect to pork supplies (consumption) and prices. He assumed that pork supplies exerted the same effect on prices each year for 5 years and for 10 years, after which they had no effect. He found the short-run elasticity of the demand for pork to be about —0.75, whereas in the long run it was about —1.25.[17]

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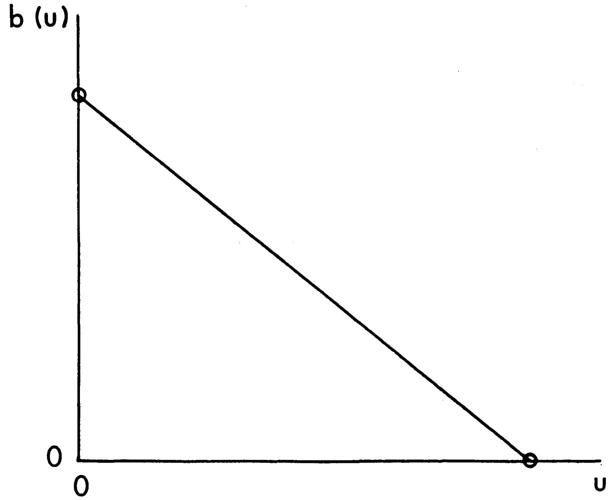
[16] J. Berger, "On Koyck's and Fisher's Methods for Calculating Distributed Lags," *Metroeconomica*, Vol. 5, pp. 89–90, 1953. Quoted from Marc Nerlove, "Distributed Lags and Demand Analysis," USDA, Agr. Handbook No. 141, p. 12. Beginning with the discussion of Koyck's assumption, the next several paragraphs are adapted from this Handbook, pp. 12–13.

[17] Elmer J. Working, "Demand for Meat," Univ. of Ill., 1954, pp. 13, 78–9.

FISHER'S SECOND DISTRIBUTION OF LAG



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KOYCK'S DISTRIBUTION OF LAG

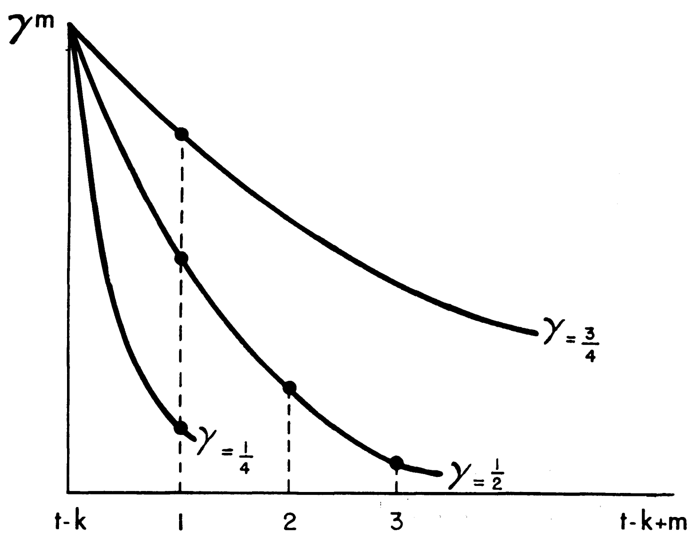

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Fig. 4.5 — Two distributions of lag: Upper section, effects decreasing by a constant amount each year; lower section, effects decreasing by a constant proportion each year.

Koyck[18] made a similar assumption to Berger's but assumed that the effect declined at a constant *proportional* rate. This distribution involves only one parameter and lends itself readily to statistical computation. It is shown graphically in the lower section of Figure 4.5.

Koyck's assumption is illustrated in the following type of formula:

Let time be measured as a discrete variable, in an equation such as

$$x_t = a + b_o p_t + b_1 p_{t-1} + \cdot \cdot \cdot = a + \sum_{i=0}^{\infty} b_i p_{t-i} \quad (5)$$

where x_t is the quantity demanded in period t; p_t, the price in period t; p_{t-1}, the price in t — 1; and so on, and the $b_0, b_1, \ldots$ are constants.

In equation (6), let ε_S be the short-run elasticity of demand (that is, the immediate effect of a one per cent change in price), and let ε_L be the long-run elasticity of demand (that is, the eventual effect of a one per cent change in price). Tinbergen proposed to interpret the short-run elasticity as

$$\varepsilon_S = b_O \frac{\overline{p}}{\overline{x}} \quad (6)$$

and the long-run elasticity as

$$\varepsilon_L = \left(\sum_{i=0}^{\infty} b_i \right) \frac{\overline{p}}{\overline{x}} \quad (7)$$

where $(\overline{p}, \overline{x})$ is the point on the demand function at which we wish to evaluate the elasticity.

Koyck's assumption is that after a certain point, say i = k, the series of coefficients b_i, i = 0, 1, . . . , can be approximated by a convergent *geometric* series, so that

$$b_{k+m} = \delta b_{k+m-1} \quad (8)$$

where $m > 0$ and $0 \leq \delta < 1$. From (5) and (8) it follows that

$$\begin{aligned} x_t &= a + b_o p_t + \ldots + b_{k-1}\, p_{t-k+1} + \\ &\quad b_k\, p_{t-k} + b_k\, \delta\, p_{t-k-1} + b_k\, \delta^2 p_{t-k-2} + \\ &\quad b_k\, \delta^3\, p_{t-k-2} + \ldots + b_k\, \delta^m p_{t-k-m} + \ldots \\ &= a + b_0\, p_t + \ldots + b_{k-1}\, p_{t-k+1} + b_k \sum_{m=0}^{\infty} \delta^m p_{t-k-m} \quad (9) \end{aligned}$$

[18] L. M. Koyck, *Distributed Lags and Investment Analysis,* North Holland Publ. Co., Amsterdam, 1954.

Thus, x_t is a function of $k - 1$ unweighted lagged prices and a geometrically weighted average of all other past prices. If time is treated as a continuous variable, Koyck's distribution of lag has the form shown in the lower section of Figure 4.5. This shows the distribution plotted for different values of the parameter δ.

If $k = 0$, the long- and short-run elasticities and the exact distribution of lag are particularly easy to estimate if the distribution has the general form assumed by Koyck. Consider equation (9) with $k = 0$. Then

$$x_t = a + b_o p_t + b_o \delta p_{t-1} + b_o \delta^2 p_{t-2} + \ldots \qquad (10)$$

If we lag (10) one period and multiply by δ, we get:

$$\delta x_{t-1} = a \delta + b_o \delta p_{t-1} + b_o \delta^2 p_{t-2} + \ldots \qquad (11)$$

Now subtract (11) from (10) to get:

$$x_t = a(1 - \delta) + b_o p_t + \delta x_{t-1} \qquad (12)$$

The distribution of lag is given by the estimate of δ, and the short-run elasticity of demand is given by $b_o \frac{\bar{p}}{\bar{x}}$. The cumulative effect of a maintained price change is

$$b_o \sum_{m=0}^{\infty} \delta^m = \frac{b_o}{1 - \delta} \qquad (13)$$

if $0 \leq \delta < 1$. Hence, the long-run elasticity of demand is given by

$$\frac{b_o}{1 - \delta} \frac{\bar{p}}{\bar{x}} \qquad (14)$$

The subject remains open for further exploration. Ladd and Tedford applied a generalized method to Working's data, and concluded that "the short-run and long-run elasticities of the demand for total meat are not significantly different on an annual basis."[19]

Brandow, in a comprehensive study of elasticities of demand for food, reached a similar conclusion for meats, and extended it to apply to other widely used foods. He also offered the criticism of Nerlove's methodology, that while it often shows market data to be consistent with the hypothesis of lagged price effects, it does not

[19] G. W. Ladd and J. R. Tedford, "A Generalization of the Working Method for Estimating Long-run Elasticities," *Journal of Farm Economics* Vol. 38, No. 2, 1959, pp. 221–33.

I am indebted to George Ladd for checking the formulas on pp. 74–77.

exclude alternative, reasonable explanations for the behavior of the data.[20]

A study of the demand for beef and pork at retail, based on quarterly data and using distributed lag methods, revealed a significant difference between the short- and long-run price-elasticities of demand for these products.[21]

For beef, the short-run elasticity was estimated to be about —0.6; the long-run elasticity, about —1.0. The period of full adjustment to a price change was estimated to be three-quarters of a year.

For pork, the results were mixed; the short-run elasticity was —0.78 according to one formula and —0.74 according to another; the corresponding long-run elasticities were —0.75 and —0.83. The period of adjustment was about one-quarter of a year.

For meat (that is, beef and pork combined) the estimates were; short-run, about —0.3; long-run, about —0.54. The adjustment period was three to four quarters.

The authors therefore conclude that the adjustment period for these meats is less than a year. And since even the long-run elasticities that they found are —1.0 or less, they conclude that programs to reduce the supplies of these products would not reduce gross incomes to beef and hog producers, even in the long run.

They conclude, however, with a word of warning about this: "Over long periods of time a consistently high or low price relative to other prices may induce changes in tastes and preferences or influence the development of substitutes. This phenomenon might be called a price-induced change in tastes. Such changes may very well result in significant consumption changes. However, they involve modification of the static demand curve (i.e., a change in structure) and should not be confused with the rigorous concept of long-run elasticities developed in this article."

COTTON

Waugh, with his pertinacious empirical bent, developed a long-run demand curve for cotton, extending Nerlove's methods further.[22]

> Some think American cotton is losing the domestic market to rayon and other manmade fibers because of high cotton prices and reduced prices of

[20] G. E. Brandow, "Interrelations Among Demands for Farm Products and Implications for Control of Market Supply," Bul. 680, Pennsylvania State University, Agr. Exp. Sta., University Park, Aug., 1961, p. 33.

[21] W. G. Tomek and W. W. Cochrane, "Long-run Demand: A Concept, and Elasticity Estimates for Meats," *Journal of Farm Economics,* XLIV, No. 3, August, 1962, pp. 717–31.

[22] F. V. Waugh, "Demand and Price Analysis," USDA, Tech. Bul. 1316, Nov., 1964, pp. 58–62.

manmade fibers. This view has been endorsed by the National Cotton Council of America and has been supported by statistical studies of Horne and McCord.[5] Yet, most of our standard analyses indicate that the short-run domestic demand for American cotton is highly inelastic. An elasticity of —0.3 is commonly used, and is supported by a study of Lowenstein.[6] A recent study[7] found a still more inelastic demand of —0.14, when adjusted to hold constant the consumption of noncellulosic fibers. An elasticity of —0.3 would mean, roughly, that a 10 percent increase in the price of cotton would reduce domestic consumption by only 3 percent. This would seem to be a profitable deal for the cotton farmer. In fact, it might seem to his advantage to set the price as high as possible.

But the three studies mentioned are not in conflict with each other. All of them recognize two main facts: (1) the short-run domestic demand for American cotton is very inelastic; but (2) the long-run domestic demand is much less inelastic—and perhaps elastic. This is because mills will gradually shift from cotton if the competing fibers have a continued price advantage over several years. Also, the final consumer will gradually shift from cotton clothing to clothing made from substitutes if the price ratios encourage the shift.

Thus, it is quite possible that the short-run domestic demand for American cotton is highly inelastic, while the long-run demand is elastic. But none of the statistical studies has yet measured the long-run elasticity. This is a key datum needed in analyzing agricultural policy. I do not claim to have anything like a final answer, but this chapter may have some bearing on a practical question of economics and politics. In any case, it explores a method which is somewhat similar to Elmer Working's, but which uses a "distributed lag" somewhat similar to those developed by Irving Fisher[8] and by Marc Nerlove.[9]

The Data and an Estimating Equation

A rise in the price of cotton has only a small direct, immediate effect upon cotton consumption. But indirectly, and over a period of years, it increases the production and consumption of rayon and noncellulosic fibers—which, in turn, affect the consumption of cotton.

The following analysis is based upon two ratios: (1) the mill consumption of cotton divided by the mill consumption of rayon and acetate, and (2) the price of Strict Middling 1/16-inch cotton divided by the price of rayon staple. The data are shown in table 8.1. My colleague, James R. Donald, helped me get appropriate data and advised me on the analysis in this chapter.

The price and consumption ratios are shown graphically in figure 8.1. Since 1933, there has been a striking increase in the ratio of cotton prices to rayon prices. There has also been a sharp decrease in the ratio of cotton consumption to rayon consumption. But, neither the rise in the price ratio nor the drop in the consumption ratio has been entirely regular. There have been many ups and downs, especially in the price ratio. A close study of the two lines indicates that changes in the price ratio do not have a large immediate effect upon the consumption ratio—rather, there is a lag. Moreover, the lag does not appear to be for a definite period—such as 3 years or 5 years, for example. Rather, it appears to be spread out over several years. In other words, the consumption ratio seems to respond not to the price ratio in any one year, but to the price ratios over several past years.

To investigate this further, I used the 3-year averages shown in table

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[5] Horne, M. K., Jr. and McCord, F. A. *Price and Today's Markets for U.S. Cotton.* National Cotton Council of America, Memphis, Sept. 1962.

[6] Lowenstein, Frank. "Factors Affecting the Domestic Mill Consumption of Cotton." U.S. Dept. Agr. Agr. Econ. Res., IV-2, p. 50, April 1952.

[7] Donald, J. R., Lowenstein, F. and Simon, M. S. "The Demand for Textile Fibers in the United States." U.S. Dept. Agr. Tech. Bul. 1301, Nov. 1963.

[8] Fisher, Irving. "Our Unstable Dollar and the So-called Business Cycle." Jour. Statis. Assoc. 20. 1925.

[9] See footnote 3, page 57.

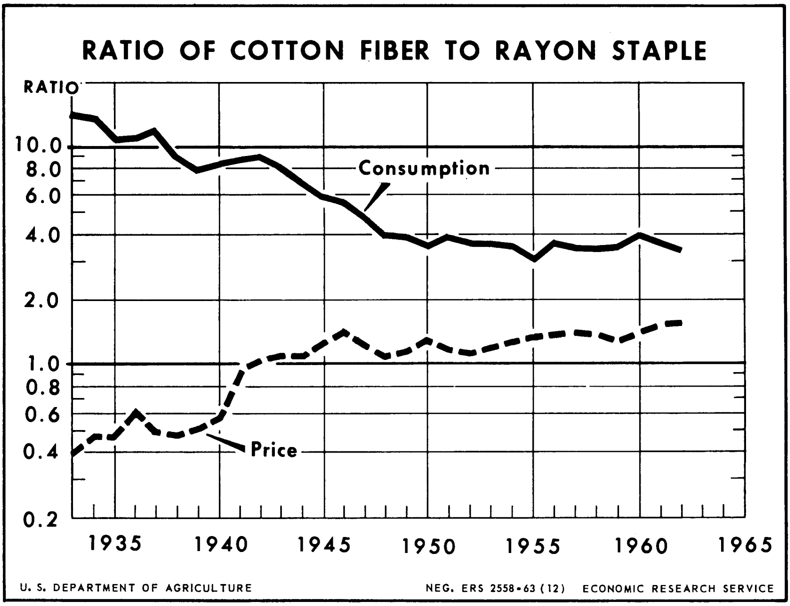

Figure 8.1

8.1. The following two alternative estimating equations are based upon these 3-year averages. The difference between these two equations is simply in the assumed lags. Equation (8.1) uses price ratios centered 3 years, 6 years, and 9 years previous to the current year, *t*. Equation (8.2) uses the ratios centered on the current year, 3 years before, and 6 years before.

$$Q_t = 11.70 - \underset{(0.70)}{4.28}\ P_{t-3} - \underset{(0.77)}{2.08}\ P_{t-6} - \underset{(0.52)}{0.23}\ P_{t-9}, \quad (R_2 = 0.95) \tag{8.1}$$

and

$$Q_t = 11.32 + \underset{(0.63)}{0.73}\ P_t - \underset{(0.69)}{4.79}\ P_{t-3} - \underset{(0.48)}{2.21}\ P_{t-6}, \quad (R_2 = 0.97), \tag{8.2}$$

where P_t is the current 3-year average price ratio.

Q_t is the current 3-year average consumption ratio, and

P_{t-3}, P_{t-6}, P_{t-9}, are price ratios centered 3, 6, and 9 years before the current year.

The last coefficient in the first equation and the first coefficient in the second equation are statistically nonsignificant. They indicate only that the true coefficients are probably close to zero.

Distributing the Effects Over Time

While either equation (8.1) or (8.2) gives a very high squared correlation, the correct equation doubtless would distribute the effects more evenly over a period of years, rather than staying at one level for 3 years and then jumping abruptly to another. Such a distributed effect can be visualized in figure 8.2. First the regression coefficients in equations (8.1) and (8.2) were each divided by 3 to put them on an annual basis. Then they were plotted on the diagram, and a smooth curve was drawn through them, except that at the extreme right of the curve, I disregarded the nonsignificant positive coefficient. It seems unreasonable to believe that the immediate effect of a rise in the price ratio would be a rise in the consumption

TABLE 8.1

CONSUMPTION AND PRICE RATIOS: COTTON AND RAYON

Year	Consumption Ratios [1]		Price Ratios [2]		Year	Consumption Ratios [1]		Price Ratios [2]	
	Annual	3-year averages	Annual	3-year averages		Annual	3-year averages	Annual	3-year aver ages
1933	14.06	14.47	0.390	0.370	1948	3.89	4.16	1.064	1.138
1934	13.50	12.73	.476	.445	1949	3.86	3.74	1.135	1.169
1935	10.64	11.64	.468	.521	1950	3.47	3.72	1.309	1.206
1936	10.74	11.12	.619	.525	1951	3.82	3.66	1.174	1.203
1937	11.96	10.54	.489	.528	1952	3.68	3.72	1.125	1.164
1938	8.87	9.58	.478	.493	1953	3.65	3.63	1.194	1.190
1939	7.91	8.33	.512	.521	1954	3.57	3.47	1.251	1.261
1940	8.21	8.30	.575	.675	1955	3.09	3.43	1.337	1.316
1941	8.77	8.68	.937	.847	1956	3.63	3.39	1.359	1.364
1942	9.07	8.63	1.028	1.018	1957	3.45	3.50	1.397	1.373
1943	8.04	7.97	1.091	1.068	1958	3.43	3.45	1.362	1.335
1944	6.79	6.90	1.085	1.139	1959	3.46	3.62	1.246	1.332
1945	5.86	6.05	1.242	1.241	1960	3.97	3.68	1.387	1.382
1946	5.49	5.39	1.396	1.284	1961	3.62	3.63	1.514	1.477
1947	4.72	4.70	1.215	1.225	1962	3.31	....	1.529	.....

[1] Mill consumption of cotton and of rayon and acetate.
[2] Price of SM 1 1/16 inch cotton divided by price of rayon staple.

All ratios are computed from data in *Statistics for Cotton.* U.S. Dept. Agr. Statis. Bul. 329. Table 13, p. 12; table 232, p. 208, 1963.

ratio. I have assumed, in drawing the curve, that the immediate effect is small but negative.

The table shown in the lower part of figure 8.2 shows the meaning of the curve. The first column is simply the values of the curve, reading backwards; that is, from right to left. For example, at time t (the current year) the price ratio would be weighted —0.25; for year t-1 the weight would be —1.00; and so on. The second column gives cumulative weights; for example, for year t-1 the cumulative weight is —0.25—100=—1.25; and so on. By the year t-8, the cumulative weight has risen to —7.94. This apparently measures the full long-run effect of the price ratio upon the consumption ratio.

What does this imply in terms of elasticity? The mean price ratio was 1.17 and the mean consumption ratio was 5.05. So the long-run elasticity *of the consumption ratio* with respect to *the price ratio* was

$$E = -7.94 \frac{(1.17)}{5.05} = -1.84. \tag{8.3}$$

This elasticity can be distributed among the 9 years. Simply multiply each cumulative weight in column 2 by 1.17/5.05. This gives column 3 which indicates an immediate elasticity of —0.06, a cumulative elasticity after 1 year of —0.29, and a final cumulative elasticity of —1.84.

Of course, these elasticities are based upon quantity *ratios* and price *ratios.* They are not conceptually the same as elasticities based upon actual quantities and actual prices. They are somewhat similar to elasticities based upon "deflated" quantities and prices. They may help bridge the gap between short-run and long-run concepts of demand. The commonly accepted short-run elasticity of —0.3 is based upon an analysis in which consumption was lagged 6 months after prices. Figure 8.2 indicates an

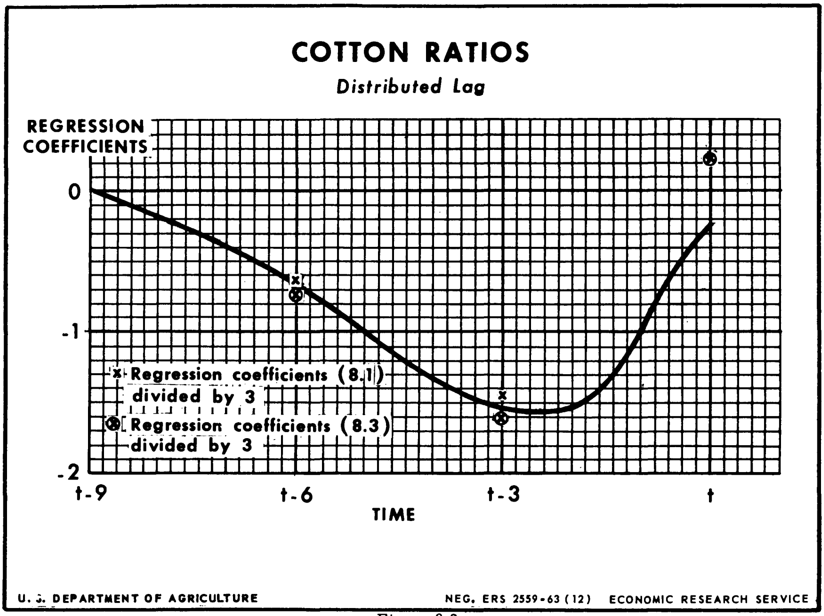

Figure 8.2

Basic Data

Time	Regression coefficient (8.1) divided by 3	Regression coefficient (8.3) divided by 3	Weights	Cumulative weights	Cumulative elasticities of the price ratio of 1.17 and consumption ratio of 5.05	Weights as a percentage
t		+0.24	-0.25	-0.25	-0.06	3.2
t-1			-1.00	-1.25	- .29	12.6
t-2			-1.55	-2.80	- .65	19.5
t-3	-1.43	-1.60	-1.55	-4.35	-1.00	19.6
t-4			-1.32	-5.67	-1.31	16.6
t-5			-1.00	-6.67	-1.54	12.6
t-6	- .69	- .74	- .67	-7.34	-1.70	8.4
t-7			- .40	-7.74	-1.79	5.0
t-8			- .20	-7.94	-1.84	2.5
t-9	- .08		0	-7.94	-1.84	0

elasticity of —0.29 after 1 year. It also strongly confirms the idea that the long-run domestic demand for cotton is elastic. If the price ratio were increased 10 percent, the immediate effect upon the consumption ratio would be insignificant. But if the price ratio were raised 10 percent *and held at the higher level for 9 or 10 years,* the consumption ratio would apparently drop by 0.6 percent immediately, by 2.9 percent in 1 year, by 6.5 percent in 2 years, and so on, until it reached a level about 18 percent below where it was originally.

The final column in the table in the lower part of figure 8.2 gives percentage weights for each year, obtained by dividing each weight in column 1 by —7.94. These percentage weights would be appropriate for computing a weighted moving average of the price ratios. Such a moving average could, for example, be plotted in figure 8.1 to smooth the irregular bumps and dips in the year-to-year data.

The "long-run demand elasticity" used here reflects changes in the output of competing fibers and also technological improvements in the qualities of both cotton and other fibers. It is not the only possible concept of long-run demand elasticity, but it is useful for some purposes.

The method used here to distribute effects over time is more like the method used by Irving Fisher than the one used by Marc Nerlove. Nerlove assumed a particular mathematical function, similar to a "decay curve" in physics. Like Fisher, I have not assumed any particular distribution function. Rather, I have tried to find one that seems to fit the observed data.

INCOME-ELASTICITY OF DEMAND

The elasticities of demand discussed above are all price-elasticities. Another kind of elasticity is *income*-elasticity.

It is a matter of common observation that consumers with high incomes spend more for food than do consumers with low incomes. Figure 1.7 in Chapter 1 showed this relationship for the United States in 1955. The income-elasticities shown in this chart are for three income groups.

Note that these elasticities are positive. Note also that the elasticities are less than 1.0.

In price-elasticity charts, demand curves with elasticity less than 1.0 are steeper than 45°. Why are the inelastic *income*-elasticity curves shown in Figure 1.7 flatter than 45° ?

The reason is that most price-quantity charts show quantity plotted along the bottom and price up the side. They show the price-elasticity of demand or of supply, or both—that is, they show the responsiveness of quantity taken or produced, or both, to changes in prices. Income-food expenditure charts, however, show income plotted along the bottom and food expenditures along the side. They show the income-elasticity of the demand—the responsiveness of food expenditures to changes or differences in income.

The reason for plotting the scales this way in the two kinds of charts is that price analysts are usually interested in explaining prices. Prices, therefore, are regarded as the dependent variable. And the convention has become established that the dependent variable is plotted up the side. In the case of income-food expenditure charts, price analysts are interested in explaining food expenditures, so food expenditures are plotted up the side.

This is all logical and consistent. But it leads to one confusing result. We measure the price-elasticity of demand by dividing the percentage change in quantity (which is plotted along the bottom) by the associated percentage change in price (which is plotted up the side). But we measure the income-elasticity of demand by dividing the percentage change in food expenditures (which is plotted *up the side*) by the associated percentage change in income (which is plotted *along the bottom*). Accordingly, a demand curve that is steeper than 45° on equal proportional scales is called *inelastic*; but an income curve that is steeper than 45° is called *elastic.*

The same situation exists with respect to expenditures for food plotted as percentages of income. Ernst Engel was the first to measure this relationship and show that it was negative; consumers with large incomes spend more money for food, but their expenditures are a smaller percentage of their incomes than in the case of consumers with low incomes. The same basic data as those shown in Figure 1.7, plotted in this percentage-of-income form, yield curves with negative slopes.

The difference between the way income-elasticity curves and price-elasticity curves are plotted comes out most clearly when incomes are plotted against *quantities* of food purchased. In this case, incomes are plotted along the bottom, the same as with the income-expenditure elasticity curves discussed above. But the quantities of food are plotted up the side, instead of along the bottom as in the case of price-quantity elasticity curves.

These income-quantity elasticity curves are positive for food as a group, and for most individual foods taken singly. But they are negative for a few foods, such as potatoes, where consumers with high incomes eat less than consumers with low incomes. These foods are called "inferior goods." This term has no reference to their nutritional or other quality, but refers only to the negative slope of the curve.