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THE RELATIONSHIP OF CAPITAL EXPENDITURE TO LABOR PRODUCTIVITY AS SHOWN BY A STUDY OF SELECTED INDUSTRIES, 1919 - 1939

by
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CHAPTER I

INTRODUCTION

The purpose of this study is to investigate the relationship of capital expenditure to the rate of increase in the productivity of labor during the period 1919-1939. Before beginning an analysis of the historical data, however, it is fitting to consider the importance of this relationship in economic life.

The productivity of labor is the best measure of the potential well-being of any society. This can be seen by the use of a few simple equations. Where Y is the total output resulting from a year's activity, P the average productivity of labor, E the size of the working force and h the average number of man-hours per man-year,

(1) $$Y = Eh\,P$$

But social welfare depends not only upon the rate at which products are made available to society, but also upon the number of people among whom the enjoyment of the product must be divided. To obtain an expression in terms of per capita output, both sides of (1) may be divided by total population N, to obtain:

$$(2) \qquad \frac{Y}{N} = \frac{E}{N} hP = khP$$

where Y/N is per capita output and k is the fraction of the population engaged in productive activity.

The relationship between productivity and well-being described by (2) can be used to illustrate a number of economic phenomena. It is clear that if the population grows, with the same fraction employed in the working force, the effect on welfare depends upon whether productivity rises or falls. If productivity is unrelated to population, so is the level of living; but if, as the absolute size of the working force grows, the average productivity of labor diminishes, then growth in the population results in a fall in welfare. This relationship, of course, lay at the foundation of the dynamics of classical economic theory.

If from some cause the productivity of labor rises, society may reap the benefit of the added ability to produce by either receiving a greater per capita flow of goods in return for effort exerted, or it may elect to receive the same flow of goods and enjoy a greater measure of leisure. The leisure may be obtained through a reduction of annual hours for those employed or by reducing the fraction of the population in the labor force. The latter alternative may take the form of allowing children to remain in school to a later age, permitting earlier retirement from the working force, and so forth. In any real case society has generally chosen to take the gains of increased productivity in some combination of these possibilities.

Although productivity sometimes rises autonomously (as, for example, in agriculture when weather conditions are good, or in

general when the quality of the labor force improves) by and large changes in productivity are a matter of conscious choice. The discoveries of engineers and inventors become available to society to use if it wishes, but seldom are such discoveries applicable to the productive process without cost. Some inventions and discoveries can be directly applied in production, but in general the application of new techniques requires that effort first be devoted to making provisions for the new process by building machinery to embody the new technique, altering existing machinery, or working up a greater stock of materials to be operated on by the new process. A new technique as such presents society with a new possibility in the use of resources. Society's problem of economy is the problem of evaluating the new alternatives presented and choosing the one which seems to provide the greatest advantage.

A rise in the productivity of labor represents a rise in the potential level of well-being. But there is nothing about a higher level of productivity that guarantees that the potential will be realized. If it is obvious that higher productivity can result in greater enjoyment of leisure, it is equally obvious that the result may be unemployment.

That there is a bitter side to the fruit of economic progress was recognized well enough by the classical theorists, but their concern seems to have stemmed primarily from their use of the wages fund doctrine. The demand for labor was held to be the stock of wage goods reserved from the operations of the previous period. If each period's operation just replaced this stock, the demand for labor would be unaltered. But if during one period a part of this stock

were advanced to hire labor to construct a fixed plant, the result would clearly not be the replacement of the stock of wage goods laid out, and the demand for labor must subsequently decline. The decline in the demand for labor would be one of short duration, since the resulting fall in wages coupled with the rise in productivity from the use of the new capital would result in higher profits yielding both the incentive for further accumulation and the enlarged income with which to accumulate. Indeed, the classical theorists believed that not only was the decline in demand for labor at worst a temporary phenomenon, but that, in reality, the rise in fixed capital was generally associated with a rise in variable capital (wages fund) as well, and the accumulation of fixed capital did not in fact usually imply a decline in the demand for labor.[1]

While the neoclassical economists recognized that in the absence of perfect mobility, economic progress necessarily resulted in technological unemployment, they felt that in the long run society exercised a rational choice among the available alternatives presented by technology and resources. The neoclassical theorist looked upon the choice between using resources for present enjoyment and using them to raise the productivity of future applications of labor as being essentially no different from the choice as to whether present effort in the production of consumption goods should be devoted to growing beans or cabbages.

It appeared to these economists that in the absence of a reward

[1] Probably the best treatment of this point is that given by Mill. cf. Principles of Political Economy, 7th edition, Book I, Chap. VI, especially sections 2 and 3.

for abstaining from present enjoyment, no family would resist the temptation to consume the whole of its income. Present consumption foregone needed to be balanced by the promise of even greater future pleasure. Thus the mechanism of the interest rate was held to maintain an optimum adjustment between the desires of families for present as against future consumption on the one hand and the technical possibilities of raising productivity on the other.

With the advent of modern macroeconomic theory the center of attention in economics shifted. In modern theory, society is not held to behave with the rationality attributed to it by neoclassical theory. Rather than evaluating available opportunities to make the most of them, society appears to decide how it wants its effort divided between present satisfaction and preparation for future satisfaction. If the available technical alternatives do not justify society's predisposition, unemployment or inflation may result.

As soon as this fact was recognized the attitude of economics toward the technical alternatives presented to society changed. For only when these alternatives somehow fit society's propensities does a full utilization of available productive capacity materialize. Correspondingly, emphasis has tended to center upon technical development as a means to employment, and the fact that investment expenditures raise the level of productivity has been viewed with secondary interest.

A complete theory of the role of technical development in the economy clearly involves bringing together these separate elements. Today's level of employment depends upon today's expenditure for capital equipment. But today's new investment generates a rise in productivity to be felt tomorrow. If the level of employment is not

to fall, a greater total output must be forthcoming. But the saving which society is disposed to make out of the higher income will be larger; thus the increased output will be forthcoming only if there is a higher level of capital expenditure. To maintain a given level of employment requires that annual investment expenditure rise at a compound interest rate.

This theory has been well formulated by Professor Evsey D. Domar in a recent series of articles,[2] and the following summary of his work along this line is in order.[3]

Any capital equipment resulting from net investment activity has, when combined with the appropriate amount of labor, a certain productive capacity per period. The ratio of this capacity to the magnitude of the net investment (I) is indicated by Domar by s. Thus the investment outlay I results in the creation of productive capacity sI. But the fact that this capacity exists does not mean that the use of the new capacity will increase total output by sI. While it is possible that it may do so, in general the new capacity will make

[2]Evsey D. Domar, "Capital Expansion, Rate of Growth and Employment", Econometrica Vol. 14, no. 2, April 1946 pp. 137-147.

"Expansion and Employment", American Economic Review, Vol. 37, no. 1. March 1947, pp 34-55.

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"The Problem of Capital Accumulation", American Economic Review, Vol. 38, no. 5, Dec. 1948, pp. 777-794.

[3]The reader familiar with Domar's work will note that certain minor changes have been made in the details of the formulation. In particular it seems to me to be more convenient to carry out the analysis in terms of average rather than marginal propensity to save.

some old equipment valueless, in whole or in part, either by producing a product making the old machinery obsolete, or by inducing labor to leave the old machinery to work the new. Or it may be that the new equipment itself cannot obtain sufficient labor to be fully employed. In any case, Domar indicates the increase in usable productive capacity per dollar of net investment by σ.

By the nature of things s and σ apply to particular investment projects. To deal in convenient aggregative terms, however, we may conceive of the average s and σ for the economy as a whole. Then if, during a particular period (0) an aggregate net investment of I_0 is made, the usable productive capacity (i.e., the potential national income) in period (1) will be given by

(3) $Y_1 = Y_0 + \sigma I_0$.

But if α is the average propensity to save,

(4) $I_0 = \alpha Y_0$

If employment in period (1) is to be as high as that in the preceding period (0), it is required that

$$I_1 = \alpha Y_1 = \alpha (Y_0 + \sigma I_0)$$

or

(5) $$I_1 = I_0 (1 + \alpha\sigma)$$

Again, however, a level of investment I_1 will be accompanied by an increase in productive capacity such that

$$Y_2 = Y_1 + \sigma I_1$$

Whence it is required that

(6) $$I_2 = I_1 (1 + \alpha\sigma) = I_0 (1 + \alpha\sigma)^2$$

If the conditions hold for n successive periods, to maintain the level of employment in the n^{th} period requires

(7) $I_n = I_0(1+\alpha\sigma)^n$

Thus Domar concludes that if the level of employment is to be maintained without outside interference the annual investment expenditure must rise at a compound interest rate equal to $\alpha\sigma$.

It will be noted that Domar formulated his theory in terms of "net" investment. It is obvious that in the accounting sense of current capital expenditure less current depreciation charges, "net" investment has little to do with productive capacity. A rate of capital expenditure just equal to depreciation charges (for a firm, industry, or economy) may well result in higher (or lower) productivity. In attempting to avoid this difficulty, Domar defined net investment as the amount of capital expenditure in excess of what is required to maintain productive capacity. σ, perforce, applies only to net investment thus defined. But, as Domar recognized, a number of difficulties are introduced by this device. To cite his handling of one of these: "If... (a).. machine worth $1000 and producing 100 units is replaced by another one also worth $1000 but producing 120 units, only $833.33 will be regarded as replacement and the remaining $166.67 as new investment."[4]

To determine the relationship between the expenditures of firms and the resulting rise in productive capacity by the use of such a net concept would require that we engage on a detailed intensive study of the actual capital items purchased and the actual equipment they replaced.

A second difficulty with this definition of "net" investment lies

[4]"Capital Expansion, Rate of Growth, and Employment", loc. cit. p. 137, footnote 2.

in the fact that the propensity to "save" which must be employed with it must be society's propensity to save out of total product net of replacement as defined. It is difficult to conceive of society's predisposition as to the use of productive effort as involving such subtle evaluations.[5]

In light of these difficulties an investigation into the relationship between expenditures of firms and the increase in productive capacity of the economy should deal with the actual, or gross expenditure for capital.

Whether we speak of the result of capital expenditure as an increase in the capacity of the economy to produce, given the labor force, or as an increase in the average productivity of labor is primarily a matter of convenience. Formally the two are identical. The advantage to formulating the problem in terms of the productivity of labor lies in the fact that it is more easily measured than any other index of productive capacity applicable to the economy.[6]

The relationship between capital expenditure and the productivity of labor, then, is important from two points of view. On the one hand, it is an indication of the gain in potential welfare derived from the use of resources to produce capital equipment. On the other hand it is an important factor in determining the conditions under which that potential will be realized.

In our theoretical discussion we have emphasized the macroeconomic role played by the relationship of capital expenditure to

[5]Domar was well aware of this problem. Cf. "Employment and Expansion", loc. cit. pp. 42-3

[6]Considerable ambiguity attaches to any attempt to measure the ability of the economy to produce. As we shall see, the measurement of the productivity of labor is no exception.

productivity. This relationship, however, is the resultant of many forces. In order to bring to light as many of these forces as possible, our investigation must be conducted on the level of individual industries. That is, by analysing the differences in the relationship of capital expenditure to productivity in different industries we can gain insight into the factors which account for these differences and thus a better understanding of the forces determining behavior of the aggregate.

It should be noted, moreover, that theoretical interest attaches to these differences in themselves. Variation in productivity trends is one of the underlying factors in the dynamics of the structure of relative costs and prices, the pattern of employment, and so forth.

The period 1919-1939 provides a laboratory for the analysis of relationships of capital expenditure to productivity. Data are readily available upon which we can base capital expenditure and productivity estimates for many industries. The fact that war-generated disturbances were at a minimum eliminates problems of evaluating wartime behavior of output and capital expenditure.

The problem may be formulated as follows: As shown by the available quantitative and qualitative data, what was the relationship between expenditure for capital in individual industries and the rate at which the productivity of labor employed in those industries rose over the period 1919-1939?

The study may be divided into two parts. In Part I (Chapters II - V) we shall investigate the long-run relationship of capital expenditure to productivity. Chapter II deals with the problems involved in the definition and measurement of productivity. In Chapter III, productivity indexes for a number of industries will be

presented. Trends fitted to these indexes will provide us with a measure of the long-run average rates of increase in productivity. Measurements of capital expenditure for these industries will be set forth in Chapter IV, and the relationships between capital expenditure and the behavior of productivity trends will be examined in Chapter V. In this examination we shall attempt to set forth the qualitative factors which give rise to differences in the effects of capital expenditure in different industries. Furthermore, we shall attempt to determine the behavior of the relationship of capital expenditure to productivity during the period of relative prosperity (1919-1929) in contrast to its behavior during the period of relative depression (1929-1939).

Part II of the study (Chapters VI and VII) is an investigation into the relationship of capital expenditure to shifts in input-output schedules. The productivity of labor actually realized at any particular time is the result of two factors: 1) the level of the input-output function, the schedule which relates the level of employment at a particular time to the resulting output of the industry, 2) the level of employment, fluctuations in which alter realized productivity along the input-output schedule. Chapter VI deals with the exact nature of the input-output function of an industry. In Chapter VII shifts in the statistically determined input-output functions of four industries will be studied in relation to the capital expenditures made by these industries. The analysis in terms of input-output schedules will give us a better insight into the relationship of capital expenditure to productivity, its variation between industries and its behavior in prosperity and depression.

PART I

LONG-RUN RELATIONSHIP OF CAPITAL EXPENDITURE TO PRODUCTIVITY TREND.

CHAPTER II

THE MEANING AND MEASUREMENT OF PRODUCTIVITY

The productivity of labor as most commonly defined is the reciprocal of the unit labor requirement of production. The unit labor requirement of production is the number of man-hours which, together with the appropriate amount of materials and other non-labor inputs, is required on the average to produce one unit of output. Thus the unit labor requirement for production in a particular industry over a given time period is the ratio of man-hours engaged in production to the total product resulting from the activity of the period.[1] The productivity of labor is simply the reciprocal of this ratio and corresponds, conceptually, to the amount of product that would be forthcoming, on the average, if one man-hour of labor were combined with appropriate amounts of non-labor inputs.

[1] In general, "total product" consists of an agglomeration of different kinds of products. Thus unit labor requirements are usually based upon some index of production rather than a simple total of homogeneous product. For the present we shall follow convenience in speaking of product as though it were homogeneous. The problem of the product index is treated below.

It is apparent that, according to this definition, man-hour productivity and unit real labor cost are alternate ways of looking at exactly the same phenomena. If, in a particular industry, the unit real labor cost of production were ten man-hours, the productivity of labor would be one-tenth unit per man-hour. Should the labor cost fall by fifty percent to five man-hours, the productivity of labor would rise by one hundred percent to one fifth unit per man-hour.

Now in this, as in any similar instance, it is futile to discuss whether the definition so commonly used is "right" or "wrong". Definitions, by their very nature, are incapable of rightness or wrongness. They are rather to be tested as to their usefulness for purposes of analysis and communication. As was indicated in the previous chapter the present analysis is concerned with the general effectiveness of labor engaged in productive activity, and for purposes of that analysis we want the term "productivity" to denote this general effectiveness.

Viewed in this light, the common definition of productivity is seen to involve a number of difficulties. In the first place, a measure of general effectiveness should take some account of the materials which are required to co-operate with labor in yielding the final product. The unit labor cost definition of productivity ignores the input requirements for all non-labor items. Thus unit labor cost, and hence productivity, might change in precisely the same manner in two industries. Yet in the one industry the reduction in real labor cost could involve merely a substitution of purchased fuel and materials for the direct employment of labor, while in the other industry unit man-hour requirements might have been reduced without

corresponding increases in other in-puts.

A consideration of some of the changes in non-labor in-puts in the recent past indicates that in many important instances the reduction of unit labor costs in one industry are in some degree offset by increased labor cost elsewhere in the economy. Perhaps the most outstanding shift in productive technique since the first World War lies in the extent to which purchased electric energy has been substituted for direct power production. In 1919, less than one-third of the horsepower installed in manufacturing establishments was operated by purchased electric energy. By 1939 this proportion had risen to well over one-half.[2] Changes of this magnitude are bound to result in apparent increases in manufacturing productivity in excess of what may be fairly attributed to the increased effectiveness of labor employed in manufacturing, since no account is taken of the additional labor required for electrical generation.

In addition to the problem of overestimation of productivity changes, the unit real labor cost measurement frequently fails to give proper weight to some changes in labor effectiveness. That is to say, it is possible for the general productivity of labor in the economy to rise without a corresponding rise in the productivity of labor employed in any particular industry. This sort of omission occurs when techniques are adopted which reduce the real materials cost of production without reducing the real labor cost. Between 1920 and 1938 the average consumption of coal per ton-mile of railway freight hauled declined from 172 pounds to 115 pounds. A similar decline in unit coal requirements ~~are~~ is indicated for railway passenger traffic,

[2] Census of Manufactures, 1939

the average consumption per passenger car mile falling from 18.8 pounds to 14.9 pounds in the same period.[3]

In the manufacture of cement, the introduction of longer kilns, improved clinker cooling equipment, waste heat boilers and similar machinery reduced the consumption of fuel per unit of output from an average of 187 pounds of coal equivalent per barrel of cement in 1919 to 159 pounds per barrel in 1935.[4] This factor, together with the rising productivity of coal mine labor represented a fall in the "consumption" of coal mine labor by cement plants from an estimated 118 man-hours per thousand barrels of cement in 1927 to an average of 101 man-hours per thousand barrels in 1935.[5]

There is no need to multiply examples to show that a unit man-hour measure of productivity falls short of showing the progress of the effectiveness of labor applied in the production of particular products.

It would be possible to make the unit real labor cost definition of productivity cover such cases in a more satisfactory way. If we were to change our notion of unit labor requirements to cover not only the man-hours applied directly within the particular industry under investigation, but to include the number of man-hours embodied in non-labor inputs per unit of product we might obtain a better

[3] Hearings before the Temporary National Economic Committee, Part 30, pp. 17525-26.

[4] Nicholas Yaworski and others, Fuel Efficiency in Cement Manufacture 1909-35, W. P. A., National Research Project Report No. E-5, 1939, table A-1, p.70.

[5] ibid. table 1, p.22. This estimate was derived from data for 87 identical coal burning cement plants, no account being taken of plants in the industry which switched to gas or other fuels during the period.

measure of the general effectiveness of applied labor. In applying this measure to a particular industry A, we should need to know the unit input requirements of each of the inputs obtained from other industries B, C, etc. If then we also knew the unit labor requirements in industries B, C, etc., we could impute a man-hour value to the unit requirement of their products as used by A, and obtain a new unit man-hour requirement for industry A's output. Some studies of labor productivity have involved just such imputations.[6]

The difficulty inherent in computing unit labor requirements on the basis of such imputations is apparent if it be borne in mind that the procedure is not a simple one step process. If unit labor costs in industry A are to be based on imputations of man-hours from industry B, it follows that the unit labor requirement of industry B

[6]For example, cf. M.E. West, Productivity and Employment in Selected Industries: Brick and Tile, W.P.A., National Research Project, report no. N-2, 1939. After examining the behavior of man-hour ratios within the brick and tile industry proper, Miss West examined the "vertical structure" of the industry. She included in this examination the man-hour ratios for fuels and transportation (of brick and tile). She likewise imputed man-hours to the wear and tear on machinery and equipment.

The imputation process is sometimes carried on "in reverse" by computing the output per man-hour in a basic industry in terms of ~~the output per man-hour in a basic industry in terms of~~ the output of industries closer to the consumer. Thus a study submitted as part of the testimony of the United Mine Workers before the T.N.E.C. showed the displacement of coal miners caused by the decline in unit man-hour requirements in coal production coupled with the declining unit coal requirements of coal consuming industries, principally rail transportation, electric power, cement, and coke production. (See Hearings, Part 30, pp. 17536 ff). A complete study would involve, in turn, the unit requirements of these products in further production until the final consumer had been reached. The difficulty of doing so is self evident. This idea is hardly new: compare F. W. Taussig, Wages and Capital, Chapter I, p. 8, D. Appleton & Co. New York, 1896.

must likewise be computed by imputing man-hours to non-labor inputs by reference to still other industries. There is, therefore, no stopping place short of an elaborate examination of a large number of industries, if not the entire economic structure.[7]

A second difficulty in the unit labor cost definition of productivity lies in the fact that since it is a real measure it takes no account of improvement in the nature of the product. Thus it has been reported that in the leather industry "the chief motive for the adoption of the few new processing machines that have appeared (since 1923) has been to improve the quality of the product; and some of them have involved the expenditure of more labor rather than less."[8]

It is possible that such improvements in product might reduce the leather requirement of production in leather consuming industries, or by facilitating production might reduce the man-hour requirements in those industries. But it is also quite possible that the improved leather might yield improved leather products and would ultimately appear as increased satisfaction to, say, the shoe consumer. To overlook the possibility of increased consumer satisfaction is to leave out of account the ultimate objective of productive activity. To the economist, the physical product is, after all, only a means to the ultimate satisfaction of human desires. When a better way is found to satisfy these desires with the application of labor to materials, we should certainly want to say that labor has become

[7] Since most industries employ a number of non-labor inputs, carrying the imputation process only two or three stages involves considerable effort.

[8] J. R. Arnold, Labor Productivity in the Leather Industry, W.P.A. National Research Project report no. B-1, 1937, p.8.

more productive. Thus a workable definition of labor productivity should be one which will easily account for both the changing real unit labor cost, but which will also make some adjustment for the want satisfying power of the final product.

In light of the shortcomings of the unit labor cost definition of productivity it is evident that some alternative definition must be used, at least as a supplementary measure, if we are to obtain a true picture of the progress of labor effectiveness in the several industries of the economy. The alternative which most readily suggests itself is to measure the contribution of a man-hour of labor to the total value of the output of the industry: that is, to measure value added per man-hour. Value added is a measure net of the value of materials, fuels, and similar non-labor inputs from other parts of the economy.[9] Thus the substitution between labor and non-labor inputs is reflected in the altered deductions made for cost of materials and fuels. Conservation of non-labor inputs similarly becomes accounted for in the industry in which the saving occurs. Thus any change which occurs in the effectiveness of labor in the economy must be accounted for in the several industries of the economy. All the value of the product must be added at some point along the line and there can be no duplication or omission.

[9] The Census of Manufactures figures for value added by manufacturing are computed as value of product less cost of materials, containers, fuels, purchased electric energy, and contract work. Since these items constitute the great bulk of non-labor inputs this statistical measure is satisfactorily close to the conceptual definition. Properly defined, however, value added runs somewhat lower than the Census figures, since the value of all services purchased from other firms should be deducted from the value of the product. Probably the largest items not included in the Census deductions are advertising and insurance.

A second strength of the value measure of productivity lies in the recognition it gives to the want satisfaction derived from the employment of labor. The most readily available index of the utility derived by consumers from the consumption of an economic good is, of course, the price they are willing to pay to get it. This proposition is true in general whether the price rises, on the supply side, from marginal production cost, or from a deliberate restriction of output by monopolistic producers. In either case the consumer reacts to the - to him - flat supply schedule by purchasing those amounts of the good which will make his position an optimum.[10]

The value measure of productivity is not, however, free of difficulties. It is strongest where the unit labor cost measure is weakest; unfortunately it is weakest where the other measure is strongest. The fluctuations of the value measure associated with the cyclical rise and fall of the general price level is, of course, a matter of little concern. Stability is obtained by deflating the measure by a suitable general price index, yielding an index of value added per man-hour expressed in terms of relative prices.

But we find ourselves confronted with another difficulty. Indexes computed in terms of relative prices will show a shift in the productivity of labor in an industry if, without any other change occurring , the prices of outputs of other industries are altered. When other prices are falling relative to the prices in the industry in

[10] Prices established on monopsonistic markets are the exception to this general rule. In such markets the consumer continues to expand his purchase of a good only so long as the marginal cost (to him) of the good is below its unit importance (marginal revenue product in the case of a consuming firm; marginal utility in the case of a final consumer.) With upward sloping supply schedules, therefore, the unit importance of the good to the consumer is greater than the price would indicate.

question, labor in the industry will appear to become more productive. Whether this fact is a defect of the measure depends upon the objectives sought in its use. In a very real sense a rise in the relative price of A represents an increase in the ability of labor employed in producing A to satisfy consumers relative to the satisfaction produced by labor employed in the production of other goods. The case may be made most easily by a consideration of the effect of a monopoly restriction of output. As we have defined productivity, restriction of output will appear in the figures as an increase in productivity due to the rise in the relative price of the monopolized product. The unit importance attached to the good by consumers is higher than formerly and they receive less of it. In interpreting this as an increase in the productivity of labor we are following general economic usage. Productivity of labor is higher in the monopolized field, and the damage done by the output restriction is precisely that of forcing productive agents from more into less productive uses.

But the main concern here is with the measurement of changes occurring in particular industries overtime, and we shall need a measure which will be largely free of influences arising from changes in the position of a given industry vis-a-vis all other industries. It was, therefore, decided to deflate the value index of productivity for each industry by an index of price of the industry's own output. In doing so we eliminate not only the influence of price changes in other industries, but also the association between the value index of productivity and consumer utility. Conceptually the resulting index measures the amount of physical product per man-hour which remains after enough product has been sold (at current prices) to purchase

the necessary non-labor inputs.

The behavior of the deflated value index leaves much to be desired. One of the most important determinants of its year to year behavior is the fluctuation of the price of raw materials relative to output prices. Since raw materials prices fluctuate over much wider ranges than do those of manufactured goods, the deflated value index should, in general, be expected to show a marked cyclical fluctuation with relatively high values in depression years and relatively low values during booms. The magnitude of this influence may be clearly seen in figure 2.1 in which the deflated value productivity index for manufacturing as a whole is plotted together with the ratio of the price index of raw materials to the index of finished manufactured goods. It is apparent that the fluctuations of the deflated value index around its trend are almost mirror reflections of the fluctuations in the relative price of raw materials.

Neither of the two methods of measuring the general effectiveness of labor is entirely satisfactory. The unit real labor cost measure excludes consideration of non-labor inputs and thus tends to overestimate changes in productivity in some cases and to underestimate them in others. The relative value measure on the other hand is too sensitive to fluctuations in the relative price of non-labor inputs. To provide an adequate picture of the behavior of productivity in the industries studied, therefore, both measures have been employed wherever possible.

Formulation of Productivity Indexes

The formulation of a productivity index requires that some measure

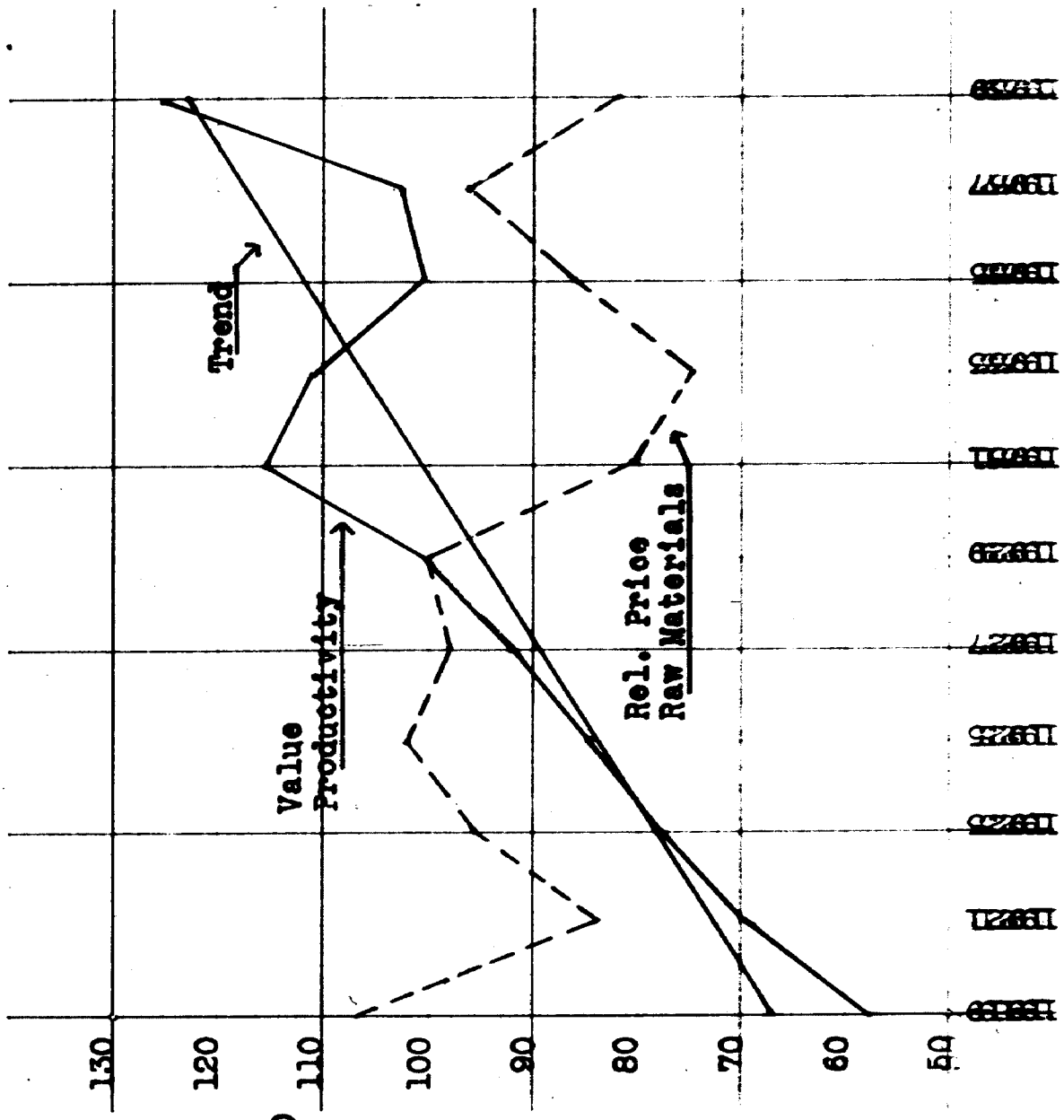


Figure 2:1 Value Productivity Index, Manufactures as a Whole, and Price of Raw Materials Relative to Price of Manufactures

of product (relative value added, index of real output) be divided by some measure of the employment of labor involved in producing the product. The measure of labor time employed occasions no special difficulty. Employees are treated as homogeneous, and the index of man-hours of labor in any year for a particular industry is the product of average monthly employment by average weekly hours per employee. If an estimate of actual man-hours of employment were desired the product could be multiplied by 52. In general, however, we are concerned only with relative movements in man-hours, and the latter multiplication is unnecessary. To facilitate comparisons the man-hour index is, of course, reduced to percentages of some base year. The year 1929 was employed for this purpose throughout the present study by virtue of its position as the central year in the period covered by the data.

Since value terms are comparable and additive, the measurement of production in terms of value added occasions no difficulty and the index of value productivity may be computed directly.

The measurement of production in real terms, however, requires the formulation of an appropriate index number. If the rates of output of the several products of an industry increase and decrease in proportion, any linear transformation of these rates of output (i.e., any weighted aggregate index) will serve as an appropriate index of production. This procedure is tantamount to selecting a convenient standard "batch" of outputs and the resulting productivity measure is easily interpreted as so many batches per man-hour. But when, as is usual, rates of production do not vary in proportion, the selection of an appropriate index is not an arbitrary matter. Table 2.1 illustrates the effect of arbitrary selection of index in a simple case.

The industry shown produces the two products A and B. The unit labor cost of A was assumed to be 1, while that of B is taken to be 1/2. The output of A and B in the years 1, 2 and 3 are assumed as shown.

Table 2.1

Output, Employment and Productivity in a Hypothetical Industry

Year	Department A		Department B		output per man-hour (year 1 = 100)
	output	man-hours	output	man-hours	
1	100	100	100	50	100
2	50	50	200	100	125
3	100	100	50	25	90

The behavior of output per man-hour shown in the last column of the table arises because total output in the industry was measured as an unweighted aggregate of A and B. In spite of the fluctuations shown in output per man-hour, it is obvious that no change has occurred within the individual departments of the industry. The entire change in the index of productivity arises from a shift in the proportions of A and B in the total product. The problem of formulating the index is the problem of selecting a procedure which will, to the greatest degree possible, remain free of this kind of fluctuation.

There are two acceptable procedures of index formulation, the one selected depending upon the amount of data available and the exact interpretation we want to give to the final productivity index. If we have data of the sort shown in table 2.1, we may retain the notion

of the standard batch, and the interpretation of productivity in terms of batches per man-hour. Rather than formulate an arbitrary index of output, we formulate some convenient standard batch of output - for example the outputs produced in a base year. Then if we know the unit real labor cost of each kind of output in each year we can compute the labor cost per batch. The reciprocal of this figure is the number of standard batches per man-hour. This procedure is complicated by the fact that it can be computed only if we already know the productivity of labor in each of the individual departments of the industry in each year. Thus the primary usefulness of this sort of index is in aggregating productivity indexes of several individual products into an index of productivity for the over-all group. When the technique is used for this purpose, the group index of productivity becomes the harmonic mean of productivities in individual departments weighted by base year man-hours of employment.

This proposition may be demonstrated as follows: Let y_{io} be the output and x_{io} the man-hours of employment of the i^{th} department in the o^{th} (base) period, and y_{it}, x_{it} the output and man-hours in the t^{th} (current) period. Then the number of man-hours necessary to produce the base year output of the i^{th} department becomes

$$b_{io} = y_{io} \frac{x_{io}}{y_{io}} = x_{io}$$

in the base period and

$$b_{it} = y_{io} \frac{x_{it}}{y_{it}}$$

in the current period.

The total labor cost of the base outputs for all departments, B_o, in the base year becomes

$$B_o = \sum b_{io} = \sum x_{io}$$

and for the current year,

$$B_t = \sum b_{it} = \sum y_{io} \frac{x_{it}}{y_{it}}$$

The productivity, P_o, for the industry as a whole in the base year becomes

$$P_o = \frac{1}{B_o} = \frac{1}{\sum x_{io}}$$

and in the current year

$$P_t = \frac{1}{B_t} = \frac{1}{\sum y_{io} \frac{x_{it}}{y_{it}}}$$

The current index of productivity in terms of the base period = 100 is given by

$$I_t = \frac{P_t}{P_o} = \frac{\sum x_{io}}{\sum y_{io} \frac{x_{it}}{y_{it}}}$$

But where j_{it} is the index of productivity of the i^{th} department in the t^{th} year,

$$j_{it} = \frac{\frac{y_{it}}{x_{it}}}{\frac{y_{io}}{x_{io}}}$$

whence,

$$I_t = \frac{\sum x_{io}}{\sum x_{io} \frac{1}{j_{it}}}$$

which is the harmonic mean of individual departmental productivities weighted by base year man-hour employments.

Among the Productivity indexes used in this study only those for the minerals industries were derived by this process.[11]

[11] V.E. Spencer, Production, Employment, and Productivity in the Mineral Extractive Industries, W.P.A. N.R.P. report no. S-2, 1940, pp. 33-35

The harmonic mean index preserves the "batch" notion of productivity, but does not employ an index of output. The alternate method of index computation employs a weighted aggregate index of outputs and is therefore simpler to use. It cannot be interpreted in quite the same terms. Rather than ask how many batches will be produced per man-hour relative to a base year, we may ask how much employment (aggregate man-hours) would be required at base year productivities to reproduce the outputs brought forth in the current year. The ratio of this aggregate to the actual aggregate of man-hours required to produce the current output is then a measure of the change in productivity over the base year. This measure is obtained when total output is measured as an aggregate of outputs of individual departments weighted by their base year unit real labor costs.

This may be shown as follows:

Using the notation given before and letting u_{io} and u_{it} represent the unit real labor costs of the i^{th} department in the base year and the t^{th} year respectively the index of aggregate output Y_t in the t^{th} year is given by

$$Y_t = \frac{\sum u_{io}\, y_{it}}{\sum u_{io}\, y_{io}}$$

while the index of aggregate man-hour employment X_t is given by

$$X_t = \frac{\sum x_{it}}{\sum x_{io}}$$

but by the definition of unit labor cost,

$$\sum u_{io}\, y_{io} = \sum x_{io}$$

whence the index of productivity I_t becomes

$$I_t = \frac{Y_t}{X_t} = \frac{\Sigma u_{io} y_{it}}{\Sigma x_{it}}$$

which is easily seen to be the ratio of the amount of employment necessary to produce the current output at base year labor costs to the employment actually required at current labor costs.

Data are not always obtainable for unit real labor costs in the production of all the outputs of a given industry. It is frequently necessary to resort to more readily available magnitudes as estimates of proper weights. The nature of index number construction makes it unnecessary to use the absolute values of weights, but some means must be employed to estimate their ratios. The usefulness of estimated weights depends entirely upon the degree to which the true man-hour ratios can be approximated and in the selection and evaluation of weights this is of primary importance.

If actual unit man-hours are unknown, the most appropriate estimate of them is unit dollar labor cost. If average hourly earnings are known, dollar labor cost can be used to approximate real labor cost with substantial accuracy. Wage rates provide good substitutes for average hourly earnings in this respect, but will involve some slight loss of accuracy. In the absence of both figures for separate departments, unit dollar labor cost must be used as such.

Unit value added is inferior to unit dollar labor cost as a weight ratio due to the presence of depreciation, tax, profit, and similar items which do not necessarily vary in proportion to unit real labor cost. Value added figures are, however, superior to unit product value figures. The latter can be used as weights only where all products in the aggregate are forthcoming at the same level of

production. Even in this case, unit product value figures are the least reliable of the weights which might be employed, since the figures include a large number of items which need not behave proportionately to unit real labor cost.

Sources and very brief descriptions of the unit labor cost indexes used in this study will be found in Appendix A. The value productivity indexes used in this study were compiled by the writer for the purpose. Details of the procedure and the basic data employed will be found in Appendix B.

CHAPTER III

PRODUCTIVITY TRENDS IN SELECTED INDUSTRIES

The selection of industries for examination in this study was based upon the availability of data. Published indexes of unit labor cost productivity are available for most industries and industrial groups. Those industries were included for which capital expenditure estimates could be obtained.

The industries and groups selected include the non-manufacturing industries of Agriculture, Coal Mining, Electric Light and Power,[1] Mining and Quarrying (excluding Crude Petroleum and Natural Gas), Petroleum and Natural Gas, Railroads, and Telephone.

In the manufacturing field are included Manufacturing as a whole, Automobiles and Automobile Equipment, Blast Furnaces, Steel Works and Rolling Mills, Boots and Shoes, Bread and Bakery Products, Canning, Cement, Clay Products other than Pottery, Confectionery, Flour and Grain Mill Products, Glass Products, Ice Cream, Leather Tanning and

[1] Productivity measures and capital expenditure estimates for Electric Light and Power exclude municipal and other publicly owned establishments.

Finishing, Lumber and Lumber Products (including Furniture), Manufactured Ice, Petroleum Refining, Printing and Publishing, Pulp, Paper, and allied industries, Rubber Products, Slaughtering and Meat Packing, and Tobacco Products. The definitions of the manufacturing industries and groups follow those of the Census of Manufactures. The industries selected include 44 per cent of the total value added by manufacturing (1929) and about 45 per cent of manufacturing employment.

Wherever possible both unit labor cost and value productivity indexes were obtained for the industries. Value indexes could not, however, be computed for the non-manufacturing industries; for Printing and Publishing and Tobacco Manufactures no satisfactory method could be determined to deflate the value index.[2]

The index of unit man-hour productivity for the Printing and Publishing Group covers only the Newspaper and Periodical part of the group. Since the capital expenditure data cover the entire census classification, the two are not strictly comparable. The index coverage includes approximately a third of the employment in the group and it was felt that it could be taken as representative of the group as a whole

The productivity index series for the selected industries are given in table 3.1.[3]

[2] There is no satisfactory index of unit value for the Publishing industry. In the case of Tobacco, unit value indexes were felt to be meaningless for the present purpose due to the large portion of tax included.

[3] For convenience in tabulation, the term "real" productivity has been used in place of the longer term "unit labor cost productivity" in Table 3.1 and the following tables.

TABLE 3.1

PRODUCTIVITY INDEXES, SELECTED INDUSTRIES, 1919-1939

Year	Agriculture	Coal Mining	Elec. Light and Power	Mining and Quarrying[a]	Petroleum & Natural Gas	Railroads	Telephone	Manufacturing as a whole	
	real	real	real	real	real	real	real	real	value
1919	84	84	83	74	54	80	92	58	58
1920	85	87	83	78	59	81	89	64	-
1921	85	90	74	77	63	82	89	70	69
1922	86	92	76	83	68	84	94	77	-
1923	88	94	73	86	73	86	94	76	77
1924	92	85	75	85	77	88	94	81	-
1925	93	108	85	89	82	93	95	86	84
1926	95	94	91	89	86	95	98	89	-
1927	96	95	97	93	91	94	99	92	92
1928	98	98	100	97	95	99	101	96	-
1929	100	100	100	100	100	100	100	100	100
1930	101	103	99	101	111	99	99	103	-
1931	101	109	105	103	123	99	112	107	116
1932	100	111	118	101	135	95	112	104	-
1933	100	104	131	98	147	107	115	110	111
1934	100	105	147	101	158	109	123	114	-
1935	103	110	154	106	170	114	128	121	100
1936	107	114	159	112	154	124	133	121	-
1937	115	117	164	119	163	126	135	120	102
1938	125	107	173	120	157	123	135	122	-
1939	131	n.a.	192	128	n.a.	131	145	132	125

[a]Excluding Petroleum and Natural Gas.

Sources: See Appendix A and B.

TABLE 3.1, continued

PRODUCTIVITY INDEXES, SELECTED INDUSTRIES, 1919-1939

Year	Automobiles & Automobile Equipment		Blast Furnaces Steel Works & Rolling Mills		Boots & Shoes		Bread & Bakery Products		Canning		Cement	
	real	value	real	value	real	value	real	value	real	value	real	value
1919	43	44	51	49	83	72	n.a.	82	78	65	60	64
1920	46	-	65	-	86	-	n.a.	-	n.a.	-	62	-
1921	57	53	59	50	81	89	n.a.	83	77	68	71	57
1922	61	-	76	-	86	-	n.a.	-	n.a.	-	79	-
1923	70	61	73	58	81	99	97	93	96	98	78	71
1924	71	-	74	-	82	-	106	-	105	-	79	-
1925	74	66	84	79	81	99	105	91	101	96	86	81
1926	79	-	87	-	88	-	111	-	104	-	87	-
1927	79	73	88	85	95	99	109	103	98	95	90	82
1928	84	-	99	-	100	-	106	-	106	-	95	-
1929	100	100	100	100	100	100	100	100	100	100	100	100
1930	106	-	95	-	97	-	101	-	112	-	104	-
1931	95	106	92	84	95	87	106	119	126	124	119	130
1932	82	-	96	-	102	-	107	-	124	-	116	-
1933	100	105	103	82	113	115	101	99	143	136	118	127
1934	101	-	101	-	115	-	104	-	137	-	120	-
1935	118	110	109	102	125	124	106	92	147	150	113	110
1936	121	-	112	-	134	-	106	-	121	-	128	-
1937	119	119	114	111	123	115	103	93	129	132	125	116
1938	118	-	116	-	127	-	108	-	138	-	129	-
1939	119	101	137	113	129	127	111	112	145	172	139	148

Sources: See Appendix A and B.

TABLE 3.1 continued

PRODUCTIVITY INDEXES, SELECTED INDUSTRIES, 1919 - 1939

Year	Clay Products		Confectionery		Flour and Grain Mill Products		Glass		Ice Cream		Leather Tanning & Finishing		Lumber & Lumber Products	
	real	value	real	value	real	value	real	value	real	value	real	value	real	value
1919	80	74	n.a.	64	64	44	59	45	73	35	71	79	96	80
1920	81	-	n.a.	-	59	-	68	-	78	-	68	-	92	-
1921	80	71	n.a.	82	72	60	69	46	76	59	88	116	102	81
1922	84	-	n.a.	-	74	-	88	-	77	-	89	-	82	-
1923	91	85	n.a.	87	76	68	86	54	77	62	95	106	87	76
1924	87	-	n.a.	-	82	-	88	-	74	-	95	-	88	-
1925	93	94	89	91	83	61	92	78	84	79	93	111	93	85
1926	94	-	97	-	87	-	101	-	86	-	95	-	93	-
1927	98	93	100	94	89	75	106	86	92	86	102	114	96	91
1928	103	-	99	-	94	-	107	-	92	-	104	-	95	-
1929	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1930	101	-	114	-	106	-	103	-	105	-	101	-	95	-
1931	104	103	116	117	111	137	122	133	109	122	97	112	110	116
1932	91	-	126	-	108	-	126	-	98	-	108	-	97	-
1933	100	97	136	144	108	136	144	145	108	110	113	140	104	106
1934	89	-	154	-	107	-	135	-	121	-	124	-	109	-
1935	96	106	165	158	104	99	159	148	128	123	129	130	110	114
1936	96	-	169	-	101	-	155	-	141	-	128	-	103	-
1937	100	111	164	154	96	89	167	159	148	137	131	113	100	107
1938	99	-	175	-	106	-	152	-	164	-	142	-	106	-
1939	114	113	186	170	115	131	182	182	183	160	152	136	121	142

Sources: See Appendix A and B.

TABLE 3.1 concluded

PRODUCTIVITY INDEXES, SELECTED INDUSTRIES, 1919-1939

Year	Manufactured Ice		Petroleum Refining		Printing & Publishing		Pulp & Paper		Rubber Products		Slaughtering Meat Packing		Tobacco Manufactures	
	real	value	real	value	real	value	real	value	real	value	real	value	real	value
1919	61	54	49	49	57	-	60	52	n.a.	46	74	60	68	-
1920	n.a.	-	n.a.	-	67	-	64	-	n.a.	-	79	-	71	-
1921	90	77	56	49	67	-	64	51	70	57	91	99	70	-
1922	n.a.	-	n.a.	-	77	-	75	-	n.a.	-	96	-	74	-
1923	93	83	71	65	82	-	80	64	78	75	94	109	77	-
1924	n.a.	-	85	-	84	-	83	-	n.a.	-	100	-	81	-
1925	113	106	93	76	89	-	88	71	86	80	99	98	84	-
1926	n.a.	-	89	-	100	-	89	-	n.a.	-	103	-	89	-
1927	128	123	95	72	98	-	95	88	99	90	101	97	88	-
1928	n.a.	-	110	-	102	-	100	-	100	-	101	-	90	-
1929	100	100	100	100	100	-	100	100	100	100	100	100	100	-
1930	n.a.	-	96	-	96	-	101	-	110	-	103	-	99	-
1931	130	132	117	120	98	-	115	95	122	153	112	119	112	-
1932	n.a.	-	124	-	96	-	115	-	137	-	113	-	106	-
1933	129	129	134	138	97	-	117	92	134	153	116	169	115	-
1934	n.a.	-	135	-	110	-	111	-	143	-	103	-	120	-
1935	142	137	148	122	119	-	118	107	145	134	104	105	140	-
1936	n.a.	-	158	-	121	-	123	-	148	-	109	-	147	-
1937	n.a.	144	167	126	120	-	124	117	145	118	106	108	145	-
1938	n.a.	-	177	-	120	-	127	-	143	-	119	-	153	-
1939	n.a.	169	193	152	129	-	134	128	156	132	126	153	162	-

Sources: See Appendix A and B.

The most convenient method of comparing the time behavior of productivity in a number of industries is to compare the slopes of the trends of their productivity indexes. Whether a value index or unit labor cost measure is employed, the year to year behavior of productivity is subject to a complex set of forces many of which (e.g. the rate of output of the industry) are not permanent in their action. The time trend derives its usefulness from the fact that it may be looked upon as the underlying central tendency around which actual productivity fluctuates under the temporary influence of less basic forces.

The effects of temporary forces cannot, of course, be entirely eliminated by the trend unless the action of the other forces is uncorrelated with time during the period studied. In the present case, this assumption is not fully justified. The first half of the period lies in the relatively prosperous years of the twenties, the latter half in the depressed thirties. This fact inevitably imparts a bias in the trend measure, the direction of which depends upon the nature of the cyclical forces in operation. In the discussion of the value measure of productivity we have already identified one such force in the cyclical behavior of relative raw materials prices. Over a very long period this cyclical behavior would be substantially eliminated as an influence on the trend; over the period under examination it probably imparts an upward bias to the value productivity trend.

Cyclical biases in the imputed trends will not impugn the results of our study. We are concerned with relative behavior of productivity and to the extent that cyclical bias arises from somewhat the same forces in all industries, the differences in bias from one industry to the next should be sufficiently small relative to the magnitudes

of the trend slopes to permit useful comparisons to be made. In Chapters VI and VII a method of analysis will be developed to determine the nature of some of these cyclical forces and their effect on productivity.

The trend used for comparison was linear, the trend slope indicating the average annual increase in productivity measured in index points. Since the index numbers are based on 1929 as 100, the slope represents the average annual increase in productivity in percent of 1929 productivity. If we bear in mind that the logarithmic and linear trends are very nearly the same in the series with which we have to deal, the linear trend slope may be thought of as the "compound interest" rate of growth. This is due to the fact that the linear slope as a percent of the central year is approximately equal to the average compound rate. It should be emphasized, however, that the linear trend is a valid measure in its own right. The interpretation of the trend as an approximate compound rate is a matter of convenience only.

The value and unit man-hour indexes for Manufacturing as a whole are plotted in Figures 3.1 and 3.2 respectively. The indexes are plotted together in Figure 3.3 for purposes of comparison. Table 3.2 summarizes the magnitudes of the trend slopes for the selected industries and groups.

Although the period 1919-1939 was marked by increasing productivity in all segments of the economy, the several upward trends were by no means uniform in magnitude. Among the non-manufacturing industries studied, Crude Petroleum and Natural Gas showed the sharpest rise (roughly 6.5% per annum) followed closely by the Electric Light and Power Industry (5.6 percent per annum). Manufacturing

TABLE 3.2

SLOPES OF VALUE AND UNIT LABOR COST (REAL) PRODUCTIVITY TRENDS FOR SELECTED INDUSTRIES FOR THE PERIOD 1919 - 1939

Industry	Slope of Trend Line	
	real	value
Agriculture	1.8	n.a.
Coal Mining	1.4	n.a.
Electric Light and Power	5.6	n.a.
Mining and Quarrying (ex. Crude Petroleum and Natural Gas)	2.3	n.a.
Crude Petroleum and Natural Gas	6.5	n.a.
Railroads	2.4	n.a.
Telephone	2.7	n.a.
Manufactures as a whole	3.4	2.8
Automobiles and Automobile Equip.	3.8	3.7
Blast Furnaces, Steel Works and Rolling Mills	3.2	3.1
Boots and Shoes	2.7	2.2
Canning and Preserving	3.4	4.8
Cement	4.0	4.1
Clay Products (other than Pottery)	1.1	2.0
Confectionery	7.3	5.3
Flour and Grain Mill Products	2.4	3.9
Glass	5.5	7.3
Ice Cream	4.7	5.5
Leather Tanning and Finishing	3.3	1.8
Lumber and Lumber Products	n.a.	2.7
Manufactured Ice	4.2	4.8
Petroleum Refining	6.6	5.3
Printing and Publishing	3.0	n.a.
Pulp and Paper	3.5	3.7
Rubber Products	5.1	4.8
Slaughtering and Meat Packing	1.7	3.2
Tobacco Manufactures	4.7	n.a.
Bread and Bakery Products	1.8	1.0

Source: Trends computed by the writer from data of Table 3.1

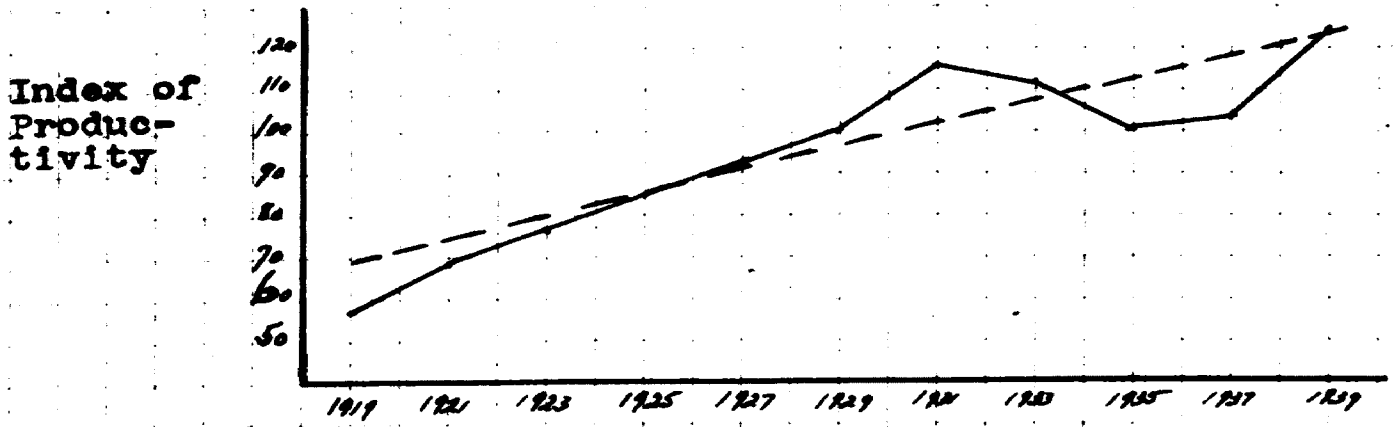


Figure 3.1 Index of Value Productivity and Linear Trend, Manufacturing as a Whole.

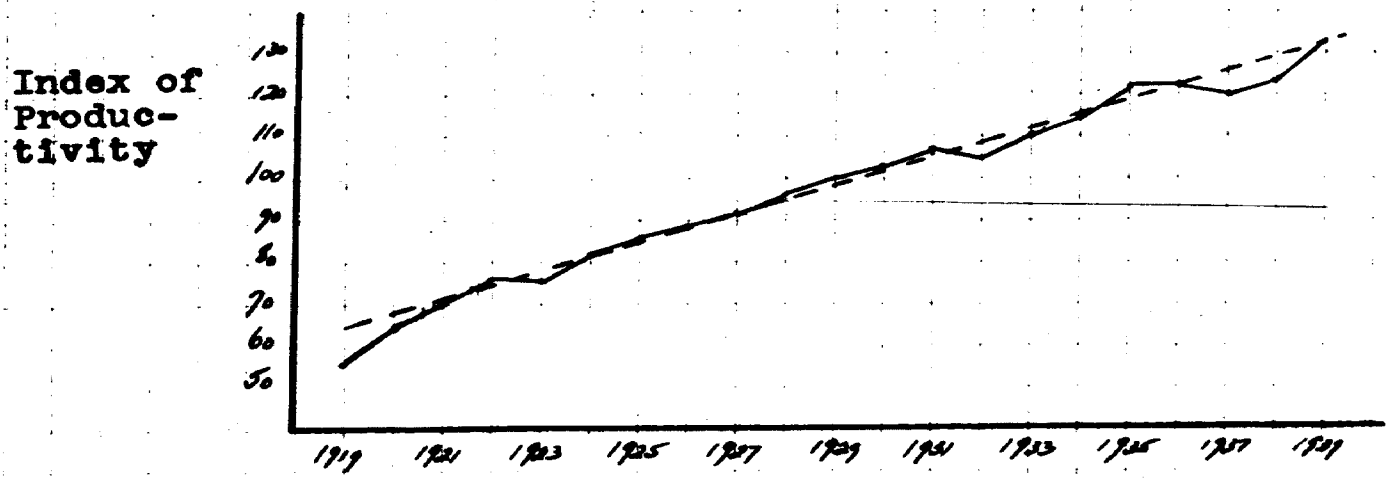


Figure 3.2 Index of Unit Labor Cost Productivity a nd Linear Trend, Manufacturing as a Whole.

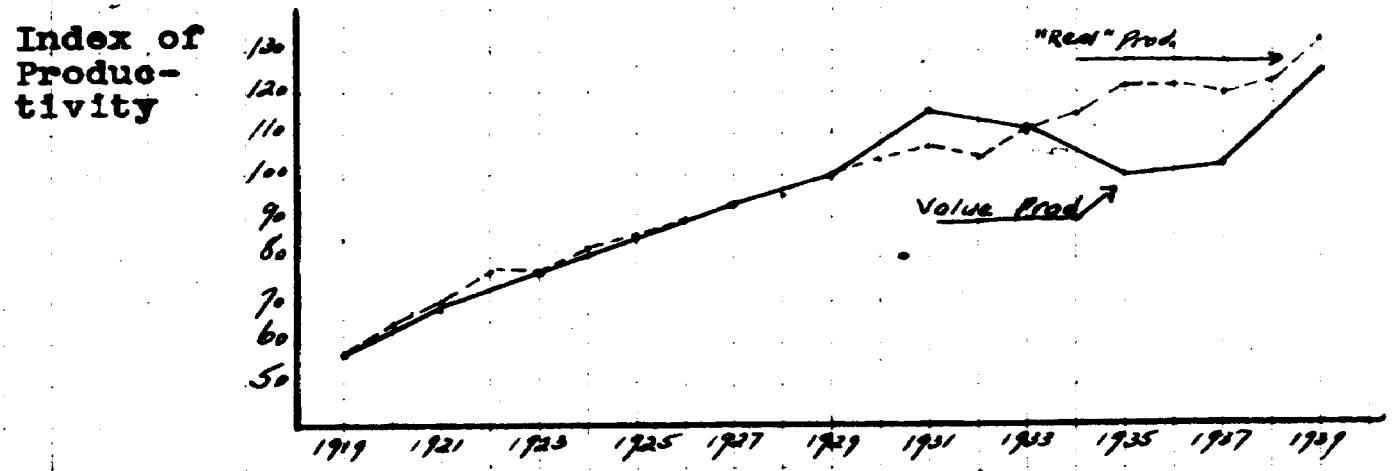


Figure 3.3 Comparison of Value Productivity Index with the Unit Labor Cost (Real) Productivity Index

productivity increased somewhat more rapidly than the median rate for non-manufacturing activity, the rate for Manufactures as a whole being 3.4 percent. The slowest increase was shown by Agriculture (1.8 percent). For purposes of comparison these trend slopes are plotted in figure 3.4.

Within the manufacturing field the spread of productivity trends was slightly wider than that exhibited by non-manufactures. Figures 3.5 and 3.6 summarize graphically the relative rates of increase in productivity of the manufacturing groups studied. It is easily seen that the unit labor cost productivity trends are distributed in a roughly normal fashion around the rate of increase for Manufacturing as a whole. The distribution of rates of increase in value productivity seems to indicate a mean value for the selected group somewhat higher than the rate of increase for Manufacturing as a whole.

The distribution of percent total value added by the manufacturing group and total group employment (1929) by magnitude of value trend slope in Figures 3.7 and 3.8 respectively indicates more clearly the extent of variation in value trends. It is evident that the trend for the group as a whole roughly approximates the trend for all manufacturing if individual productivities are weighted by employment. But falls somewhat above the average for all manufactures if value added weights are utilized. A similar distribution made on the basis of the unit labor cost productivity index trend in Figures 3.9 and 3.10 reveals that the dispersion of real index trends is considerably less than that of the value trend measures, and that there is considerable concentration at the average for all manufacturing regardless of the weighting used.

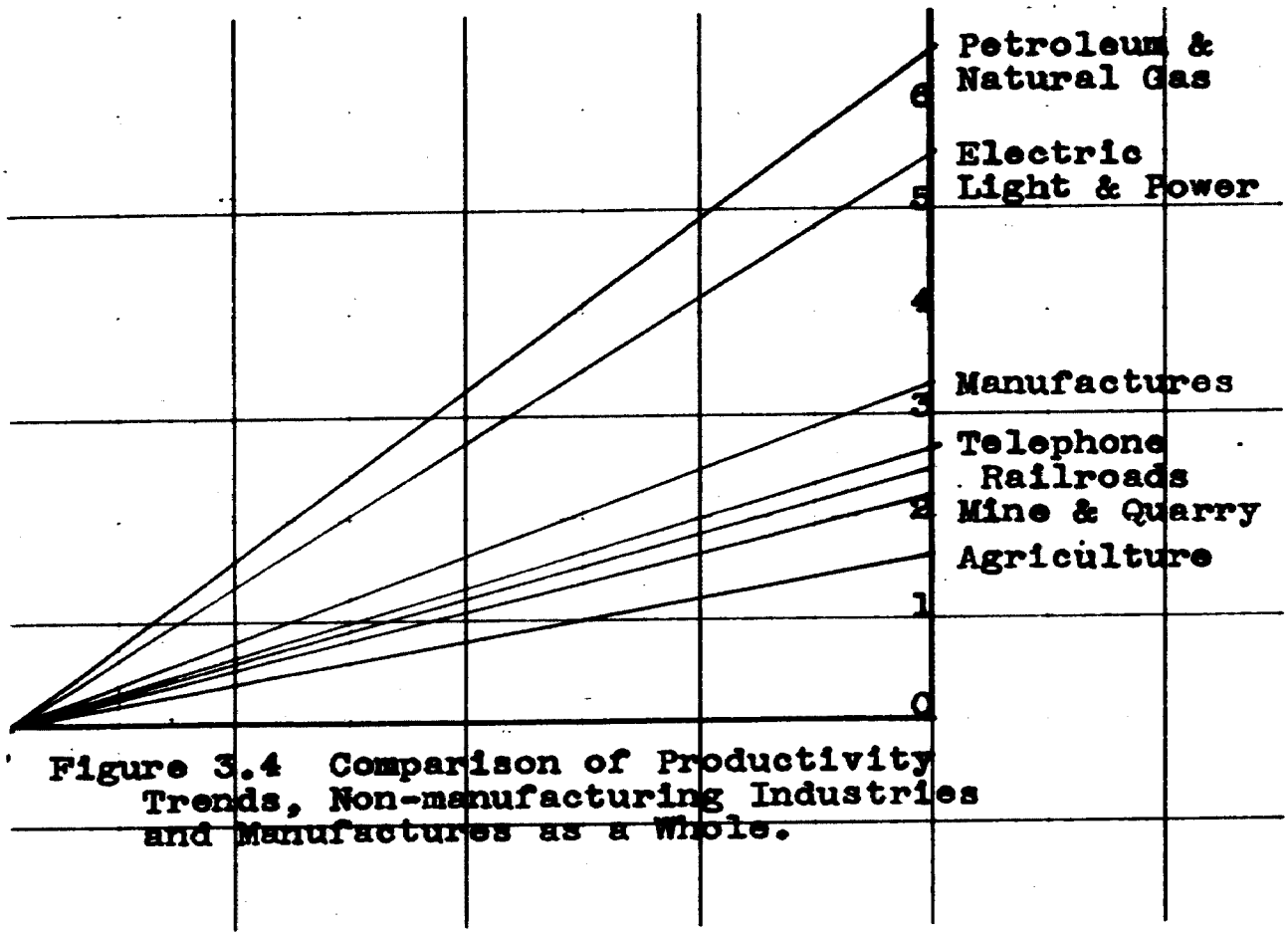


Figure 3.4 Comparison of Productivity Trends, Non-manufacturing Industries and Manufactures as a Whole.

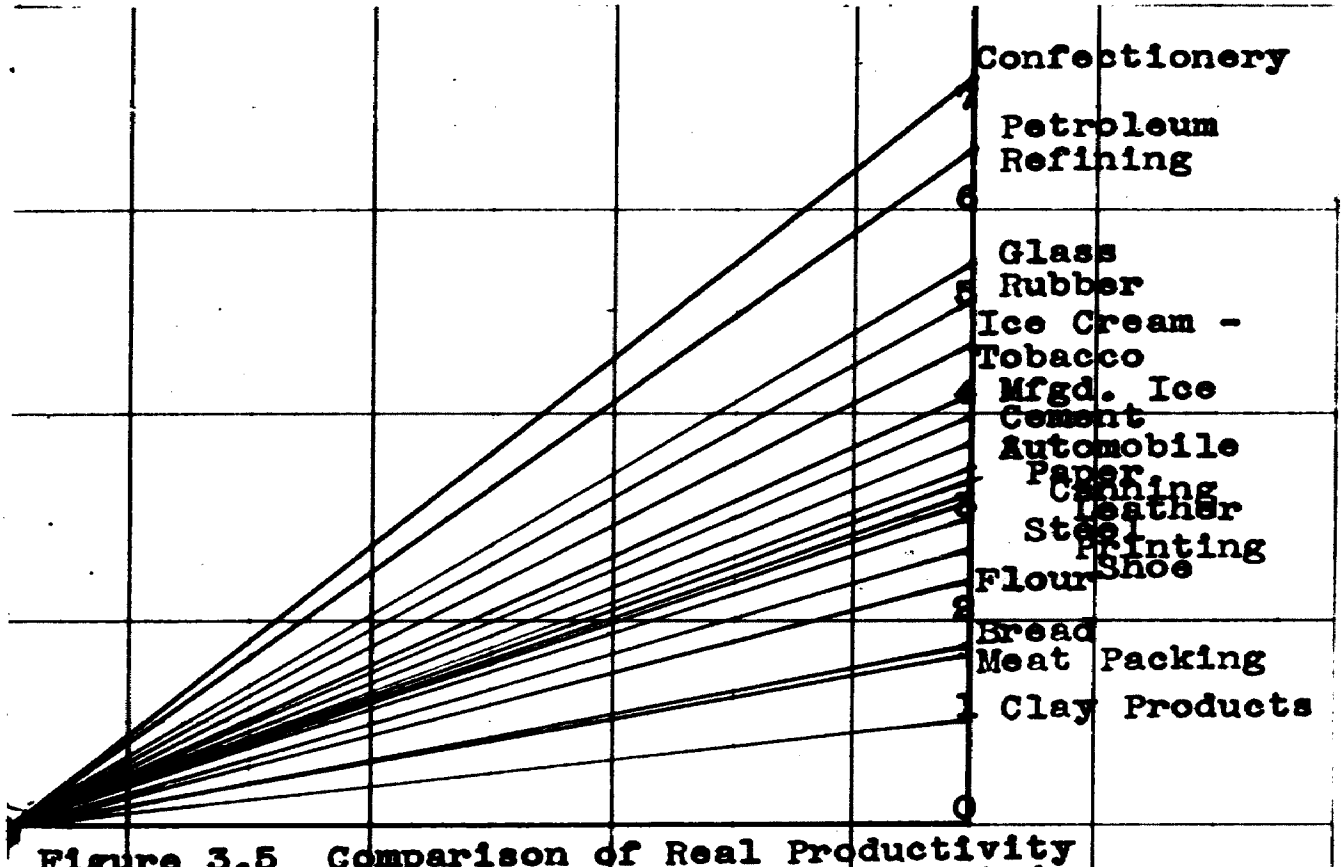


Figure 3.5 Comparison of Real Productivity Trends, Manufacturing Industries

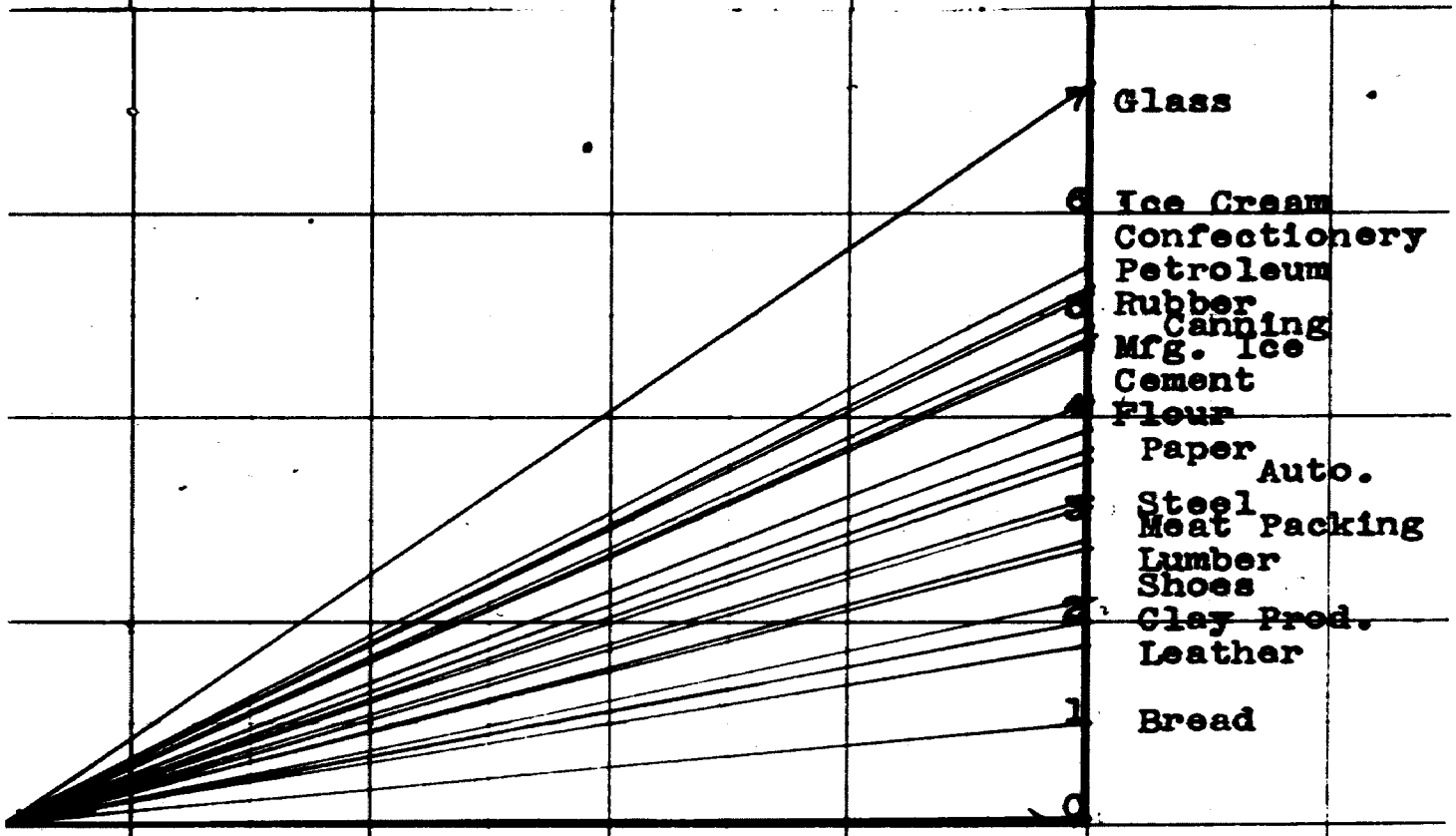


Figure 3.6 Comparison of Value Productivity Trends, Manufacturing Industries

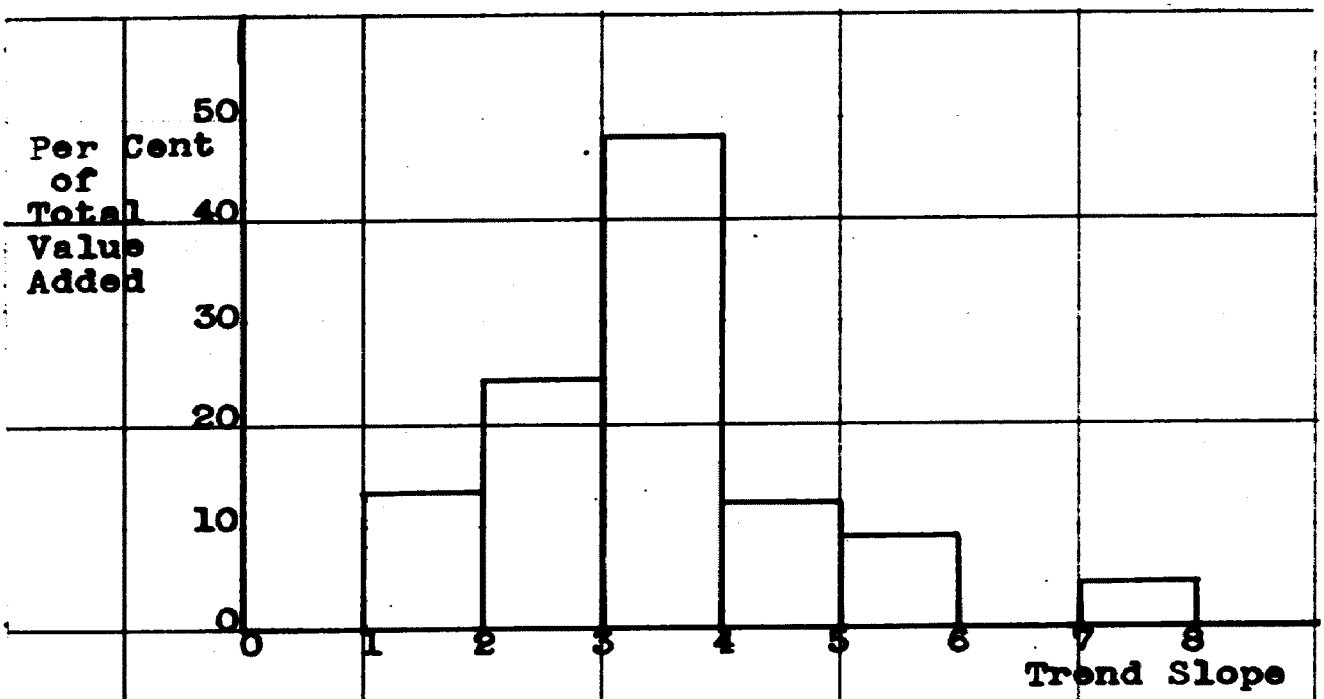


Figure 3.7 Percentage Distribution of Manufacturing Value Added by Slope of Value Productivity Trend.

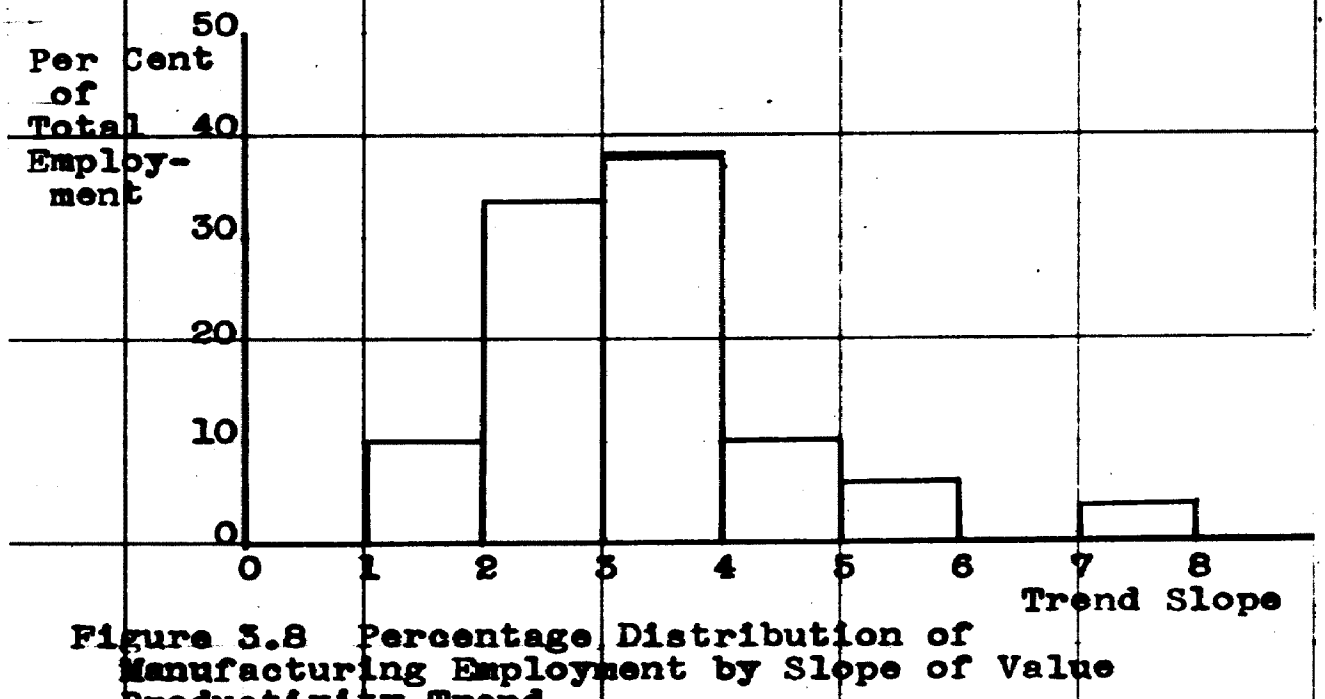


Figure 3.8 Percentage Distribution of Manufacturing Employment by Slope of Value Productivity Trend.

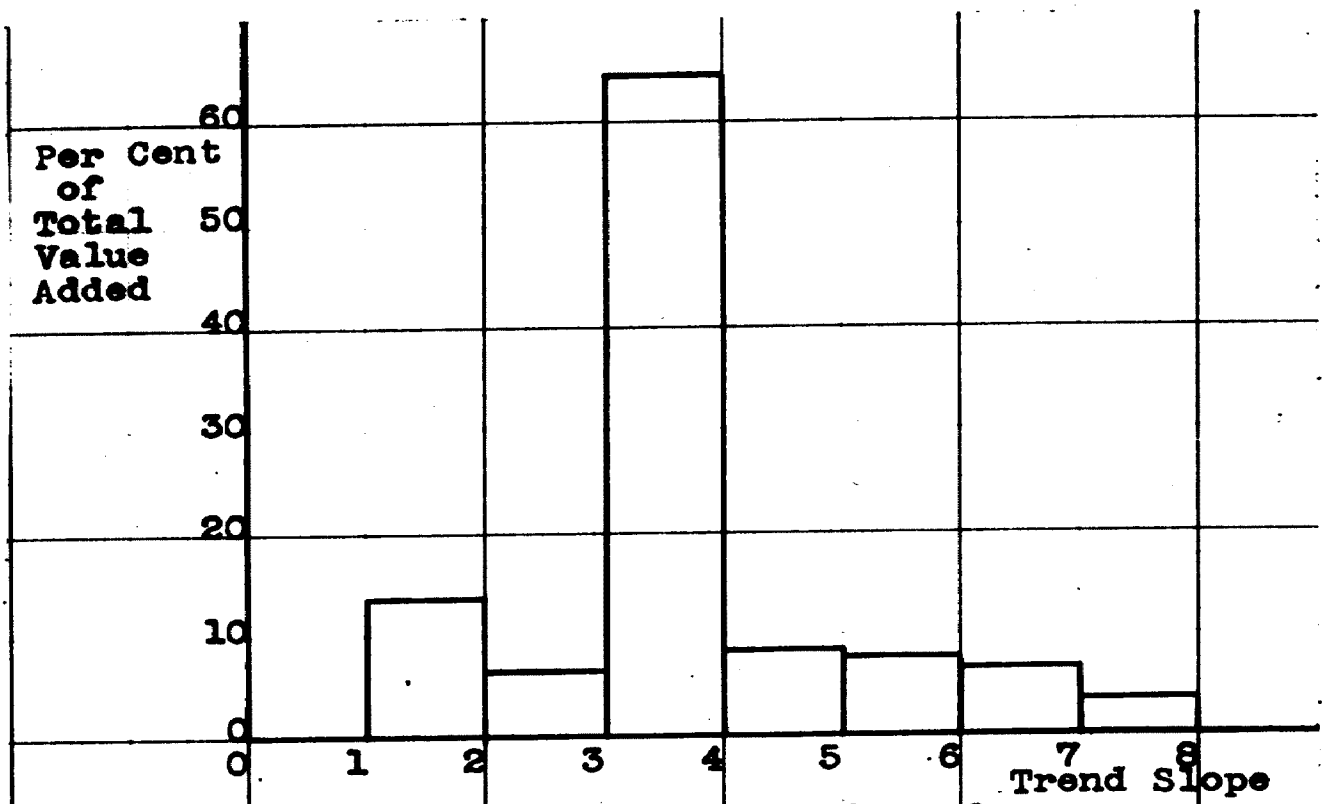


Figure 3.9 Percentage Distribution of Manufacturing Value Added by Slope of Real Productivity Trend.

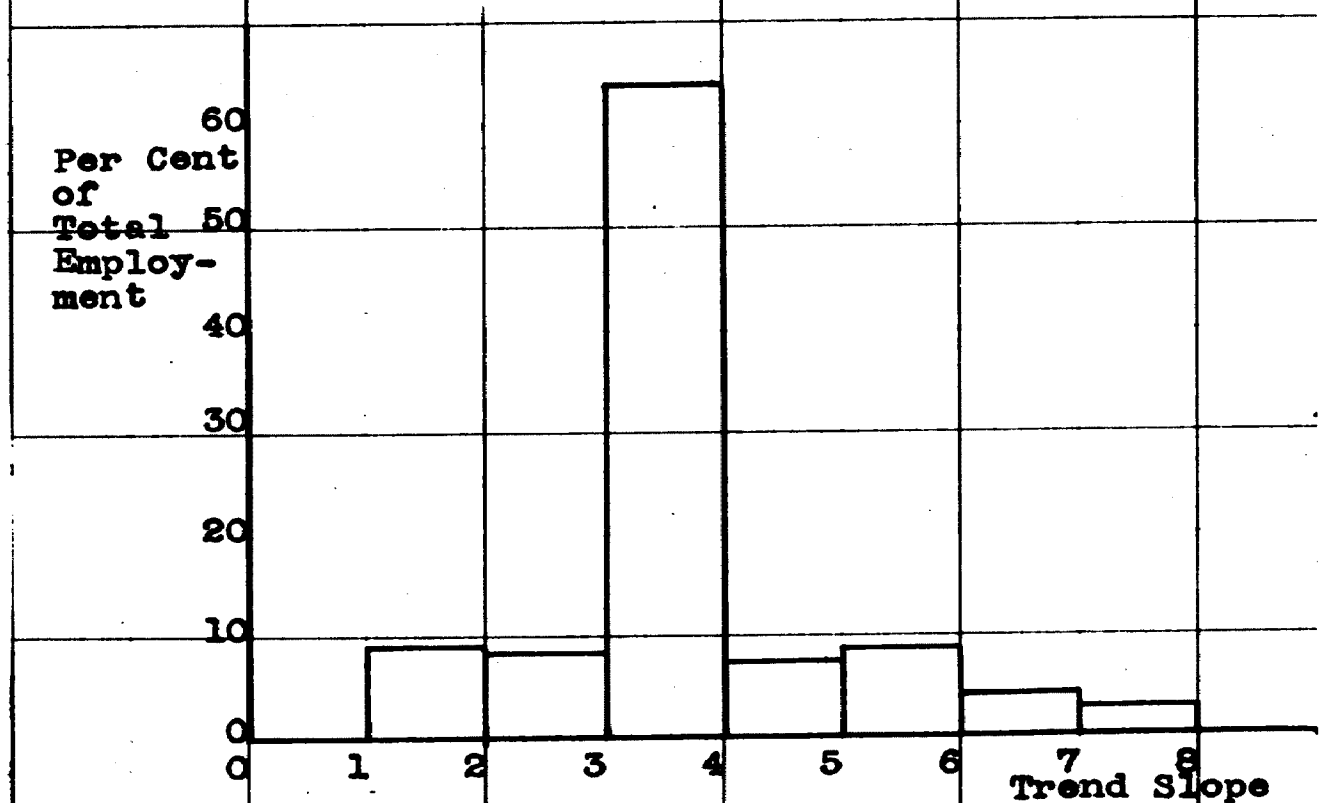


Figure 3.10 Percentage Distribution of Manufacturing Employment by Slope of Real Productivity Trend.

Industry by industry comparison of the two trend measures may be made by reference to Table 3.2. It is evident that there is substantial agreement between the two measures. In those cases where significant differences occur between the magnitudes of the two trend measures there seems to be no systematic bias in the direction of the difference.

CHAPTER IV

CAPITAL EXPENDITURE BY SELECTED INDUSTRIES

Having established the behavior of productivity trends in a number of industries, we turn our attention to the problem of relating these trends to the quantitative and qualitative behavior of capital expenditure. In order to do this, estimates of the magnitude of capital expenditure must be obtained. Before proceeding to a discussion of the estimates employed here, however, it is important to consider exactly what we mean by "capital" expenditure.

In the broadest sense of the term, practically all expenditure made by firms in carrying out production is "capital" expenditure. Payments to productive agents, almost without exception, precede the ultimate disposition of the product by some period of time, and this time period is the essence of capital. But capital expenditure in this sense is the whole production complex. We are concerned only with that portion of expenditure devoted to durable instrumentalities.

Our interest in expenditure on plant and equipment has a two-fold basis. In the first place we know from historical experience that such expenditures have played an important role in the rise

in labor productivity. In the second place the fact that such expenditure constitutes a major commitment by the firm with regard to its activity for a considerable future period implies that a special set of psychological and institutional factors dominate in the determination of its volume.

The line of demarcation between durables and non-durables is not easily drawn, but in light of the special attitude which business firms are expected to have with regard to the purchase of durable equipment, it follows that any measurement of capital expenditure must involve some decision as to which instrumentalities are to be considered as subject to special consideration and which are not. The basis for drawing such a line depends upon the kind of data we expect to use in deriving the estimates.

When data are obtained from the reports of business firms, either in the form of reports for their own use or replies to questionnaires submitted by the Census or the Department of Commerce, we may, in general, limit our attention to those items which the firm reports as subject to depreciation, or purchased on "capital account". This classification usually excludes the purchase of hand tools, minor repairs and maintenance, etc. which are either too troublesome to include in elaborate capital accounts or are considered complementary to the process of production and are expensed against current operations. In most cases the treatment given an expenditure item by a firm may be taken as <u>prima facie</u> evidence of the firm's attitude toward it, but this is sometimes misleading. Accounting procedures are sometimes arrangements convenient for tax purposes or of tradition or habit. They do not necessarily reflect the current attitude of enterprisers toward operations and one hesitates to accept some firm

classifications of items as capital or non-capital expenditure at their face value.

An example of the sort of difficulty which is sometimes involved in the interpretation of firm reports is found in the Crude Petroleum industry. It is customary for oil firms to divide the costs of drilling and bringing in a well into two catagories. Outlays for well casing, unrecoverable portions of drilling derricks, pumping, flowing, and heading equipment, and similar items are classed as "tangible" development costs; the remaining costs, primarily outlay for labor for the actual drilling, are classified as "intangible" development costs.[1] While the tangible costs are typically capitalized and subject to depreciation, the intangible costs are often written off against current income.[2]

Although most frequent, and because of the magnitudes involved most important in the petroleum industry, this practice is met with in most of the mineral extractive industries. In making his estimates of capital consumption, Professor Fabricant concluded that roughly half of total outlay for development by Mining and Quarrying firms was charged against current income during the period 1919-1935.[3]

[1] "Production costs of Crude Petroleum", a study prepared by the Tariff Commission, Sen. Msc. Doc. No. 267, 72nd Cong. 3rd Sess. p. 15.

[2] A study of the extent of this practice was made by J.F.S. Arthur, "Accounting Policies and Practices as Reflected by Published Statements of Several Oil Companies," Papers Presented at the 53rd Annual Meeting, American Institute of Accounting, p.243. Mr. Arthur examined the published statements of thirty-two oil companies and found that twelve companies made no mention of their handling of intangible development cost, while four of the remaining concerns charged such outlays to income as incurred.

[3] Solomon Fabricant, Capital Consumption and Adjustment, National Bureau of Economic Research, New York, 1938, p.50.

Some of the basic date for the estimates of capital expenditure by the mineral industries were derived from the reports of firms to the Census of Minerals Industries. In light of the ambiguity attached to the treatment of development cost, a separate estimate was made by the author for such outlays by the crude petroleum and natural gas industry. Data were not obtainable for similar treatment of the other minerals industries, but it was felt that the problem there was not sufficiently serious to cause a major distortion in the result.

When capital expenditures are estimated from the flow of producer durable goods rather than the reports of firms, as were those of Kuznets[4] and certain of those published by Terborgh[5] the procedure involves the use of an independent criterion of which goods to include in the class of those subject to special determining factors. The criterion usually established is one of durability; those items are included in capital expenditure which have an expected economic life of five years or longer. Durability is not, of course, an absolute concept. The expected economic life of a piece of equipment depends, among other things, upon its prospective replacement cost, repair costs, demand for its service, the interest rate, etc.[6] But the variation

[4] Simon Kuznets, Commodity Flow and Capital Formation, 2 Vols, National Bureau of Economic Research, New York, 1938.

[5] See below pp 51

[6] That is to say, the life expectation of a piece of equipment is , like other input decisions, a variable in the profit maximization process. It is generally believed, however, that it is not a variable of great significance in most case, although a fall in the cost of replacement is sometimes associated with premature abandonment of existing equipment and the shortening of the life expectation of replacements. A number of interesting theoretical studies have been made of the nature of economic life expectation, dealing both with its implications for depreciation accounting and with its bearing on business cycle theory. For example see: (continued)

in life expectation of a given piece of equipment is obviously not so great as to render the assignment of a time period meaningless, and this criterion can, therefore, be applied.

CAPITAL EXPENDITURE ESTIMATES

With the exception of the estimates for the minerals industries, the estimates of capital expenditure for non-manufacturing industries employed in this study are those published by Mr. George Terborgh[7]. Terborgh derived his estimates from the following sources:

Railroads - Expenditures for plant and equipment by the railroad industry were estimated from figures compiled by the Association of American Railroads and data published by the Interstate Commerce Commission. The data were adjusted to make allowance for capital expenditures of class II and III roads and switching and terminal companies.

Electric Light and Power - The estimates of capital expenditure by electric light and power firms were prepared by the Department of

6 (continued)
Harold Hotelling, "A General Mathematical Theory of Depreciation." Journal of the American Statistical Association, Vol. 20, no. 8, Sept. 1925, pp 340-353

G.A.D. Preinreich, "The Economic Life of Industrial Equipment," Econometrica, Vol. 8, no. 1, Jan. 1940, pp. 12-44.

Benjamin Caplan, "Reinvestment and the Rate of Interest," American Economic Review, Vol. 30, no. 3, Sept. 1940, pp. 561-568.

Joe S. Bain, "The Relation of the Economic Life of Equipment to Reinvestment Cycles," Review of Economic Statistics, Vol. 21, no. 2, May 1939, pp. 79-88.

[7]George Terborgh, "Estimated Expenditure for Durable Goods," 1909-1938, Federal Reserve Bulletin, Vol. 25, no. 9, Sept. 1939, pp. 731-736
"Estimated Expenditure for Durable Goods, 1939", Federal Reserve Bulletin, Vol. 26, no. 2, Feb. 1940, pp. 116.

Commerce and originally based on data submitted by the Edison Electric Institute. The data do not include expenditures by government owned utilities.

Telephone - Statistics for the telephone industry were supplied by the American Telephone and Telegraph Corporation and cover the entire telephone industry.

Agriculture - The estimates of capital expenditure in agriculture include production buildings, wells, fences, and similar improvements to farm real estate, farm machinery, farm trucks, tractors, and parts and accessories but not major repairs. The estimates were prepared by the Bureau of Agricultural Economics.

The estimates of capital expenditure in the following manufacturing industries are those published by L. J. Chawner:[8] Automobiles and Automobile Equipment, Blast Furnaces, Steel Works, and Rolling Mills, Lumber and Lumber Products, Petroleum Refining, Printing, Publishing and Allied Industries, Pulp, Paper and Allied Industries, Rubber Products, and Manufacturing as a whole.

In his estimating procedure Chawner used the expenditures for plant and equipment reported by industries in the Census of Manufactures, 1939 as a "bench-mark". He compiled a number of series of annual figures for the production of special industry machinery from production reported in the biennial Census of Manufactures, and from sales reports of machinery manufacturers. Census figures were inter-

[8] L. J. Chawner, "Capital Expenditure in Selected Manufacturing Industries, Part I," Survey of Current Business, Vol. 21, no. 12, Dec. 1941, pp. 19-26

"Capital Expenditure in Selected Manufacturing Industries, Part II," Survey of Current Business, Vol. 22, no. 5 May, 1942, pp. 14-23.

polated for intercensal years by reference to figures of sales of machinery manufacturers reported in the Statistics of Income. The 1939 bench-marks were then applied to his annual series for the respective industries to obtain his estimates of annual expenditure for plant and equipment. In estimating the capital expenditure of the Automobile and Automobile Equipment Industry, Chawner employed a series of reported expenditures covering a substantial portion of the industry.

The reliability of bench-mark estimates depends (aside from the problem of the reliability of the series upon which the estimates are based) upon the extent to which the estimated sample expenditures remain a stable proportion of the total capital expenditure of the industry. Unfortunately there is no way of testing this stability and the technique is primarily justified by the absence of any other method. Since we are less concerned here with the exact magnitudes of capital expenditure, but rather are interested in a general measure of the relative magnitudes which the expenditures of the various industries bear to each other, this difficulty may not be serious.

The remaining capital expenditure series used were estimated by the writer: Coal Mining, Mining and Quarrying (excluding Petroleum and Natural Gas), Crude Petroleum and Natural Gas, Boots and Shoes, Bread and Bakery Products, Canning, Cement, Clay Products, Confectionery, Flour and Grain Mill Products, Glass Products, Ice Cream, Leather Tanning and Finishing, Manufactured Ice, Slaughtering and Meat Packing, and Tobacco Products. A description of the data and techniques employed in the estimates will be found in Appendix C.

The estimates of annual capital expenditure for the industries selected for study are presented in Tables 4.1-a and 4.1-b.

TABLE 4.1-a

ESTIMATED ANNUAL CAPITAL EXPENDITURE, SELECTED MANUFACTURING INDUSTRIES, 1919 - 1939

(figures in millions of dollars)

Year	Automobiles & Automobile Equipment		Blast Furnaces Steel Works & Rolling Mills		Boots & Shoes		Bread & Bakery Products		Canning		Cement	
	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	59	52	160	140	16.6	14.6	12.8	19.2	8.9	7.0	4.9	4.3
1920	171	144	190	160	14.0	11.8	45.6	38.5	20.8	17.5	8.7	7.3
1921	52	46	100	88	9.5	8.4	23.5	20.7	12.6	11.1	5.9	5.2
1922	44	43	100	101	12.5	12.3	30.9	31.2	20.2	20.4	6.7	6.8
1923	87	86	120	119	11.5	11.4	32.9	32.7	23.7	23.6	9.2	9.2
1924	98	98	180	180	11.1	11.1	32.0	32.0	21.4	21.4	8.1	8.1
1925	88	88	200	201	12.8	12.9	38.1	38.3	23.9	24.0	10.4	10.5
1926	111	114	230	235	15.6	16.0	49.7	51.0	25.2	25.8	8.9	9.1
1927	131	135	160	164	13.1	13.5	44.4	45.6	17.9	18.4	11.6	11.9
1928	113	116	200	204	12.9	13.2	53.0	54.2	22.8	23.3	14.5	14.8
1929	150	150	150	150	12.7	12.7	46.0	46.0	20.9	20.9	11.0	11.0
1930	94	99	300	316	10.1	10.6	33.9	35.8	15.0	15.8	5.7	6.0
1931	49	54	120	133	10.8	11.9	23.6	26.0	9.9	10.9	3.9	4.3
1932	37	43	40	47	9.6	11.4	13.7	16.2	6.1	7.2	1.9	2.3
1933	25	31	50	62	9.3	11.5	15.9	19.6	7.7	9.5	1.4	1.7
1934	48	55	40	46	10.1	11.6	20.8	23.9	14.8	17.0	2.6	3.0
1935	99	115	122	142	11.8	13.7	26.0	30.1	22.1	25.6	4.1	4.7
1936	109	126	200	231	12.3	14.2	21.0	24.2	27.1	31.3	5.5	6.3
1937	119	129	316	343	11.2	12.1	39.6	42.7	28.9	31.2	5.1	5.5
1938	112	118	132	140	10.7	11.3	30.0	31.7	15.1	15.9	5.1	5.4
1939	83	82	110	108	12.0	11.8	37.8	37.1	10.1	10.0	7.6	7.5

Sources: See text.

TABLE 4.1-a, continued

ESTIMATED ANNUAL CAPITAL EXPENDITURE, SELECTED MANUFACTURING INDUSTRIES, 1919 - 1939

(figures in millions of dollars)

Year	Clay Products		Confectionery		Flour & Grain Mill Products		Glass Products		Ice Cream		Leather Tanning and Finishing	
	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	9.4	8.3	6.1	5.4	17.8	15.6	10.2	9.0	17.2	15.1	4.6	8.5
1920	16.5	13.9	5.7	4.8	12.2	10.2	18.2	15.3	16.0	13.5	7.9	6.6
1921	10.4	9.0	3.4	3.0	7.2	6.3	12.6	11.1	9.5	8.4	5.2	4.6
1922	15.6	15.7	3.7	3.7	8.5	8.6	8.6	8.7	10.5	10.6	6.1	6.2
1923	21.4	21.2	3.3	3.3	8.1	8.0	8.2	8.1	9.0	8.9	5.3	5.3
1924	17.7	17.7	3.0	3.0	6.8	6.8	6.8	6.8	8.4	8.4	4.5	4.5
1925	19.9	20.2	3.4	3.4	7.6	7.6	8.2	8.2	9.5	9.5	4.6	4.6
1926	18.6	19.0	4.3	4.4	8.8	9.0	11.4	11.7	12.0	12.3	5.3	5.4
1927	17.1	17.6	3.6	3.6	7.8	8.0	9.5	9.8	10.5	10.8	4.1	4.2
1928	19.3	19.7	3.6	3.6	8.9	9.2	13.3	13.6	10.1	11.3	3.4	3.5
1929	17.8	17.8	2.4	2.4	7.7	7.7	11.3	11.3	6.7	6.7	2.6	2.6
1930	9.0	9.5	2.4	2.5	5.8	6.1	7.2	7.6	6.7	7.1	1.8	1.9
1931	5.7	6.3	2.5	2.8	4.1	4.5	7.8	8.6	7.0	7.7	1.7	1.9
1932	2.3	2.7	1.5	1.7	2.2	2.6	3.9	4.6	4.1	4.9	1.5	1.8
1933	2.0	2.4	1.8	2.2	2.2	2.7	5.8	7.1	5.0	6.2	1.5	1.8
1934	2.1	2.5	2.5	2.9	3.6	4.1	7.7	8.8	7.1	8.2	1.7	2.0
1935	3.7	4.3	3.3	3.8	5.1	5.9	10.9	12.6	9.3	10.8	2.1	2.4
1936	6.4	7.3	4.3	5.0	5.6	6.4	15.2	17.5	12.1	14.0	2.5	2.9
1937	7.6	8.1	4.7	5.1	6.7	7.2	14.5	15.6	13.3	14.4	2.5	2.7
1938	5.2	5.6	3.6	3.8	4.9	5.2	11.5	12.2	10.2	10.8	2.3	2.4
1939	5.7	5.5	4.6	4.5	5.9	5.8	13.7	13.5	12.9	12.7	2.6	2.5

Sources: See text.

TABLE 4.1-a, continued

ESTIMATED ANNUAL CAPITAL EXPENDITURE, SELECTED MANUFACTURING INDUSTRIES, 1919 - 1939

(figures in millions of dollars)

Year	Lumber & Lumber Products		Manufactured Ice		Petroleum Refining		Printing, Publishing & Allied Indust.		Pulp, Paper & Allied Products		Rubber Products	
	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	124	109	23.4	20.6	75	66	85	75	101	89	70	61
1920	159	134	46.0	38.6	100	84	113	95	158	133	105	89
1921	71	63	22.0	19.3	55	48	85	75	89	78	25	22
1922	110	111	26.5	26.7	.	.	107	108	63	64	23	23
1923	118	117	25.6	25.5	aver.	aver.	124	123	102	101	22	22
1924	105	105	21.7	21.7	65	65	114	114	93	93	21	21
1925	120	121	22.8	22.9	.	.	130	131	85	85	29	29
1926	143	146	33.1	33.8	85	87	129	132	92	94	32	33
1927	94	97	32.2	33.1	80	82	114	117	116	119	41	42
1928	89	91	42.0	43.0	120	123	102	104	129	132	38	39
1929	104	104	39.6	39.6	125	125	119	119	137	137	54	54
1930	50	53	26.6	28.1	85	90	81	85	110	116	22	23
1931	30	33	15.1	16.7	65	72	52	58	54	60	17	19
1932	15	18	6.5	7.1	55	65	30	35	28	33	11	13
1933	20	25	3.8	4.7	65	80	27	33	29	26	13	16
1934	22	25	4.9	5.6	70	80	41	47	40	46	16	18
1935	32	37	6.0	7.0	55	64	54	63	66	77	15	17
1936	47	54	8.2	9.5	90	104	75	87	98	113	22	25
1937	62	67	8.8	9.5	144	156	82	89	183	198	32	35
1938	43	46	5.7	6.0	132	139	57	60	70	73	27	29
1939	61	60	6.0	5.9	130	128	58	57	86	85	33	32

Sources: See text.

TABLE 4.1-a, concluded

ESTIMATED ANNUAL CAPITAL EXPENDITURE,
SELECTED MANUFACTURING INDUSTRIES
(figures in millions of dollars)

Year	Slaughtering and Meat Packing		Tobacco Products		Manufacturing as a whole	
	Curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	8.1	7.1	12.0	10.0	-	1841
1920	21.2	17.9	16.0	14.0	-	2320
1921	11.8	10.4	7.6	6.7	-	1149
1922	15.2	15.3	7.3	7.4	-	1650
1923	15.6	15.5	7.5	7.5	-	2060
1924	13.9	13.9	7.4	7.4	-	1745
1925	15.4	15.5	8.0	8.1	-	1995
1926	24.7	25.3	10.7	10.9	-	2420
1927	25.6	26.3	10.5	10.8	-	2150
1928	26.2	26.8	10.0	10.2	-	2320
1929	19.1	19.1	10.6	10.6	-	2683
1930	15.8	16.7	9.3	9.8	-	2140
1931	13.3	14.7	7.3	8.1	-	1339
1932	7.4	8.8	3.3	3.9	-	850
1933	7.9	9.7	2.3	2.9	-	1090
1934	11.6	13.4	2.8	3.2	-	1249
1935	15.3	17.6	3.5	4.0	-	1506
1936	19.6	21.1	5.5	6.3	-	1975
1937	20.2	21.4	7.7	8.3	-	2370
1938	14.6	15.4	5.5	5.8	-	1488
1939	17.4	17.1	7.0	6.8	-	1540

Sources: See text.

TABLE 4.1-b

ESTIMATED ANNUAL CAPITAL EXPENDITURE,
SELECTED NON-MANUFACTURING INDUSTRIES
(figures in millions of dollars)

Year	Agriculture		Coal Mining		Electric Light & Power	
	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	1237	1086	74	65	260	229
1920	1376	1160	78	66	437	368
1921	556	491	42	37	276	243
1922	575	580	50	51	395	399
1923	750	747	60	60	723	720
1924	704	704	42	42	827	827
1925	800	850	45	45	766	771
1926	845	864	53	54	704	720
1927	907	934	49	50	722	743
1928	901	923	49	50	679	695
1929	992	992	54	54	774	774
1930	730	770	30	32	835	880
1931	411	455	12	13	538	595
1932	191	226	7	8	257	304
1933	234	288	8	10	113	139
1934	356	410	15	17	126	145
1935	591	675	17	18	166	192
1936	729	840	27	31	251	289
1937	919	992	29	29	400	432
1938	764	809	25	26	422	447
1939	695	685	27	27	373	367

Sources: See text.

TABLE 4.1-b, concluded

ESTIMATED ANNUAL CAPITAL EXPENDITURE, SELECTED NON-MANUFACTURING INDUSTRIES, 1919 - 1939

(figures in millions of dollars)

Year	Mining & Quarrying (excluding Petroleum and Natural Gas)		Crude Petroleum and Natural Gas		Railroads		Telephone	
	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $	curr. $	1929 $
1919	239	210	586	515	374	329	132	116
1920	307	357	676	570	630	531	203	171
1921	139	123	438	386	550	494	229	202
1922	172	174	513	516	434	438	265	269
1923	215	214	524	521	1077	1070	318	316
1924	182	182	474	474	901	901	385	385
1925	170	171	536	540	728	732	385	387
1926	201	206	634	648	883	904	404	413
1927	174	179	563	579	751	772	397	408
1928	177	181	573	586	673	688	457	468
1929	191	191	671	671	840	840	615	615
1930	109	114	516	545	865	912	612	645
1931	36	40	280	310	360	398	408	451
1932	32	27	327	383	164	194	252	299
1933	29	35	266	328	101	127	171	212
1934	94	108	385	442	218	251	185	213
1935	66	77	447	519	166	192	206	239
1936	101	116	569	657	306	353	261	301
1937	99	107	708	765	525	566	348	366
1938	95	101	551	585	238	252	318	336
1939	99	97	534	525	362	356	333	328

Sources: See text.

CHAPTER V

CAPITAL EXPENDITURE AND PRODUCTIVITY TRENDS

In the present chapter we bring together the productivity trends and the estimates of capital expenditure to investigate the differences in the effect of capital expenditure on productivity a) among the several industries, and b) within individual industries, between the period of relative prosperity (1919-1929) and the period of relative depression (1929-1939).

As we indicated in Chapter III, the year to year variations in productivity result in large measure from variations in factors less permanent than plant and equipment. For this reason trends in productivity were computed, and it is to these trends that the capital expenditure histories of industries must be compared. This means that the association must be examined between the average annual rate of increase in productivity and some measure of average annual capital expenditure. To attain maximum comparability in these averages it is essential that the disturbances introduced by fluctuations in machinery prices be kept to a minimum. The computation of

annual average capital expenditure therefore involved a reduction of current dollar figures to some common price level. To this end, the current expenditure figures were reduced to 1929 prices by deflating by an index of capital goods prices. The deflated figures appear in Tables 4.1-a and 4.1-b of Chapter IV. The price index used was that compiled by Kuznets.[1]

A mere comparison of average annual capital expenditure with average annual increases in man-hour productivity among a number of industries of different size would be meaningless. It is obvious that, other things equal, a capital expenditure of a certain size in a small industry, spread over a few employees, will tend to have a greater influence on productivity than an expenditure of the same amount spread over a larger number of workers. The most convenient way to reduce expenditure figures to comparability is to make the comparisons in terms of expenditure per employee.

Average annual capital expenditure and average annual expenditure per employee, both magnitudes measured at 1929 prices, will be found in Tables 5.1A and 5.1B, columns 2 and 3.

CORRELATION OF CAPITAL EXPENDITURE PER MAN-YEAR AND PRODUCTIVITY TRENDS

When average annual expenditure per man is plotted on a logarithmic scale, a positive correlation appears between productivity trend and average expenditure per man year. Figures 5.1 and 5.2 show the scatter and regression of, respectively, real and value productivity trends on the log of average capital expenditure per

[1] Simon Kuznets, National Product Since 1869, National Bureau of Economic Research, N.Y., 1946, table I-6, pp. 36-37

TABLE 5.1-a

AVERAGE CAPITAL EXPENDITURE, PRODUCTIVITY TREND, AND EXPENDITURE EFFECTIVENESS, SELECTED MANUFACTURING INDUSTRIES

(dollar figures in terms of 1929 prices)

Industry	Average Capital Expenditure Per Year (millions of $)	Average Capital Expenditure Per Man-year (dollars)	Productivity Trend real	Productivity Trend value	Expenditure Effectiveness real	Expenditure Effectiveness value
Automobiles & Equipment	91.6	249	3.8	3.7	.0152	.0148
Blast Furnaces, Steel Works and Rolling Mills	157.5	415	3.2	3.1	.0077	.0075
Boots and Shoes	12.3	61	2.7	2.2	.0442	.0362
Bread and Bakery Products	31.3	169	1.8	1.0	.0106	.0063
Canning and Preserving	18.5	179	3.4	4.8	.0190	.0268
Cement	6.9	249	4.0	4.1	.0161	.0165
Clay Products	11.3	155	1.1	2.0	.0071	.0129
Confectionery	3.6	61	7.3	5.3	.1195	.0870
Flour and Grain Mill Products	7.0	232	2.4	3.9	.0103	.0168
Glass Products	10.5	160	5.5	7.3	.0343	.0456
Ice Cream	10.1	530	4.7	5.5	.0089	.0104
Leather Tanning and Finishing	3.7	71	3.3	1.8	.0465	.0254
Lumber and Lumber Products	76.9	105	n.a.	2.7	n.a.	.0257
Manufactured Ice	20.3	860	4.2	4.8	.0049	.0056
Petroleum Refining	88.4	1230	6.6	5.3	.0054	.0043
Printing, Publishing and Allied Industries	86.0	273	3.0	n.a.	.0110	n.a.
Pulp, Paper, and Allied Prod.	93.6	424	3.5	3.7	.0083	.0087
Rubber Products	31.5	246	5.1	4.8	.0270	.0195
Slaughtering and Meat Packing	16.6	133	1.7	3.2	.0077	.0075
Tobacco Products	7.7	65	4.7	n.a.	.0724	n.a.
Manufacturing as a whole	1800.	191	3.4	2.8	.0178	.0147

Sources: See text

TABLE 5.1-b

AVERAGE CAPITAL EXPENDITURE, PRODUCTIVITY TREND, AND EXPENDITURE EFFECTIVENESS, SELECTED NON-MANUFACTURING INDUSTRIES.

(all dollar figures in terms of 1929 prices)

Industry	Average Capital Expenditure		Productivity Trend		Expenditure Effectiveness	
	Per Year (millions of $)	Per Man-year (dollars)	real	value	real	value
Agriculture	773	70	1.8	n.a.	.0257	n.a.
Coal Mining	37	65	1.4	n.a.	.0215	n.a.
Electric Light and Power	490	3610	5.6	n.a.	.0015	n.a.
Mining and Quarrying (excluding Petroleum and Natural Gas	139	188	2.3	n.a.	.0122	n.a.
Crude Petroleum and Natural Gas	527	3720	6.5	n.a.	.0017	n.a.
Railroads	539	365	2.4	n.a.	.0066	n.a.
Telephone	340	1253	2.7	n.a.	.0018	n.a.

Sources: See text.

man year. The coefficient of correlation shown by the sample of Figure 5.1 (25 items; Coal Mining and Manufacturing as a whole were, of course, eliminated from the correlation) is .5 and the computed regression is described by:

$$s = \underset{(.32)}{1.78} \log z - .61$$

where s is average rate of increase in productivity (trend slope) and z is average capital expenditure per man-year. The figure in parentheses is the standard error of the regression coefficient, naturally quite large.[2]

This correlation conforms both in direction and in its logarithmic nature to what we would be prone to expect. The relationship described exhibits a characteristic akin in form to (but by no means identical with) the diminishing marginal productivity of capital.[3] But the theory of production of which that concept is a part applies to the extension of capital facilities by a single firm (or, under appropriate qualification, by a single industry). Furthermore, diminishing productivity is characteristic of a schedule of prospective amounts of capital which might be employed by a firm (industry) at a particular time; it does not follow from this that successive additions

[2] With so small a sample it is not considered appropriate to compute the standard error of the correlation coefficient. Using the Fischer method ($t = \frac{r\sqrt{N-3}}{\sqrt{1-r^2}}$) we can say, however, that the probability of a correlation as large as .5 appearing in a sample of 25 items drawn from an uncorrelated population is considerably less than .01.

[3] The greatest care must be exercised in interpreting statistical studies, especially "cross-section" studies such as the above, in terms of economic theory. See the chapter following for a discussion of certain aspects of the difficulty of interpreting statistical results.

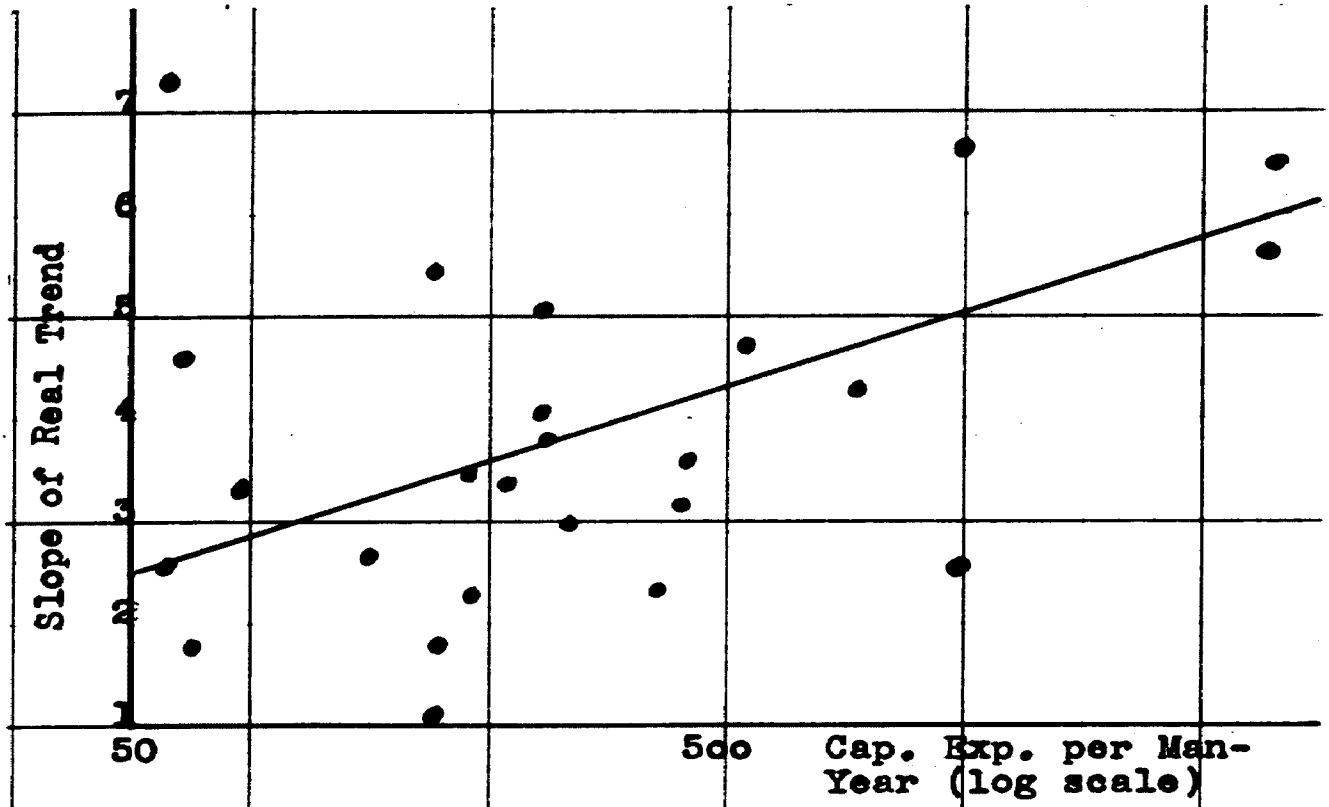


Figure 5.1 Scatter of Real Productivity Trend on Log Capital Expenditure per Man-Year.

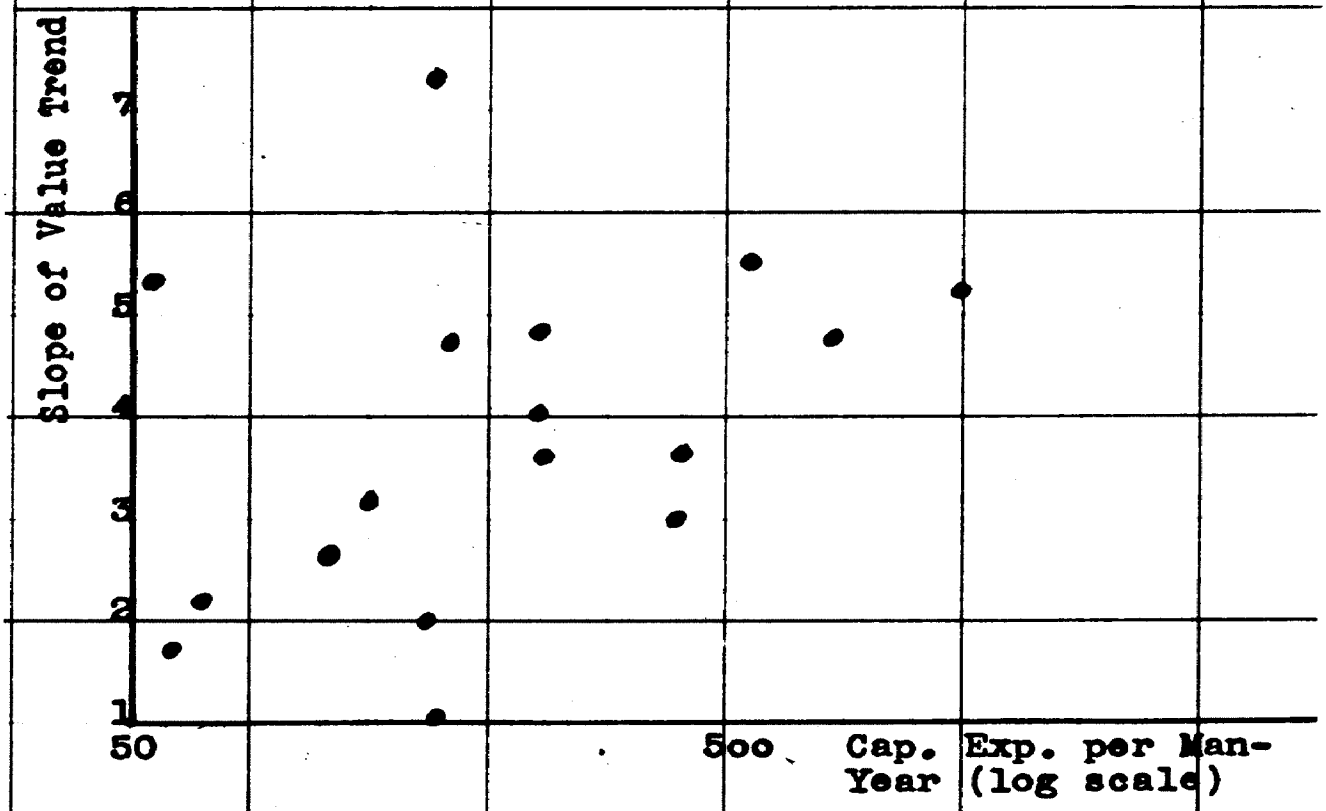


Figure 5.2 Scatter of Value Productivity Trend on Log Capital Expenditure per Man-Year.

to capital - even within a single firm - should actually exhibit a diminishing contribution to output. The entire schedule of capital productivity may shift upward or downward over time.

Thus, in spite of the fact that we might be prone to expect the sort of statistical result that we found, it does not seem likely that the real character of the observed relationship has anything to do with the theoretical grounds upon which it might have been expected.

Finally it must be noted that the greatest part of the variation in rates of increase in productivity is not accounted for by the correlation. Those industries with the lowest average capital expenditure (under one hundred dollars per man-year) show unit labor cost productivity trends ranging from the second lowest (Coal: 1.41 percent per year) to the highest exhibited by any industry (Confectionery 7.3 percent per year). The Glass and Tobacco industries show rapidly rising productivity with relatively low capital expenditure, while Telephone, with considerably larger capital expenditure exhibited a relatively low trend. This is merely to say that a correlation of .5, if it "explains" anything at all, necessarily leaves about three-fourths of the observable variation unaccounted for.[4]

To examine the variation in the association of capital expenditure with productivity, we may use a measure which, for want of a better term may be called the "effectiveness" of capital expenditure. This measure is the ratio of the annual rate of increase in productivity to the estimated average annual capital expenditure per man.

The measure of expenditure effectiveness must, however, be used

[4] I.e., the coefficient of non-determination ($= 1 - r^2$) is .75

with care. It is well to note at the outset that there will be a degree of negative correlation between the magnitude of capital expenditure and its "effectiveness". This will follow first from the logarithmic correlation given above, and secondly from the fact that there is a natural spurious negative correlation between capital expenditure and productivity trend divided by capital expenditure. These spurious relationships need not interfere with the analysis, however, if we avoid comparisons within which they occur.

Although the measure may seem, at first sight, somewhat arbitrary, there is a close formal relationship between expenditure effectiveness and the Domar "sigma".[5]

This may be shown as follows:

Let y_i, I_i, p_i, represent, respectively, the level of output, capital expenditure, and productivity in a certain industry in the i^{th} year, and let N represent the level of employment, assumed the same in each year. Using the Domar σ,

(1) $y_1 = y_o + \sigma I_o$.

If, however, we emphasize the productivity of labor, rather than the total increase in product, we write

(2) $y_o = Np_o$

(3) $y_1 = Np_1 = N(p_o + \Delta p) = y_o + N\Delta p$

where Δp is the increase in productivity accompanying the expenditure I_o .

But from expressions (1) and (3):

$\sigma I_o = N\Delta p$

[5] See Chapter I, p. 6

from which it follows that

$$(4) \qquad \sigma = \frac{\Delta P}{\frac{I_o}{N}}$$

The right side of expression (4) is, of course, the measure of capital expenditure effectiveness.

This formal analogy cannot be pressed too far without considerable alteration in the details of Domar's theory. σ was intended by Domar as a measure applicable to the rate of net investment, but "net" in the rather peculiar sense noted in Chapter I.[6] Furthermore σ was intended to measure the net increase in productive capacity after adjustment had been made for losses caused by the shift of labor away from other employments, not only from jobs in the same industry, but from others as well.

But, aside from detail, the measure of expenditure effectiveness and the Domar σ are, at bottom, the same. When, as here, productivity increases and capital expenditures are measured as trends and averages over a long period, the measure of expenditure effectiveness is essentially an index of a long run "average sigma" for the industry in question.[7]

The estimated levels of expenditure effectiveness in the selected industries are set forth in columns 4 through 7 of Tables 5.1A and 5.1B. It is clear that the effectiveness of expenditure by manufacturing industries was, on the average, substantially higher than that in non-manufacturing activity, with the exception of Agriculture,

[6] Above p. 9

[7] The fact that we have measured productivity in terms of indexes (1929 = 100) requires that the measure of expenditure effectiveness be translated before it can be used as a measure of σ. See Chap. VIII.

and Mining and Quarrying (excluding Petroleum and Natural Gas). The expenditure effectiveness in Agriculture (.0257) which showed the slowest rate of increase in productivity of all non-manufacturing industries, was substantially higher than that of the Crude Petroleum and Natural Gas industry within which the rate of increase in productivity was most rapid. The distribution of expenditure effectiveness in manufacturing lies in an extensive range between that of the Confectionery industry (.087 on a value measure of productivity; .122 on a unit labor cost measure) and that of Manufactured Ice (.0056, value measure; .0049, unit labor cost measure).

QUALITATIVE ANALYSIS OF VARIATIONS IN EFFECTIVENESS

The explanation of variation in the effectiveness of capital expenditure from industry to industry is not a simple task. A number of factors are at work in each industry, and the differences in these factors and the variety of the complex of their interrelationships from industry to industry is difficult to trace.

Ultimately a complete explanation involves a firm by firm analysis of each industry. Short of a detailed analysis, however, it is possible to identify some of the factors at work and to relate their behavior in a general way to the observed facts. The factors do not fall into neatly distinct catagories, and in any treatment considerable overlapping is unavoidable. We shall attempt to distinguish six factors, the behavior of which affects the observed magnitude of expenditure effectiveness. This treatment does not pretend to be exhaustive, but it does, I think, include the more important items.

1. "Non-capital" elements in increasing productivity. It is obvious that, other things equal, expenditure effectiveness will

appear high in industries in which productivity is rising due to technical changes which are unrelated to capital. In general it is impossible to assess the relative importance of such elements in rising productivity, but in some cases it is clearly large. In Agriculture the introduction of superior hybrid seed, changes in cropping practices, selective breeding and scientific feeding of livestock, and similar developments often involve little or no expenditure for equipment. In the manufacturing industries similar developments are found in the use of time study methods, incentive pay techniques, or the introduction of superior materials. These need not be accompanied by purchase of equipment.

A partial list of such developments in manufacturing compiled by the Bureau of Labor Statistics includes such items as more adequate and even flow of materials to manufacturing industries, improved factory lay-out, better organization of the working force (including personnel and distribution), improved working conditions and better adjustment and utilization of working time.[8]

In addition to such factors, higher productivity has been observed in connection with shorter working hours, That shortening hours should raise average productivity per man-hour is fairly obvious, but in some cases it has been further maintained that the reduction in hours has resulted in increased output per man-shift and per man-year.[9]

[8] "Influence of Non-Mechanical Factors on Productivity", Handbook of Labor Statistics, Bureau of Labor Statistics, 1936, pp. 734-735.

[9] This is said to have been true in the steel industry following the reduction of the 10 and 12 hour shift to 8 hours. (ibid. p. 735.)

Some of these factors may require capital expenditure to make them effective. A reduction of working hours may require the introduction of machinery which completes a process in shorter time, or which will handle smaller batches; improved factory lay-out may be possible only in new plants, and the full effect of new lighting, ventilation and related techniques may have to wait on new buildings. In such cases the behavior of productivity is quite properly attributed to capital expenditure.

Where, however, the purchase of new plant and equipment is unrelated to the introduction of the technique the coincidental capital expenditure and rise in productivity create an illusion of high capital expenditure effectiveness.

2. Existing Capital Intensity. For a given improvement in the efficiency of machinery, the effectiveness of capital expenditure depends upon the magnitude of the existing stock of equipment relative to the labor force. A given expenditure per man in an industry with a low concentration of capital per worker may have a much greater effect on the productivity of labor in the industry than a similar expenditure in an industry with high capital intensity.

3. Type of Technical Improvement. Equipment may be roughly divided into two types. On the one hand there are requirements for production in most industries in the form of what may be called "basic capacity" equipment. The existing amount of basic equipment sets an upper limit to industrial capacity. Steel production requires furnaces and rolling equipment; the manufacture of brick requires kilns. To take an extreme example, the production of crude petroleum requires extensive investment in deep holes in the ground.

On the other hand, most industries also employ what we may term "auxiliary" equipment, the effect of which is to reduce the amount of labor required to operate the basic capacity. Auxiliary equipment to increase the speed and reduce the labor required in handling materials, to increase the rapidity and reliability of communication, to reduce breakage and accident, and to increase control over operations, to mention only a few types, may often be adopted by firms without substantial alteration of basic equipment. Improvements in auxiliary equipment, therefore, tend to reflect themselves in rapid increases in productivity and to show a high effectiveness of capital expenditure. Changes in the efficiency of basic capacity equipment are generally slower to reflect themselves in higher productivity and exhibit a somewhat lower expenditure effectiveness.

Of course, insofar as auxiliary equipment may require reorganization of existing plant, or the use of new designs in basic equipment before it can be employed, it must wait upon the purchase of new basic capacity before it can contribute to higher productivity.

Auxiliary equipment may in some cases appear to lower, rather than raise, the productivity of labor. If the devices are primarily designed to prolong the life of basic equipment the result may be the substitution of labor for capital in the productive process. Improvements in pumping and flowing equipment tend to prolong the life of crude petroleum wells. The result of their use is, thus, that labor in petroleum operations tends to be used on older, slower flowing wells rather than with gushers where labor productivity is, of course, higher. This is simply to say that a change in the arrangement of inputs (including capital) designed to lower the

average total cost of production may very well result in higher, rather than lower, unit labor costs.[10]

4. Expansion of Capacity. If the acquisition of new equipment implies the abandonment of less efficient older machinery the effect of capital expenditure will appear higher than if the new equipment is merely added to the stock of machinery in use. Furthermore if auxiliary equipment is available which can be applied to old basic plant, capital expenditure will, in general, appear lower if the industry is expanding. If the capital expenditure were concentrated on auxiliary equipment, a certain effect on productivity would be observed. The additional outlay for basic capacity obviously "spreads" this productivity increase over a larger volume of capital expenditure.

It is notable in this connection that several of the industries studied which were characterized by very high average capital expenditure per man were industries in which large expansions of employment were experienced. By 1929 employment in Telephone, Crude Petroleum and Natural Gas, and Electric Light and Power had increased by amounts of from fifty to one hundred fifty percent over the 1919 level. Although productivity rose rapidly in these occupations they were characterized by extraordinarily high rates of average capital expenditure per man.

Beyond these outstanding exceptions, however, the data do not reveal any substantial correlation between expansion of employment and expenditure effectiveness. A linear multiple regression of

[10] This is, of course, a special application of the distinction between capital using and capital saving innovations, of which much has been made by followers of the "stagnationist" school.

change in productivity between 1919 and 1929 (measured in percentage points) on the log of average capital expenditure per man over the eleven years, and the percentage increase in employment (for a twenty-two industry sample) did show a negative relationship between productivity and increase in employment, but the correlation index was nearly zero. Despite exceptional cases to the contrary, therefore, there is conclusive evidence that the expansion of employment did not play a role in the determination of expenditure effectiveness commensurate with that of other factors.

5. Exhaustion of Resources. In some industries, characteristically mineral extraction, the process of production involves the exhaustion of a natural resource. In some mining operations, e.g. anthracite coal, the depletion of highly productive deposits proceeds so slowly relative to the available material that any decrease in productivity on this account is of little significance over short periods of time. But where available mineral beds or pools are rapidly exhausted, the productivity of labor tends to fall over time if not offset by technological innovation, or by larger and larger capital expenditures. The productivity of labor in the crude petroleum industry, for example is in part maintained at the cost of deeper wells, under-sea drilling, and longer lines of transportation. On the other hand, technical innovation may transform erstwhile useless deposits of material into usable, or even "high grade" deposits. Examples of this are given by Barger and Schurr for a number of mineral industries.[11]

[11] Harold Barger and Sam H. Schurr, The Mining Industries, 1899-1939, National Bureau of Economic Research, New York, 1944, Especially pp. 250-254.

Where these technical innovations require new equipment, capital expenditure is clearly of high effectiveness, but the measure of effectiveness falls short of an indication of the true state of affairs since it does not take into account the lowering of productivity which would otherwise occur.

6. Rate of Technical Improvement. Finally, and most obviously, the effectiveness of capital expenditure varies between industries with the rate of improvement in equipment which is specific to the respective products. In some industries the design of equipment and general productive technique remain unaltered over long periods. In others technique may change completely within the space of a few years.

CAPITAL EXPENDITURE IN PROSPERITY AND DEPRESSION.

One interesting general conclusion to be drawn from the above analysis is that we have reason to expect that a period of depression should be marked by a sharp rise in the observed effectiveness of capital expenditure: a) To the extent that "non-capital" improvements in productivity arise at a fairly steady rate the smaller expenditures characteristic of depression years will be associated with an apparent higher effectiveness. b) Furthermore we have good reason to believe that the "whiplash" incentive of depression losses may increase the rate of such innovations and the eagerness of business to adopt them. c) The proportion of expenditure representing auxiliary equipment becomes a larger part of the total, and d) purchases of basic capacity are associated with the replacement of old equipment rather than the expansion of capacity.

This conclusion is subject to a partial test. If it is true it should follow that a comparison of the behavior of each industry during

the period 1919-1929 with its own behavior during 1929-1939 should exhibit an upward shift of expenditure effectiveness during the latter period. Productivity trends are not suited to this comparison, since the very low productivity characteristic of many industries during the early thirties gives a strong upward bias to 1929-1939 trends. The increase in productivity during each period was, therefore, measured as the difference between the indexes for the first year and the last year of the period. This difference was then divided by average expenditure per man-year over the period to obtain a measure of the effectiveness of capital expenditure.

The results of the comparison are summarized in Table 5.2. It is clear from inspection of the table that in most of the industries studied a definite upward shift in expenditure effectiveness occurred during the depression period. Of the total of twenty-three industries for which data in both periods were available, nineteen exhibited a higher measure of expenditure effectiveness during the period 1929-1939. In three of the remaining four industries the downward shift was substantial. In Agriculture, however, the decline was small, expenditure effectiveness falling from .14 to .12. It is noteworthy, however, that the importance of industries showing a decline in expenditure effectiveness was sufficiently great to result in a downward shift in the effectiveness of capital expenditure considered for manufacturing as a whole.

While the statistical evidence bears out the expectation that the effectiveness of capital expenditure should appear higher in the depression period than during the boom, independent evidence is required to show the extent to which the several factors participated in the result.

There is no doubt that the number of machines of auxiliary and special purpose nature became a larger proportion of the total number of machines in use during the thirties. A study of identical plants in the Twin Cities area of Minnesota in 1931 and 1936 revealed increases in the percentage of such machines in all but one of the industries studied.[12] This shift was accompanied by a marked increase in the extent to which operations were made automatic.[13]

Intensive studies of individual industries give similar results. In their study of the Brick industry, Van Tassel and Bluestone reported that "after ... 1925, the objective of capital expenditures began to change gradually until, under the conditions of sharply curtailed production, the emphasis after 1929 definitely shifted to the purchase of machines and auxiliary devices designed primarily to reduce production costs or to improve quality. The objective has been to accomplish these results without major capital investments. The replacement of major production units has been kept at a minimum and, where they are essential, the choice of replacement has been dictated by considerations of cost reduction...rather than increased output."[14]

Weintraub and Kaplan, in summarizing the findings of the National Research Project have indicated that the increased use of auxiliary

[12] Charles A. Koepke and S. Theodore Woal, Changes in Machinery and Job Requirements in Minnesota Manufacturing, 1931-1936, W.P.A. National Research Project, Report no. L-6, July 1939, pp. 9-11.

[13] ibid. pp. 11-14.

[14] Alfred J. Van Tassel and David Bluestone, Mechanization in the Brick Industry, W.P.A. National Research Project report no. M-2 June, 1939. pp. 65-66.

TABLE 5.2

AVERAGE CAPITAL EXPENDITURE, INCREASE IN PRODUCTIVITY, AND CAPITAL EXPENDITURE EFFECTIVENESS, SELECTED INDUSTRIES, 1919 - 1929 AND 1929 - 1939

Industry	Capital Expenditure per Man-year		Increase in Productivity		Expenditure Effectiveness	
	1919 to 1929	1929 to 1939	1919 to 1929	1929 to 1939	1919 to 1929	1929 to 1939
Automobiles & Equip.	290	215	57	19	.19	.09
Blast Furn. Steel Works & Rolling Mill	400	425	49	37	.12	.09
Boots and Shoes	62	60	17	29	.27	.48
Canning	225	150	22	45	.10	.30
Cement	266	224	40	39	.15	.16
Clay Products	176	118	20	14	.11	.12
Flour and Grain Mill Products	258	213	36	15	.14	.07
Glass Products	156	172	41	82	.26	.47
Ice Cream	513	534	27	83	.05	.15
Leather	91	49	29	52	.32	1.06
Petroleum Refining	1190	1320	51	93	.04	.07
Printing & Publishing	325	196	43	29	.13	.14
Pulp and Paper	472	397	40	34	.08	.09
Slaughtering and Meat Packing	139	130	26	26	.19	.20
Tobacco Products	68	51	68	62	1.00	1.21
All Manufactures	259	233	42	32	.16	.14
Agriculture	74	59	11	7	.14	.12
Coal Mining	81	48	16	15*	.20	.31
Electric Light and Power	4770	2760	17	92	.003	.03
Mining & Quarrying (ex. Pet. & Nat. Gas)	227	167	26	28	.11	.17
Petroleum and Natural Gas	3740	3780	46	60*	.012	.016
Railroads	385	344	20	31	.05	.09
Telephone	1680	1251	9	45	.005	.03

*estimated

Sources: See text.

equipment was generally characteristic of industry during the depression period.[15]

While the increased expenditure for auxiliary equipment may be characteristic of most industrial activity, it is also true that the depression behavior of capital expenditure effectiveness depends upon characteristics peculiar to individual industries. In the Electric Light and Power industry, for example, productivity is clearly related to the extent of capacity utilization. Estimates prepared by Jacob M. Gould on the use of generating capacity show that although total kilowatt capacity nearly tripled between 1919 and 1929 it merely kept pace with increasing demand, and actual output during the period amounted to only about a third of capacity.[16] The decline in the rate of capacity expansion during the thirties resulted in forty percent utilization of generating capacity by 1940.[17] Thus it may be that the observed change in expenditure effectiveness in Electric Light and Power is related in only a small degree to the purchase of additional equipment.

Yet the fact that capital expenditure played some role in the increase in productivity is indicated by the fact that while roughly a quarter of total generating capacity was in hydro-electric plant throughout the period 1920-1929, by 1939 water power generation

[15] David Weintraub and Irving Kaplan, Summary of Findings to Date, March 1938, W.P.A. National Research Project, p.28. This volume also contains an interesting discussion of the types of auxiliary equipment which were being introduced during the period 1919-1938 (pp. 13-21).

[16] Jacob M. Gould, Output and Productivity in the Electric and Gas Utilities, 1899-1942, National Bureau of Economic Research, New York, 1946, pp. 63-69.

[17] ibid. Table 19, p. 65.

amounted to nearly a third of total capacity.[18] Thus it is clear that capital expenditure during the depression was devoted in greater proportion than formerly toward hydro-electric plant.[19]

An interesting special factor may be noted which affects the effectiveness of capital expenditure in Crude Petroleum and Natural Gas operations. During periods of high prices a portion of capital expenditure represents outlays for exploratory drilling. During periods of slack demand, activity is more closely restricted to the development of proven reserves. The proportion of unproductive (dry) holes is naturally substantially higher in "wild cat" exploration than in developmental drilling. Thus a greater part of capital outlay results in producing wells during depressed periods. During the period 1927-1929 over thirty percent of all holes completed were dry. The corresponding proportion for the three years 1933-1935 was slightly less than twenty percent, with a low of seventeen percent in 1934.[20]

Incidentally, one of the important contributions to expenditure effectiveness in the Crude Petroleum and Natural Gas industry has been the development of auxiliary techniques for exploration which, by reducing the amount of expenditure resulting in dry holes, increases the effectiveness of outlays for drilling.[21]

[18] ibid. Table 20, p.68

[19] To the extent that hydro-electric capacity was built by governmental units, of course, neither the expenditures nor the effect on productivity are included in the indexes used in the present study.

[20] Figures for drilling activity are published by the American Petroleum Institute in Petroleum Facts and Figures, and include Natural Gas operations.

[21] Barger and Schurr, op.cit. 200-202.

It is necessary to note in conclusion that considerable ambiguity attaches to the significance of the indicated shifts in capital expenditure effectiveness, since they may, in some cases, be largely spurious. The year to year behavior of productivity depends upon the operation of short-run factors, and the cyclical operation of these factors may give rise to an apparent shift in expenditure effectiveness, upward or downward.

It may be argued, for example, that a boom period is accompanied by purchase of new equipment to expand output. With a cut-back in volume, less efficient, older equipment may be kept idle, less efficient plants shut down and a general rise in productivity result. Any capital expenditure would thus be associated with a rapidly rising productivity and its effectiveness would appear to be high. On the other hand, it may be argued that in many industries, plants operate most efficiently at the levels of output characteristic of a boom period. Gains from the idleness of inefficient plant may be more than off-set by the fall in productivity due to curtailed operation of the remaining equipment. Capital expenditures made under these circumstances will appear to have low effectiveness.

A complete analysis of the relationship of capital expenditure to productivity must, therefore involve an examination of the short-run behavior of productivity. To that study the second part of our analysis is devoted.

SUMMARY

In Part I we have measured the average rate of increase in productivity for a number of industries and found wide variation among the trends. Estimates of capital expenditure have been presented and in

the present chapter we have attempted to analyse the relationship between average capital expenditure per man-year and the rate of increase in productivity.

Although there is a positive correlation between the rate of increase in productivity and the log of average capital expenditure per man-year, most of the variation in productivity trends must be explained on other grounds. In order to analyse the variation in the association of capital expenditure with the rate of increase in productivity, the measure of capital expenditure effectiveness was defined as the ratio of annual average increase in productivity to average capital expenditure per man-year.

Differences in capital expenditure effectiveness were attributed to six factors: 1)"non-capital" elements involved in increasing productivity, 2)existing capital intensity, 3) type of technical improvement taking place, 4) rate of expansion in capacity, 5) rate of exhaustion of natural resources,and 6) the rate of technical improvement in equipment. Little can be said as to the relative roles played by these factors in producing the observed variations in expenditure effectiveness between industries, but within individual industries it appeared that capital expenditure had, in most cases, a higher effectiveness during the period 1929-1939 than during the period 1919-1929. Independent data indicates that these upward shifts in effectiveness of capital expenditure were, in general, associated with increases in the proportion of capital expenditure devoted to the purchase of auxiliary equipment, although other factors were important within particular industries.

PART II

CAPITAL EXPENDITURE AND CHANGES IN THE INPUT-OUTPUT FUNCTION.

CHAPTER VI

THE MATHEMATICAL THEORY OF AGGREGATIVE INPUT-OUTPUT FUNCTIONS

Capital expenditure affects the central tendency of labor productivity; the observed productivity of labor fluctuates about this central tendency in response to short-run forces. While the trend of productivity, taken over a sufficiently long time, may approximate the behavior of this central tendency, a thorough understanding of the role of capital expenditure requires more than this.

At any particular time the total output of an industry depends somehow on the total amount of labor input. The type and amount of capital equipment with which labor co-operates in its activity determines some of the parameters of this relationship. For some industries the functional relationship existing between labor input and output of product at various times can be statistically determined, and the shifts in this function, properly interpreted, will shed considerable light on the relationship between capital expenditure and productivity. As a necessary part of that interpretation, the present chapter is devoted to the mathematical theory of input-output

functions.

THE PRODUCTION FUNCTIONS OF THE FIRM

Economic theory has always taken as a starting point the assumption of a technical relationship between inputs and outputs. That is, the assumption that amounts of various outputs can be had only by using appropriate amounts of the proper inputs. This technical relationship is usually referred to as a production function.

At the outset two characteristics of the production function must be made clear. First, the relationship does not contain "market-place" variables such as prices, degree of competition, demand, income, etc. Thus the production function may be thought of as a physical law, although in the strictest sense this degree of abstraction from market variables is not possible. Inanimate inputs combined in prescribed ways will produce desired outputs without regard to cost, but the result of employing a human laborer often depends, in part, upon the rate at which he is paid, the relationship between his pay and his performance, and the differential between his wage and that of other laborers.[1] In most modern industrial activity, however, variation in output from this cause is of secondary significance.

Secondly it should be noted that the production function describes the necessary ways in which outputs are related to inputs. It is always possible to hire additional inputs without getting additional

[1] It should, perhaps, be pointed out that this qualification of the nature of the production function does not alter in any way the enterpriser's problem of deciding on the most advantageous arrangement of inputs and outputs. If the wage rate is itself associated with variations in output he is capable of adjusting to the variation in a way designed to maximize profit.

output. For example, labor can be added to the payroll and given nothing to do. The production function, therefore, describes the minimum necessary amounts of inputs which will produce a specified set of outputs. In other words the production function relates possible sets of outputs to specified sets of inputs so that, if a particular set of outputs is specified, no input may be reduced in amount without either increasing another input or failing to produce the specified output. Conversely, if a set of inputs is specified, no output may be increased in amount without either reducing the amount of another output or increasing the amount of some inputs.

This treatment of the nature of the production function is not novel. The latter restriction of the function leads directly to the iso-product contour analysis of modern theory.

A generalized production function may be described mathematically in the implicit form

(1) $$\phi(x_1,\ldots,x_n,y_1,\ldots,y_m) = 0$$

where x_i is the amount of the ith input and y_i the amount of the ith kind of output. But if we fasten our attention upon a plant with a single product[2] the function may be written

(2) $$y = \theta(x_1,\ldots,x_n)$$

It follows that if we are interested in output variations associated with the variations in the input of one particular factor service, the remaining inputs held constant, we may write

(3) $$y = f(x)$$

In order to make explicit the relationship between productivity

[2] Or a set of products which can be meaningfully aggregated into a single product index.

and the production function we may divide both sides of (3) by the amount of factor service used, to obtain:

(4) $\frac{y}{x} = g(x)$.

Formulation (4) indicates that the average output per unit of input x, holding technique and all other factors constant,[3] depends upon the amount of input x employed. The productive technique and the amounts of co-operating factors in use enter into the form of the production function (3) and hence into the "productivity" function (4).

The relationship between the production function and the productivity function enables us to draw further on established economic theory and distinguish two types of change in productivity which may occur. "Short run" changes are those which follow from changes in the amount of factor input, given the form of the productivity function. "Long run" changes are those which, for given rates of input, arise because of changes in the form of the function due to changes in technique or alteration in the rate of input of other factors. Thus viewed the productivity function is seen to be a schedule relating average output per unit of input to the amount of input. Alterations in average productivity occur along this schedule in association with variations in input. On the other hand, for a given level of input, productivity may change in association with a general shift in the productivity schedule itself.

[3] If other inputs are strictly complementary to x, the unit of input should be so defined as to include the complementary items. E.g. if more materials must be used with more workers, the unit of labor must include both worker and material, since hiring one without the other would violate the conditions set forth in the definition of the function. It was for this reason that the definition was couched in terms of "sets" of inputs and outputs.

Once the relationship between the production function and the productivity function are established we may continue our analysis in terms of the former, more familiar concept. To the short run and long run changes in productivity there correspond changes in output. Outputs vary along a schedule as inputs vary, but for given inputs, output may change as the schedule itself shifts.

THE PRODUCTION FUNCTION FOR AN INDUSTRY

If we imagine an establishment in which a fixed and rigidly defined capital facility and productive technique are used, and if we abstract from the accidental variation due to worker morale, weather and similar conditions, we are picturing a situation in which the sole determinant of output is the number of man-hours of labor employed. Such an establishment would have a well defined production function. But actual production generally involves the operation of a number of such facilities, each with its own production function. Yet statistical analysis which attempted to deal with the individual inputs and outputs of each of the several firms would soon become an unwieldy instrument. Fruitful analysis requires that we formulate some procedure whereby we may reach general conclusions with regard to the aggregative variables involved: the employment and the output of the industry as a whole.

In formulating such a procedure considerable care must be exercised. The limitations as to what can be said in terms of aggregative variables are not, it seems to me, intuitively obvious - at least not until they are pointed out. Failure to examine critically the precise nature of statements of general aggregative relationships may lead to results of questionable validity and even of doubtful

meaning. To cite a specific case in point, it may be noted that the conclusions reached by Professor Paul Douglas and his associates as to the production function for large economic groups[4] have been subject to attack from the point of view of the statistical method employed.[5] But more important for the present issue are the questions which have been raised with regard to the actual meaning of the function, as a function, entirely aside from its statistical content.[6]

The general problem of aggregative relationships is best dealt with in mathematical terms, and we shall first treat it in that way. The results of the general analysis may then be interpreted in geometrical form for the special case of two firms. The rationale of the mathematical formulation was suggested by Lawrence R. Klein in his article "Macroeconomics and the Theory of Rational Behavior."[7]

[4] Paul H. Douglas, Theory of Wages, MacMillan, N.Y. 1934, see esp. Part II, pp. 113-225

[5] Horst Mendershausen, "On the Significance of Professor Douglas' Production Function," Econometrica, Vol. 6, no. 2, April 1938, pp. 143-153

[6] See, for example, Melvin W. Reder, "An alternative Interpretation of the Cobb-Douglas Production Function," Econometrica, Vol. 11, No. 3-4, July-October, 1943, pp. 259-264.
M. Bronfenbrenner, "Production Functions: Cobb-Douglas Interfirm, Intrafirm," Econometrica, Vol. 12, no. 1, Jan. 1944, pp. 35-44.

[7] Lawrence R. Klein, "Macroeconomics and the Theory of Rational Behavior," Cowles Commission Papers, New Series No. 14, Cowles Commission, Chicago, 1946.
cf. also:
Shou Shan Pu, "A Note on Macroeconomics," Econometrica, Vol. 14, no. 4, October, 1946, pp. 299-302.

Let us assume an industry of n firms each of which is characterized by a well defined production function.

For the i^{th} firm,

(2.1) $y_i = f_i(x_i) \qquad (i = 1,\ldots,n)$

where y_i is the output and x_i the employment of the i^{th} firm. Rather than work with the variables of the individual firms we define aggregative transformations such that

(2.2) $X = F(x_1,..,x_n)$

(2.3) $Y = G(y_1,..,y_n)$

where X is "aggregate" input and Y is "aggregate" output. For the moment we shall leave unspecified the exact nature of these transformations. There are, of course, an infinity of possibilities. To mention only a few of the more common forms, the transformations might be weighted, or unweighted arithmetic, or geometric means or totals; they might involve some sort of root-mean-square operation or some combination of these or any other possibilities.

Most of the possible transformations have no economic significance at all. Among the remainder, the economic implications of many are obscure. We must bear in mind, then, that whatever aggregation transformation is ultimately selected, it must be required to have economic meaning. In particular we may require, at the least, that the transformation give some weight greater than zero to the output and input of each firm in the industry. That is, we may require that

(2.4) $$\frac{\partial F}{\partial x_i} > 0 \qquad (i = 1,\ldots,n)$$
$$\frac{\partial G}{\partial y_i} > 0$$

for all values of x_i and y_i that lie within meaningful region. This implies that an increase in output by one firm, other firms' outputs held constant, must always increase the aggregate output of the industry, and similarly for inputs.[8]

Having transformed the individual firm variables into industrial aggregates we then wish to formulate an aggregative production function for the industry:

(2.5) $$Y = \phi(X)$$

Since restriction on X and Y are imposed by the production functions of the individual firms, the aggregate production function (2.5) need not in general exist. Whether the function exists or not depends upon the selection of the aggregative transformations (2.2) and (2.3). The mathematical requirement for the existence of (2.5) is that the n x 2 matrix

$$\begin{bmatrix} \frac{\partial F}{\partial x_i} & \frac{\partial G}{\partial y_i} \; \frac{\partial f_i}{\partial x_i} \end{bmatrix}$$

be of rank 1. That is, that every second order determinant in the matrix must vanish identically and at least one element of the matrix must not vanish. The latter requirement is satisfied by the restrictions imposed on the transformations by (2.4). For the former requirement to be satisfied it is necessary that

(2.6) $$\frac{\frac{\partial G}{\partial y_i}\frac{\partial f_i}{\partial x_i}}{\frac{\partial G}{\partial y_j}\frac{\partial f_j}{\partial x_j}} \equiv \frac{\frac{\partial F}{\partial x_i}}{\frac{\partial F}{\partial x_j}} \qquad (i,j = 1,\ldots,n)$$

[8] There are other methods of dealing on an aggregative level which avoid the use, at least in any specific form, of the sort of transformations defined above. The Marshallian concept of the "typical" firm is one such. In the present instance we are working toward the statistical analysis of behavior andhence become involved in the transformation problem.

Thus if we can, by appropriate selection of aggregative transformations, make expression (2.6) obtain, the aggregate production function will exist.

The conditions (2.6) may be interpreted as follows:

If we select any aggregate output

$$Y = G(y_1,..,y_n) = K$$

the marginal rate of substitution between the output of the i^{th} and the j^{th} firms is given by

$$M = -\frac{\frac{\partial G}{\partial y_i}}{\frac{\partial G}{\partial y_j}}$$

That is, when the output of one firm is increased while that of another is decreased by small amounts, the operation to leave aggregate output unaffected, the ratio between the changes is M.[9] Similarly the marginal rate of substitution between the inputs of two firms, the aggregate input held constant is given by

$$m = -\frac{\frac{\partial F}{\partial x_i}}{\frac{\partial F}{\partial x_j}}$$

The term $\frac{\partial f_i}{\partial x_i}$ is, of course, the marginal productivity of input to the i^{th} firm.

The conditions (2.6) may then be stated as the requirement that for every pair of firms, the ratio of the marginal rate of substitution between their outputs (as just defined) to the marginal rate of

[9] Note that this is a marginal rate of substitution between individual firm outputs when aggregate output is given. The customary marginal rate of substitution involves substitution between outputs (inputs) of a single firm when aggregate input (output) is given.

substitution between their inputs must for all possible combinations of outputs and inputs be equal to the ratio between the marginal productivities of inputs in the respective firms.

If we can find economically meaningful definitions of aggregative output and input which satisfy these conditions, a production function for the industry will exist. If we cannot find such definitions, the function cannot possibly exist. The difficulty lies with the form of the production functions of the individual firms. If these have the cubic form generally attributed to them in text books, the aggregative transformations that will satisfy the conditions set forth will have no economic meaning.

Consider the result obtained from the use of linear aggregative transformations - the type most frequently used in statistical work. If we define

$$X = F(x_1,\ldots,x_n) \equiv \sum a_i x_i \qquad \text{and}$$

$$Y = G(y_1,\ldots,y_n) \equiv \sum b_i y_i$$

where a_i and b_i are constant weights applied to the input and output of the i^{th} firm then

$$\frac{\partial F}{\partial x_i} = a_i \qquad (i = 1,\ldots,n)$$

$$\frac{\partial G}{\partial y_i} = b_i$$

The conditions (2.6) then require

$$\frac{b_i \frac{\partial f_i}{\partial x_i}}{b_j \frac{\partial f_j}{\partial x_j}} \equiv \frac{a_i}{a_j} \qquad (i,j=1,\ldots,n)$$

i.e. that

$$\frac{\partial f_i}{\partial x_i} \equiv \frac{a_i b_j}{a_j b_i} \frac{\partial f_j}{\partial x_j} \qquad (i,j=1,\ldots,n)$$

That is, that the marginal productivity of x in the i^{th} firm must be some constant proportion of the marginal productivity of x in the j^{th} firm, without regard to how much x is employed or y produced by either firm. The existence of diminishing returns for only one firm would be sufficient to make the condition impossible of fulfillment. If, in particular our transformations are unweighted aggregates, it would be required that the marginal productivity of x in all firms be identically equal.

There is one case in which the linear transformation is applicable. If the firms in the industry are characterized by constant marginal cost within the region of observable economic behavior we are free to define our transformations as linear aggregates provided only that we select weights such that the ratio between the weights assigned to the input and output of each firm is equal to the marginal productivity of the input in the firm. If we wish to treat the outputs of all firms as homogeneous, then, we may do so by weighting their inputs by the (constant) marginal productivities associated with them in the several operations. On the other hand, we may treat the inputs as homogeneous and weight the outputs by the reciprocal of marginal productivity. Our transformations would then become

$$X = \sum x_i$$

$$Y = \sum \frac{1}{a_i} y_i$$

where a_i is the marginal productivity of x in the i^{th} firm.

The possibility of defining aggregates in this fashion does not guarantee that they will prove useful in analysis. In general we should not expect such definitions to have significance since the number of industries to which they may be applied is limited by the

requirement of constant marginal cost. Yet a closer inspection reveals that this treatment corresponds exactly to the reasoning employed in developing a measure of total output in Chapter II.[10] For $1/a_i$ is the marginal unit man-hour requirement of production in the i^{th} firm. In Chapter II the assumption of constant average unit labor cost (hence constant marginal cost equal to the average) was implicitly made. At that point we were concerned with the measurement of aggregates of heterogeneous products. The analysis just completed follows exactly the same logic, but involves the treatment of outputs of firms with differing (constant) marginal productivities as heterogeneous products which must be weighted into a meaningful aggregate.

From the argument above it is a simple step to a general transformation which will always serve the end of assuring us of the existence of a production function in the aggregate variables. Inputs may be treated as homogeneous, provided outputs are weighted by the reciprocal of marginal productivity. If marginal productivity is a constant we obtain a constant weighted aggregate which has economic significance and usefulness. If, however, the marginal productivities of the firms vary with variations in input, the weights in the aggregate must be varied to correspond to the correct magnitude of marginal productivity in each situation. This fact removes any usefulness that the aggregation procedure may have.

Even in the most favorable case- that of constant marginal productivity in the short run - the technique is subject to a severe shortcoming. We are concerned with studying the changes in the production function. If the marginal productivity of labor in a

[10] See pp. 28-9 above.

firm changes due to long run shifts in the firm's production function, we are required to redefine the aggregative transformation to correspond to the new situation. With each succeeding economic development a new measure of aggregate output must be employed; no comparison is possible between behavior before and after the change, and the remaining usefulness in the aggregating technique employed is obliterated.

THE INDUSTRY INPUT-OUTPUT FUNCTION

Fortunately there is a more fruitful path to follow. To make clear what is involved it is useful to recapitulate the foregoing argument in geometrical form. To keep within the limitations of the flat page the treatment will be limited to an industry of only two firms. The extension to larger numbers will be apparent once the argument is presented.

Let us define the total amount of labor X used by the industry as

$$X = x_1 + x_2$$

In figure 6.1, x_1, the amount of labor employed by firm 1, is plotted on the horizontal axis, x_2, employment in firm 2, on the vertical. Any aggregate amount of employment may be divided between the firms in ways described by a right line corresponding to the aggregate. Thus each point on line X in figure 6.1 corresponds to a way of dividing the total employment X between the two firms. Points on X', similarly, represent possible divisions of a larger amount of labor.

Within each firm a particular output corresponds to each input,

hence, to each point on line X there corresponds an output for each firm. In figure 6.2 is plotted the locus of combinations of firm outputs which correspond to the various points on curve X. To each point a on line X there corresponds a point a' on curve Y in figure 6.2. Similarly points such as b and b' correspond on X' and Y'. Now to require that there exist a functional relationship between X and Y implies that we can somehow define a relationship of the form

$$Y = G(y_1, y_2)$$

which will describe the curve Y in figure 6.2;

$$Y' = G(y_1, y_2)$$

describes the curve Y', etc. Each aggregate employment X (hence each curve X in figure 6.1) must describe a curve Y in figure 6.2, to which curve a number can be assigned by knowing any one point located on it. This number is then the measure of aggregate output. Conversely, if we know the number of any curve Y we can immediately trace out all the possible combinations of outputs to which that number might refer. The aggregative production function, then becomes simply a method of relating particular X curves (i.e. particular aggregate inputs) to the number of the corresponding Y curve (i.e. the resulting aggregate output).

When this principle is understood, it can be seen why the existence of an aggregative production function depends upon ratios between marginals. Once a satisfactory numbering system for Y has been set up we can set up an infinity of systems simply by multiplying all the numbers by any constant: hence the initial requirement in terms of ratios. But in addition we may add or

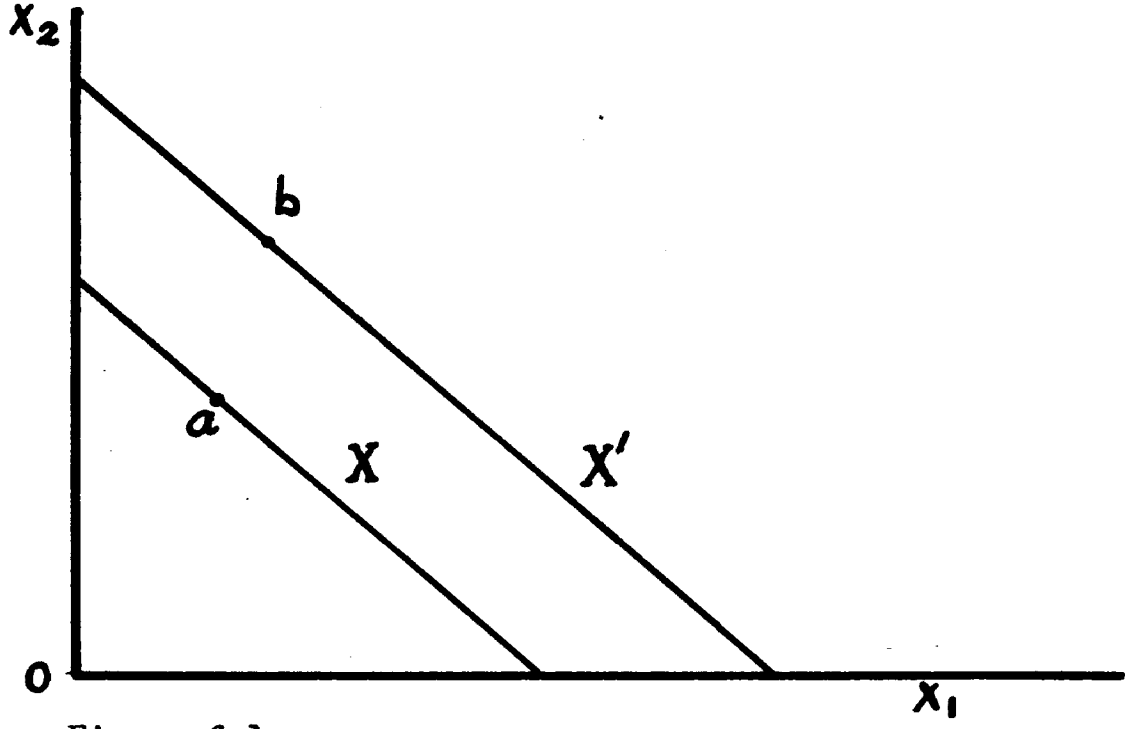


Figure 6.1
Possible Distributions of Given Aggregate Inputs

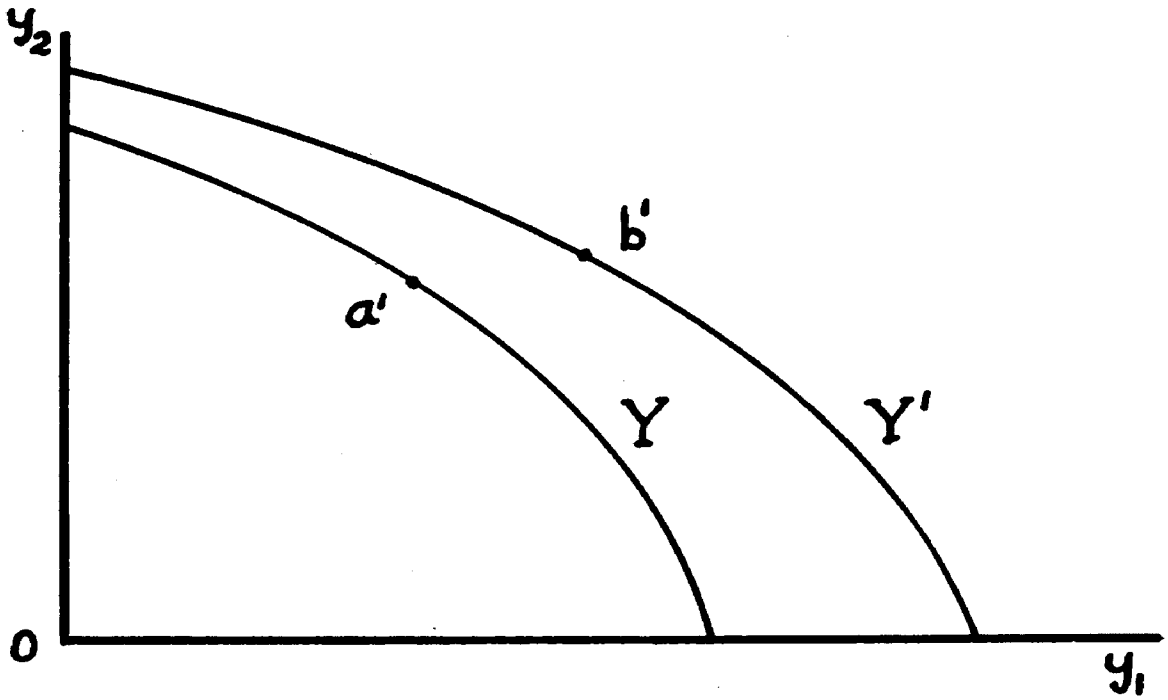


Figure 6.2
Possible Distributions of Outputs with Given Aggregate Inputs

subtract any constant and still have a usable system, hence the dependence upon marginals.

We have seen however, that production functions which depend upon this aggregating technique are, in general, useless, unless we are particularly well favored by the nature of the production functions of the individual firms. Let us, therefore, try a different attack. Suppose we retain our definition of aggregate input and simply define aggregate output in some meaningful way. For simplicity we may assume homogeneity in the product and define

$$Y = y_1 + y_2$$

Having defined both aggregate output and aggregate input transformations we have no assurance that there is a functional relationship between the two, and in general there will not be one. That is to say, many possible aggregate outputs will correspond to a given level of aggregate input. But the extent of these possibilities is limited. This may be illustrated geometrically by figure 6.3. The curve Y in figure 6.3 is carried over from figure 6.2, and represents the possible distribution of outputs between the two firms with a given aggregate input X. Each right line in figure 6.3 represents the locus of possible ways individual outputs could be distributed between the two firms to obtain a given aggregate output. Each right line, then, represents a particular level of total output, the level rising as the lines shift upward to the right.

Each point of the curve Y lies on some right line, corresponding to some level of aggregate output. Thus the point a' corresponds to an aggregate level of output I, while a'' indicates a level of

output II. To any given level of aggregate input X, there corresponds an infinite number of points such as a', and hence an infinite number of possible aggregate outputs. But it must be noted that the magnitudes of these aggregate outputs must fall in a limited range. Given aggregate input X, and hence curve Y, the minimum possible output would be III, resulting from the concentration of all employment in the least efficient firm.[11] On the other hand, the aggregate output cannot exceed II, corresponding to the distribution of inputs a''. Aggregate output, for the given input X, may have any value between these limits; the particular value which actually arises depends upon the way in which inputs (hence outputs) happen to be divided between the firms.

Now although a production function, free of market variables may not exist, there may still be a determinate relationship between aggregate input and aggregate output. The existence of such an input-output function depends upon whether there is an additional law whereby a given aggregate output (or input) is always distributed between the firms in a particular way. If, for example, the "normal" operation of the market imposes a behavior pattern on firms which pattern will, of itself, "see to it" that the conditions (2.6) above are fulfilled, then so long as the "normal" operation of the market is not interfered with, an aggregate input-output function will exist.

This is the case in pure competition. The behavior of the firms in maximizing profit with given input and output prices

[11] Firm 1, could of course produce less than this amount of output, but only by deliberately wasting labor.

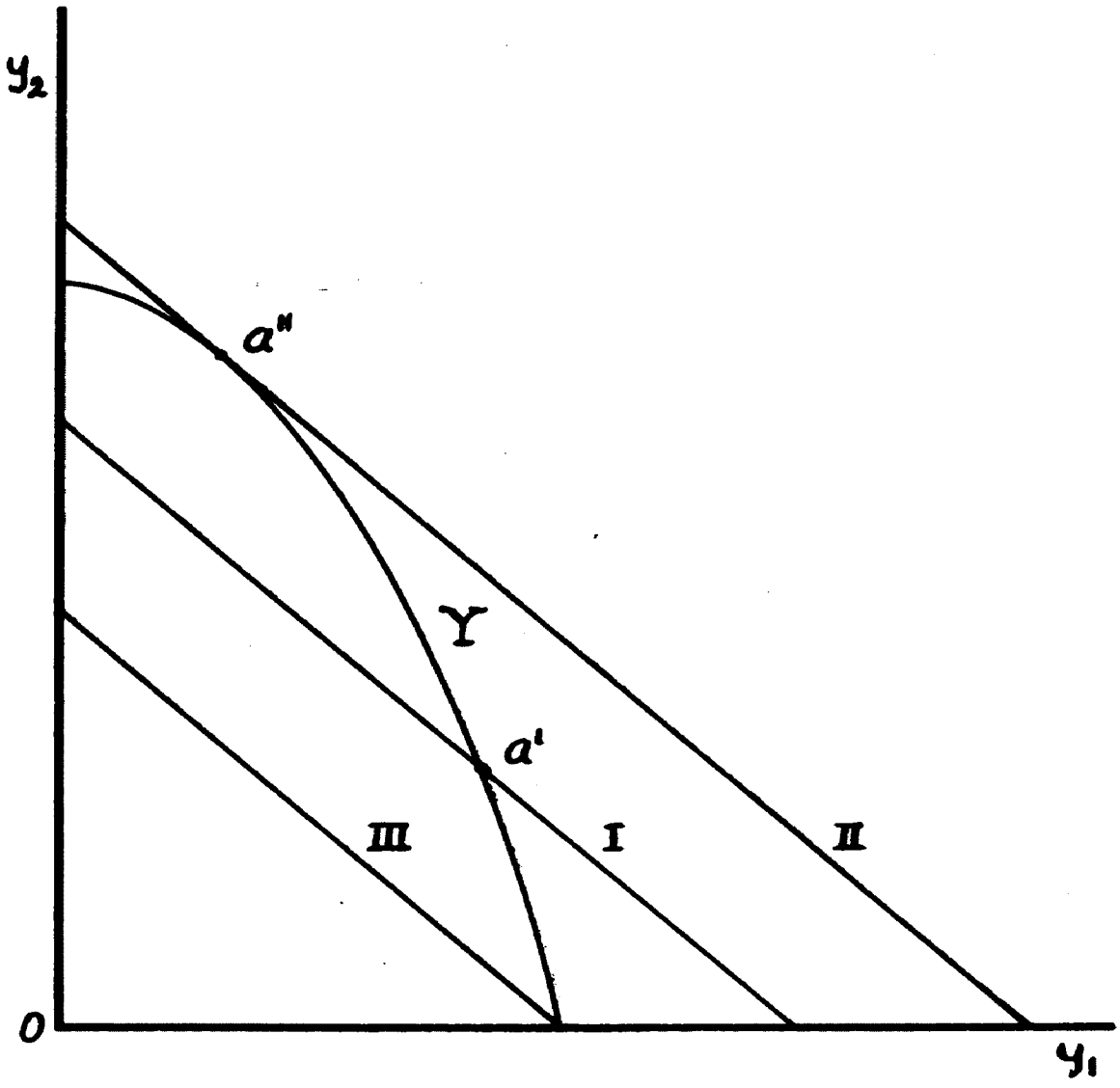


Figure 6.3
Possible Aggregate Outputs with Given Aggregate Input

results in the maximum aggregate output from any given aggregate input. The point a" of figure 6.3, i.e. the point at which the curve Y is tangent to a right line, indicates the nature of the behavior pattern imposed.

The purely competitive results can also be seen in terms of the conditions (2.6). According to our definitions of aggregate input and output,

$$\frac{\partial F}{\partial x_i} \equiv 1 \qquad (i = 1,\ldots,n)$$

$$\frac{\partial G}{\partial y_i} \equiv 1$$

hence the conditions (2.6) become merely

$$(2.7) \qquad \frac{\partial f_i}{\partial x_i} \equiv \frac{\partial f_j}{\partial x_j} \qquad (i,j = 1,\ldots,n)$$

that is, that the marginal productivity of input must be the same for all firms in the industry. This condition fails as a strict identity, since, unless the marginal productivities are all equal and constant, we can imagine distributions of outputs between firms in a way in which it would not be fulfilled. But the equality expressed in (2.7) is precisely the condition brought about by the profit maximizing behavior of competitors.[12]

It is clear from the above why a statistically determined aggregative input-output relationship is not a production function in the true sense of the term. It is only a relationship which obtains within the "normal" operation of the market. If we disturb the market operation, e.g. by rationing outputs among the firms, the aggregate output resulting from a given aggregate input will

[12] Profits are maximized under pure competition when price equals marginal cost. If p is price and w the wage rate, this implies

$$\frac{\partial f_i}{\partial x_i} = \frac{w}{p} \qquad (i = 1,\ldots,n)$$

not, in general conform with the market-determined relationship.

INPUT-OUTPUT FUNCTIONS IN IMPERFECT COMPETITION

Pure competition is not characteristic of the industries met with in actual practice. To what extent must the analysis be modified to be useful in investigations of actual conditions? The relationship between aggregate input X and the distribution of possible outputs (indicated by curves Y in figures 6.2 and 6.3) is technically given and cannot be altered by market phenomena. But the law of market behavior by which the particular points on the Y curve are selected cannot, in general, be formulated. To consider the worst possible case: because of its "circular" nature the problem of adjustment under oligopoly has thus far failed to yield a determinate analytical solution.

But our inability to express a formal law does not mean that a law does not exist. Since market behavior is not a matter of random activity, let us postulate the existence of a law of market behavior. If such a law has no basis in theoretical analysis, it appears to have substantial basis in fact.

Such a law of market behavior may be formally stated as the proposition that the proportion of total output sold by each firm in an industry is some function of the total sales of the industry. Figure 6.4 illustrates the operation of the law. Line OS in the figure indicates the proportion between the shares of the respective firms which apply to each level of output. If the industry is operating with aggregate input X (and hence aggregate output indicated by some point on Y, OS indicates that the point of operation will be a. Firm 1 will produce output y_1', firm 2 will produce y_2'.

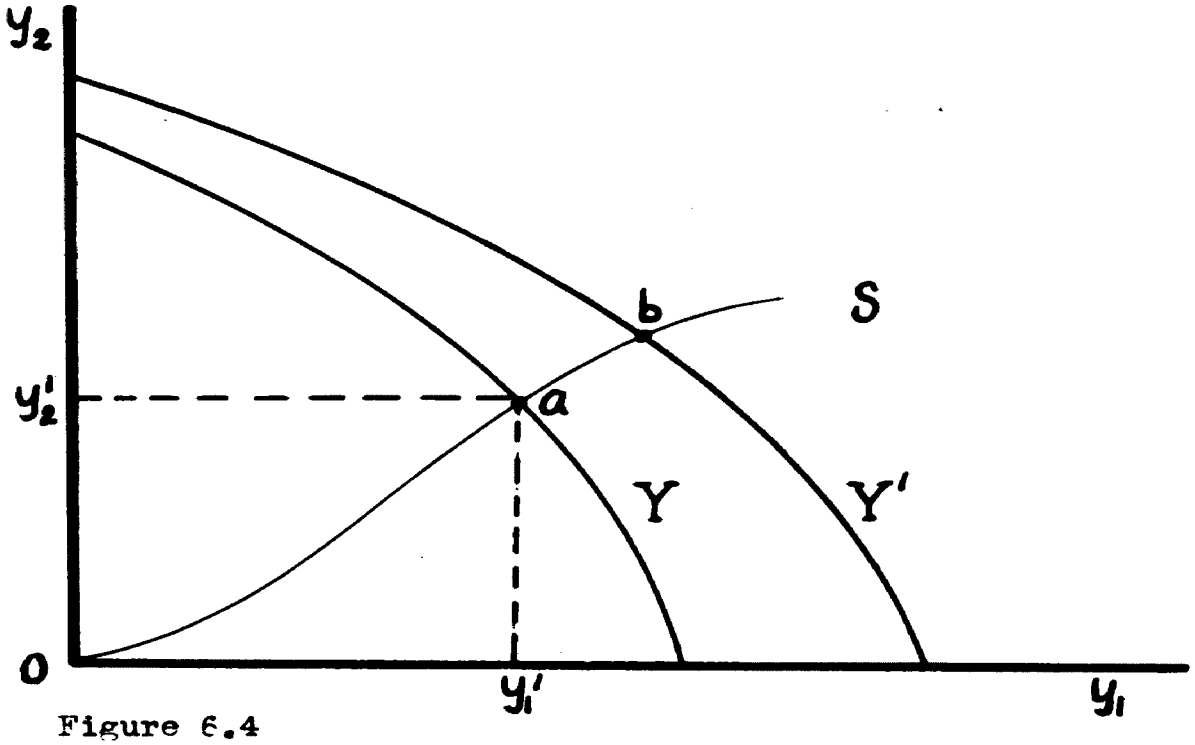


Figure 6.4
Illustration of a Market Law

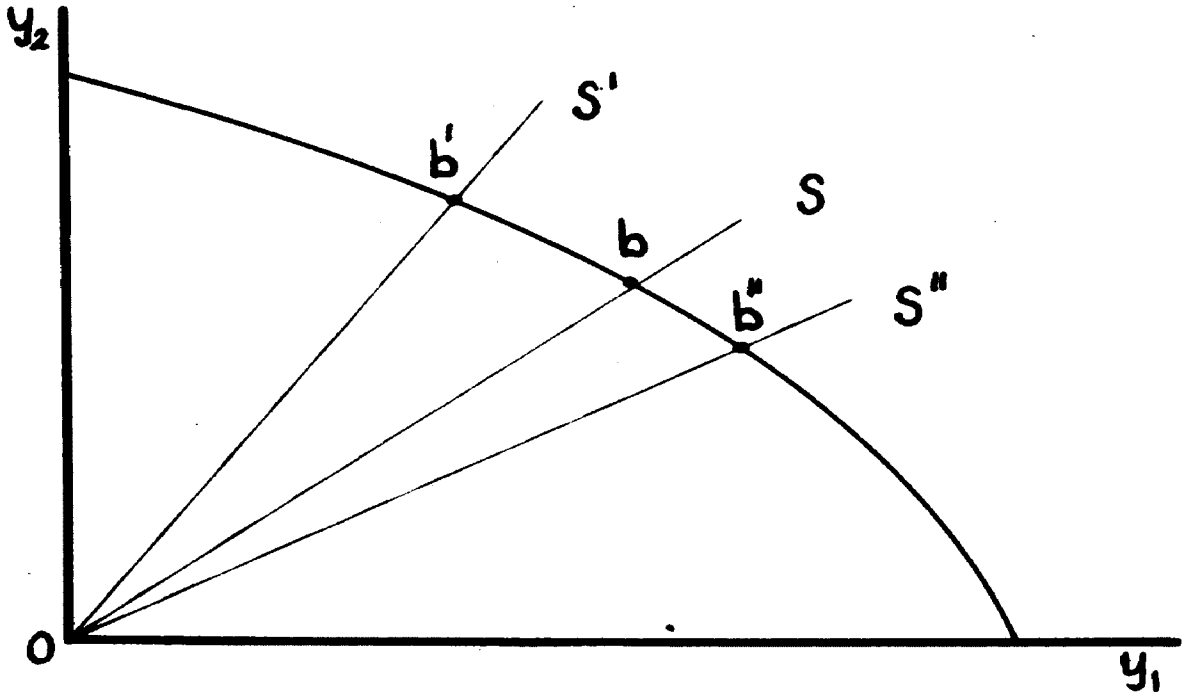


Figure 6.5
Illustration of a Stochastic Market Law

If the industry were operating at some larger output Y', the shares of the two firms are determined at point b.

If, in particular, each firm has a constant share of the total output at all levels, the curve OS becomes a straight line. There is, however, no reason to suppose that OS is even a continuous function. A certain firm may have zero output until the market calls forth a level of production above some threshold value, the firm receiving some determined market share of marginal output beyond this point.

Although for convenience we speak of the postulated market law as if it were exactly determinate in a mathematical sense, we must recognize that this is not likely. If a market behavior law exists it is a stochastic law. There is not a single line OS, but rather a pencil of lines, to each member of which is attached a certain probability. The line OS may represent the mathematically expected (i.e., the most probable) market sharing at various levels of output but the realized shares may vary over a wide range. In figure 6.4 the expected distribution of outputs between the firms corresponds to point b. In actual operations, however, the distribution of output may correspond to b' or b" or some other point with the probability attached to OS', OS", or some other line. If we extend our treatment to an industry of n firms, figure 6.4 becomes an n-dimensional hyperspace. The curves Y become hypersurfaces, and the pencil OS becomes a probability pencil, the rays of which assign probabilities to each of the points on each of the hypersurfaces.

Since the aggregative input-output function is, then, a

probability function, the statistical problem may be stated as one of determining the expected value of aggregate output, given aggregate input, by the use of data arising from actual operations.

RELATIONSHIPS BETWEEN FIRM PRODUCTION FUNCTIONS AND THE AGGREGATIVE INPUT-OUTPUT FUNCTION.

When the economist speaks of marginal productivity, he refers to a result in output which would occur if additional units of input service were employed. It may be that the additional service is not employed precisely because its marginal productivity would make its employment incompatible with maximum profit. Marginal relations derived from an aggregative input-output function, on the other hand, are relationships between actual employment of additional units and actual resulting outputs when the operation of market forces somehow justifies the increased employment.

True marginal productivity, derived from the production functions of individual firms, and marginal relations derived from aggregative input-output functions are, however, related, in that the aggregative function is a locus of points of actual operations by individual firms. At each point of actual operation, marginal productivity within each firm has a certain value and these values are related to the aggregative marginal relationships in the following way: The industry of n firms is characterized by firm production functions:

$$y_i = f_i(x_i) \qquad (i = 1,\ldots,n)$$

For the present, however, it is easier to work with the inverses of the production functions (i.e. the real labor cost functions).

$$(3.1) \quad x_i = f_i^{-1}(y_i)$$

Each of these functions represents the total labor, x_i required by the i^{th} firm to produce a given output y_i. The market law for the industry may be given by

(3.2) $y_i = S_i(Y)$.

That is, y_i, the share of the i^{th} firm in total output depends upon the total output, Y, of the industry.

(3.3) $x_i = f_i^{-1}[S_i(Y)]$

or, since $X = \sum x_i$

(3.4) $X = \sum f_i^{-1}[S_i(Y)]$

Equation(3.4)is an expression of the unexciting proposition that the total real labor cost to the industry involved in the production of any aggregate output Y is the sum of the real labor costs of all the individual firms. The virtue of this formulation of the obvious lies in the marginal aggregative expression that derives from it.

Aggregate "marginal labor cost" becomes:

(3.5) $\frac{dX}{dY} = \sum \frac{df_i^{-1}}{dy_i} \frac{dS_i}{dY}$

Whence aggregative "marginal productivity" is

(3.6) $\frac{dY}{dX} = \frac{1}{\sum \frac{df_i^{-1}}{dy_i} \frac{dS_i}{dY}}$

But $\frac{df_i^{-1}}{dy_i} = \frac{1}{\frac{df_i}{dx_i}}$

and

$\sum \frac{dS_i}{dY} = 1$

(i.e. the marginal aggregative output is equal to the sum of marginal firm outputs). Thus the expression for aggregate "marginal productivity" becomes:

$$(3.7)\qquad \frac{dY}{dX} = \frac{\sum \frac{dS_i}{dY}}{\sum \frac{1}{\frac{df_i}{dx_i}} \frac{dS_i}{dY}}$$

That is, the aggregate "marginal productivity" of labor in the industry is the harmonic mean of marginal productivities of labor in each of the individual firms, weighted by the marginal contribution of the firm to aggregate output.

The importance of this conclusion for the interpretation of observed shifts in statistically determined aggregative input-output relationships is, I think, obvious. For a given law of market behavior, the aggregate "marginal productivity" of labor can shift only if there is a change in marginal productivity within the firms in the industry. But for given marginal productivity schedules for the individual firms, aggregate "marginal productivity" will shift if the marginal shares contributed by the several firms are redistributed.

The diagramatic analysis presented in Figure 6.6 will aid in clarifying the relationship between firm production functions, the market law, and the aggregative input-output function. In Figure 6.6 the curves concave to the origin represent, as before, possible distributions of output between two firms, given a certain aggregate input: For convenience let us assume that the successive curves correspond to successive additions to aggregate input of equal amounts. (I.e. the curves represent the possibilities presented by equal marginal aggregate inputs.) The right lines in Figure 6.6, as in the figures above, represent the ways output may be shared between the firms, if a given aggregate output is to be obtained. These may be drawn to show equal marginal aggregate outputs. If now the market

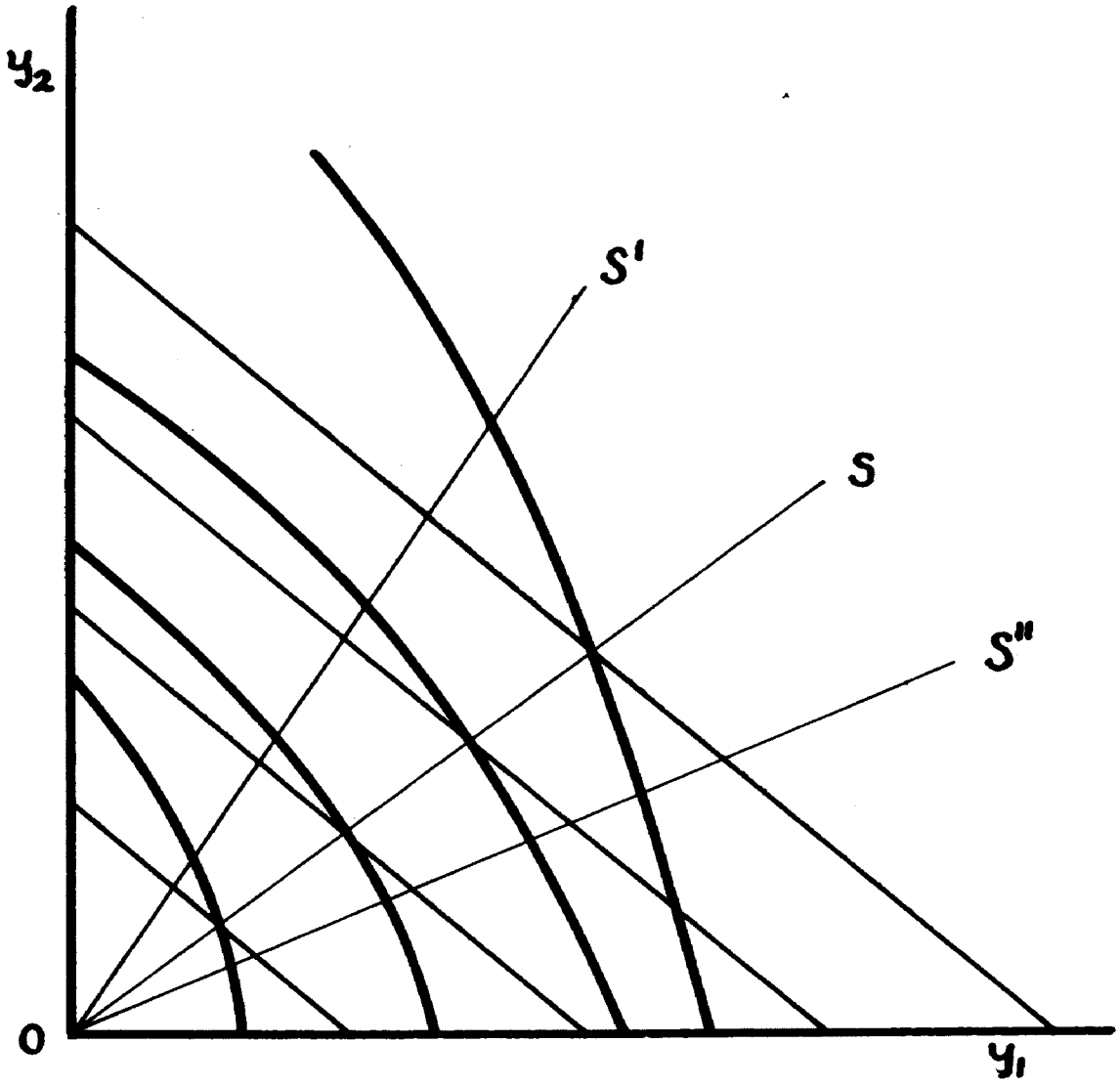


Figure 6.6
Illustration of the Relationship between the Law of Market Behavior and the Input-Output Function

function passes through the intersections of successive curves and lines (market law OS) the equal marginal inputs will produce equal marginal outputs and the aggregative input-output function will exhibit constant "marginal productivity." On the other hand, a market law such as OS' will exhibit increasing "marginal productivity" while OS" will exhibit decreasing "marginal productivity."

SUMMARY

Our investigations into the nature of aggregative input-output relations lead us to these conclusions. At any particular time there exists an aggregative input-output relationship. Changes in the average productivity of labor occur, in the short run, in response to changes in the rate of production along this schedule. Long run changes in average productivity occur through shifts in the input-output schedule itself.

The aggregative input-output schedule or function is not a true production function. It depends, rather, upon the production functions of the individual firms and upon the way in which these firms share in the output market. Thus the aggregative function may shift as a result of either changes in technique or changes in market shares.

It should not be concluded, however, that the market law is independent of productive technique. We saw how, in the case of pure competition, market shares are determined by the profit maximizing behavior of the individual firms when prices are beyond their control. A change in productive technique will, then, change the shares which various firms obtain of total output. In other cases the market law is indeterminate under ecomonic analysis, but it does not follow that, whatever the law may be, it is independent of productivity within

the participating firms.

It is certainly true that substantial shifts in the market law can occur in the absence of technical changes. A change in market aggressiveness, or the use of a more efficient method of aggression - new advertising techniques, product differentiation, etc. - may shift the competitive position of the firm. Changes in the composition of the market - mergers, failures, new firms - certainly change market positions, as would any change in the basis of understandings as to "acceptable" behavior, collusive agreements, or, on the other side, anti-trust action.

Even in some of these cases, however, it may be argued that shifts in the market law have their basis in technique. A change in the terms of a restrictive agreement may be forced by a firm whose new efficiency and capacity give it a stronger bargaining position. Increased market aggressiveness may be generated by increased ability to profit from aggression, etc.

Furthermore, to the extent that firms struggle to maintain competitive position, it is probably true that most activity designed to alter that position in favor of one firm by other than technical changes is to a considerable extent off-set by counter measures taken by rivals.

On the other hand, there is nothing about technical innovation by a firm which will, in and of itself, reduce the position of that firm in the market, while there is a strong probability that it will tend to increase it. I feel, therefore, that we can assert with considerable confidence that the two effects, changing technique and changing market function, go together and that changes in the

aggregative input-output function are (although sometimes indirectly) primarily determined by changes in technique rather than of market maneuvering independent of technical change.[13] This is simply to say that, ~~spectacular~~ spectacular exceptions to the contrary notwithstanding, the industries in the economy behave more like institutions for the achievement of welfare than like playthings for cartels.

[13] Cf. however the discussion of certain aspects of this problem in connection with the analysis of the behavior of the input-output function for the Cement industry given below, pp. 132-136

CHAPTER VII

STATISTICAL INPUT-OUTPUT FUNCTIONS AND CAPITAL EXPENDITURE

In the present chapter we shall determine statistical input-output functions for four selected industries. By relating the observable shifts in the functions of these industries to the type of capital expenditure which was being made we may obtain a greater insight into the determinants of capital expenditure effectiveness.

Formal economic theory is a study of the behavior of certain systems of relationships; supply and demand schedules, consumption functions, production functions, utility schedules and so forth. While the economist is satisfied that these relationships have meaning in real existence, it does not follow that all or any of them can be mathematically determined by analysis of past data. Historical data arise from a succession of economic states which result from the particular way the underlying relationships combine. That is, the list of values of variables making up the economic vector describing an economic state are the equilibrium values determined by the underlying relationships. The fact that the particular values taken on by

the economic vector in one period differ from those of another does not, in general, yield any information as to the nature of the individual relationships producing the result, for the relationships are, themselves, changing. Indeed were it not for the fact that they did change, the economy would merely repeat its behavior, i.e., exist in a stationary state.

To cite a familiar example, the price-quantity vector which describes the state of a market at a particular time depends upon the inter-action of a particular demand and a particular supply. Unless one of these schedules change the market state is unaltered. But when the price-quantity state of the market does change, a comparison of the two historical positions will not, alone, yield any information as to, let us say, the elasticity of demand. The new state may have been produced by a shift in the demand itself. The economist knows something about demand schedules and their elasticity, but he did not learn much of it from the statistical analysis of historical data.

Under fortunate circumstances, nevertheless, functional relationships between economic variables can be determined. If we knew that the demand schedule in the example above had not shifted, the various price-quantity combinations produced by supply variations would map out this demand. Even if the demand were subject to small variations, the statistical "demand schedule," while it would not correspond to any actual demand which had existed during the period of observation, would approximate to a useful degree the nature of the "real" demand.

The implications of this discussion for the statistical analysis of aggregative input-output relationships is obvious. The functions we are looking for are subject to shift over time. Indeed, this shift

is what principally interests us. Yet we can determine the function only insofar as it fails to shift. To meet these requirements the following technique was employed. Using monthly data, scatter diagrams of output on employment were plotted. Upon inspection of the scatters, those successive years were grouped together within which the distribution of points did not appear to exhibit significant differences in regression. Linear regressions were fitted to each of the groups of points thus selected. The observed correlations were unusually high (most of them better than .9) indicating that the variation in output within each period was almost entirely explained by variation in labor input and that there was a minimum shift in the relationship. But a comparison of the regressions for different periods reveals statistically significant shifts in the parameters of the aggregative input-output function.

INTERPRETATION OF THE STATISTICAL FUNCTION

The statistically determined regression equation has, in each case, the general form:

$$Y = aX + b$$

The parameter a occasions no difficulty in interpretation; it is the "marginal productivity" of labor in the industry, discussed in the previous chapter. Although, as we have seen this is not a true marginal productivity in the sense in which it is commonly employed in economic theory, no confusion will result from our dropping the awkward quotation marks.

The interpretation of the parameter b is not so straightforward. If man-hours of employment were zero, output would be equal to b.

If b is not zero, however, this does not make sense. For in that case either some positive output is obtained with no labor at all ($b > 0$), or the output in the absence of labor input is negative ($b < 0$). Yet shifts in the magnitude of b indicate that the average productivity of labor has somehow changed. If in particular b increases with no change in a it indicates that the change in average productivity at given levels of output has not been accompanied by any change in marginal productivity.

A suitable interpretation of the parameter may be found by setting output to zero. We then find

$X = -b/a$.

That is, the aggregative input-output function behaves as if this compound parameter were a magnitude of "fixed" or "overhead" labor, necessary to, but not sufficient for productive operations. (See Figure 7.1).

It is emphasized that the function behaves as if this were an "overhead" constant. Actually the mathematical aggregative input-output function is not defined in the neighborhood of zero aggregate output. There is some threshold value (e.g., an output sufficient to cover the variable costs of the most efficient firm) which must be attained if any output is to be forthcoming at all. Furthermore, although the statistical function may approximate the expected mathematical function over the observable range, we have no information as to the nature of the function below this range. Figure 7.2 indicates a possible relationship between the behavior of the "true" function and the apparent behavior of the statistical function.

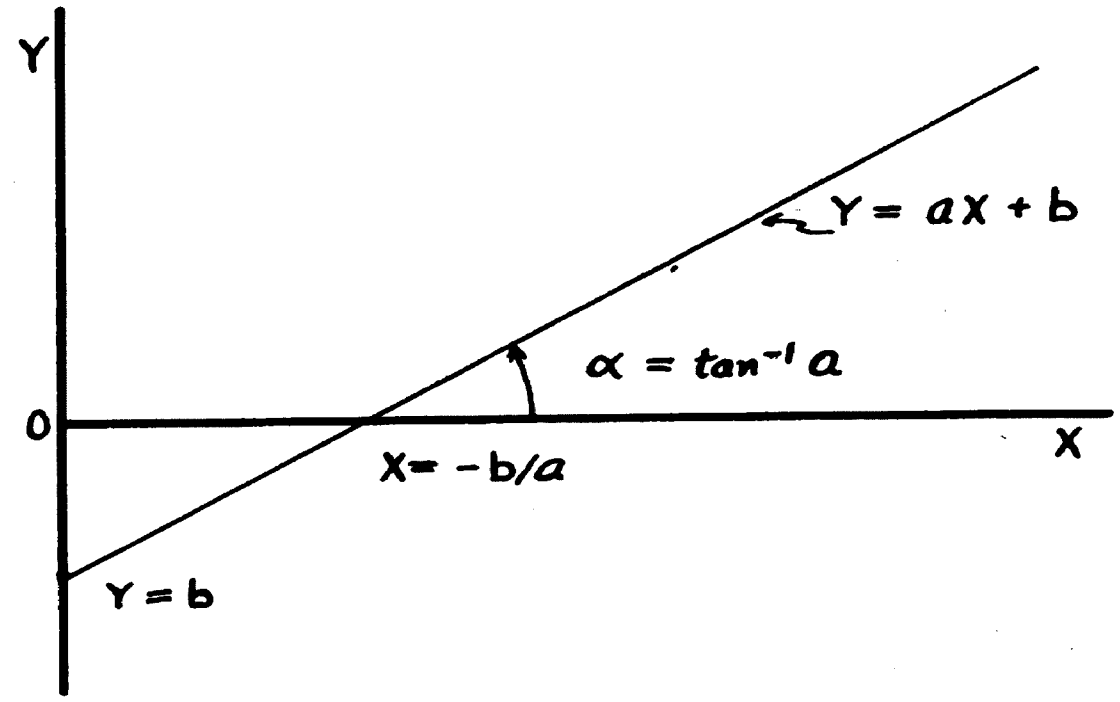


Figure 7.1
A Lineer Input-Output Function and its Parameters

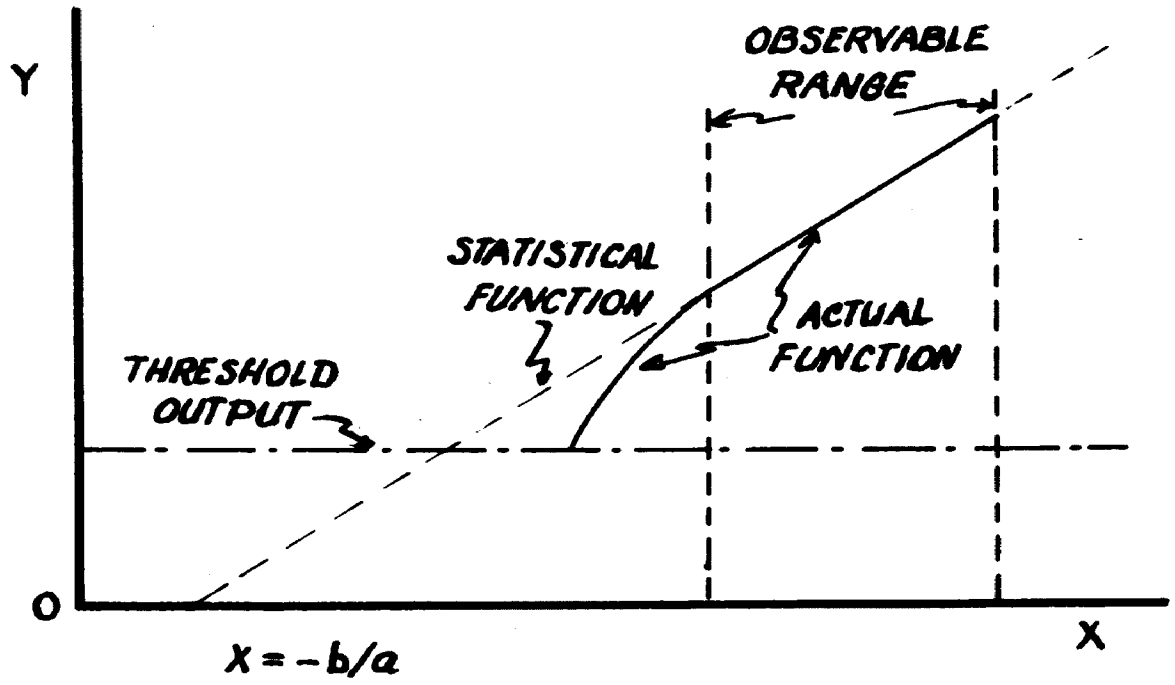


Figure 7.2
Illustration of a Possible Relationship between an Observed Input-Output Function and the "Actual" Function

SUMMARY OF RESULTS FOR FOUR INDUSTRIES

Four industries were selected for analysis; 1) Blast Furnaces, 2) Steel Works and Rolling Mills, 3) Rubber Tires and Tubes, and 4) Cement. The selection of these industries was made on the basis of the availability of reliable monthly data and upon the magnitude of the variations observable in the monthly series.[1] Only one of the industries thus selected (Cement) conforms to the grouping employed in the earlier part of the study. The definition of each of the industries is identical with that used by the Census of Manufactures.

Blast Furnaces

As an index of output, a series for monthly pig-iron production was employed.[2] To obtain an index of man-hours of labor input, monthly employment figures were multiplied by a monthly series for average weeklyhours. Employment data for census years were obtained from the Biennial Census of Manufactures; intercensal years were not employed in the analysis. For 1921-1933 the National Industrial Conference Board series for average weekly hours in Iron and Steel Manufacturing was used as a measure of hours in Blast Furnace operations.[3]

[1] If the variation in the series is small, no useful statistical results can be obtained since the variation in output due to employment will probably be of nearly the same magnitude as that induced by random factors. Thus the Shoe industry, for which excellent monthly series are available, shows a correlation between input and output (24 months) of only .4.

[2] Survey of Current Business, Vol. 20 no. 9, October 1940, p. 14.

[3] M. Ada Beney, Wages, Hours and Employment in the United States 1914-1936, National Industrial Conference Board Study No. 229, 1936

For 1935-1939, the Bureau of Labor Statistics series for Blast Furnaces, Steel Works and Rolling Mills was used for this purpose.

By reference to the scatter of points (see Figure 7.3) three periods were selected for analysis: I, 1921-1923 (24 months), II, 1929-1933 (36 months) and III, 1937-1939 (24 months). The results are summarized in Table 7.1. In addition to the magnitudes of the parameter, -b/a, the standard error of a, σ_a, and the adjusted coefficient of correlation r, are included in the table.

Table 7.1

Parameters of Statistically Determined Input-Output Function $Y = aX + b$, Blast Furnaces, Three Periods.

Period	Number of Months	a	σ_a	b	-b/a	r
I.: 1921-23	24	1.948	.002	-.40	.205	.99
II: 1929-31-33	36	2.880	.083	-.00	.00	.98
III: 1937-39	24	4.119	.2	-.08	.019	.94

It is evident from the behavior of the function that the improvement in productivity in blast furnace operations involved a rise in marginal productivity of labor. No substantial change occurred in the magnitude of overhead, but it was, in any case, a small part of total employment.

It would appear from an examination of the behavior of the input-output function that the trend toward higher productivity had been fairly uniform since 1919. The nature of the underlying causes, however, did, in fact, change after 1933 as a more detailed analysis

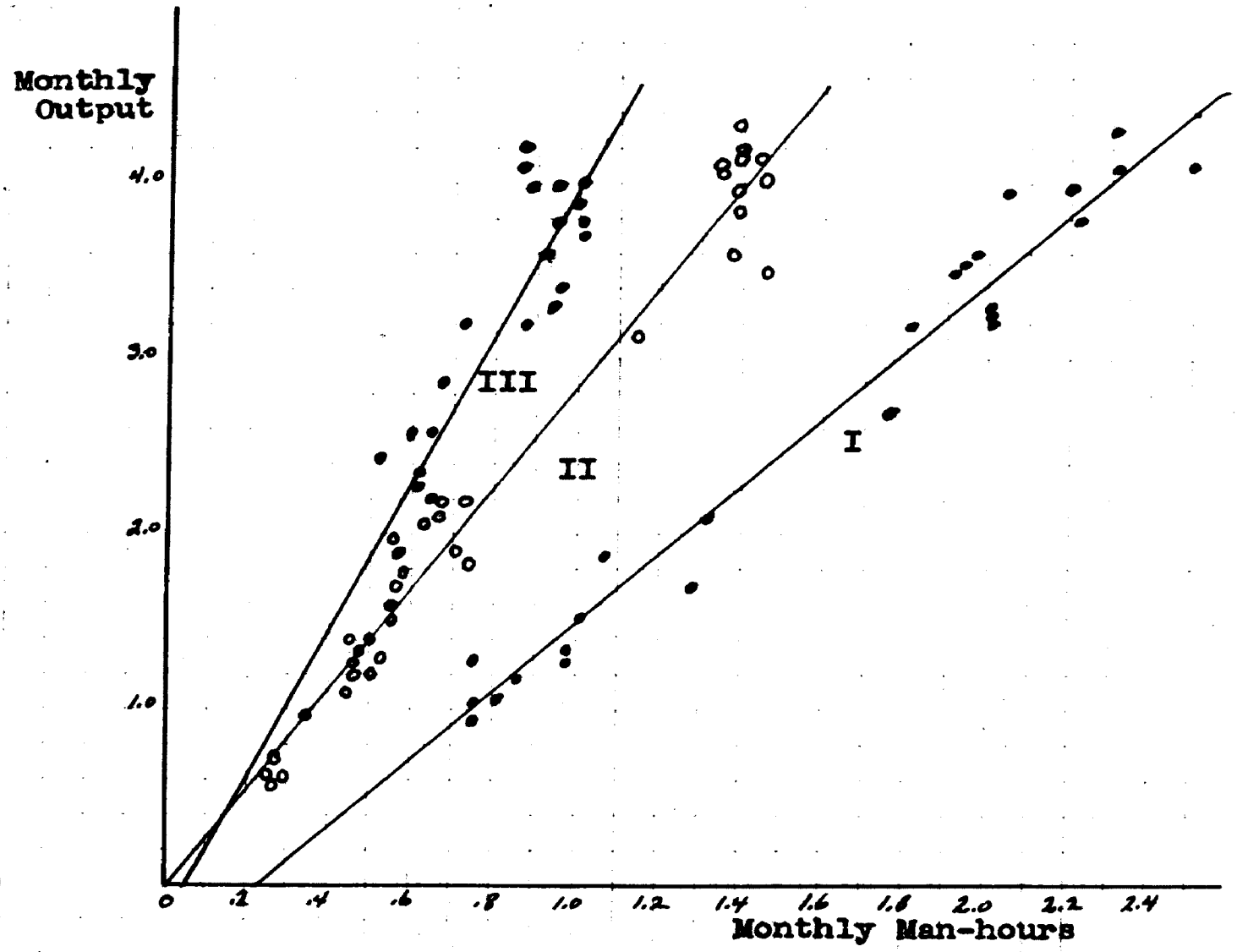


Figure 7.3
Blast Furnace Industry, Regressions of Monthly Pig Iron Output on Monthly Man-hours of Labor Input.

of the industry indicates. Increases in the productivity of labor in blast furnace operation may occur in two ways. The output per stack-day of operation may be increased, or the labor time involved in operation per stack-day may be decreased.[4]

Basically, the operation of a furnace requires a certain number of employees in attendance and this number is not appreciably affected by the size of the furnace in blast or the resulting output. Thus the trend toward larger furnaces of better design led to increased output per furnace without increasing the labor required in production and resulted in higher efficiency.

The average capacity of furnaces in blast during period I (1921-23) was something less than 400 long tons per day. By period II, the capacity had risen to 560 tons per day and by period III, (1937-39) to about 620 tons per stack-day.[5]

On the other hand, although auxiliary equipment cannot replace furnace capacity in the production of pig-iron, it can serve to reduce the labor required in tending operations. Among the most important auxiliary equipment adopted in the period of the twenties were pig-casting machines and skip hoists, the latter employed in the mechanical charging of furnaces. The extent of these changes can be grasped from the fact that in 1919 only about half of blast furnace output was

[4] An excellent discussion of the factors involved in the productivity of labor in the blast furnace industry will be found in "Labor Productivity in the Merchant Blast Furnace Industry", Bureau of Labor Statistics Bulletin no. 474, December 1928. An analysis of findings in an investigation of a number of individual plants (pp. 25-47) provides corroborative evidence of some of the trends discussed here.

[5] These averages were computed by the writer from Department of Commerce data on number and capacity of furnaces in blast.

machine cast and mechanically charged. By 1927, eighty-one percent of output was machine cast, and ninety-one percent was mechanically charged.[6]

Although both these factors played an important role in the behavior of productivity during the twenties, their relative importance increased after 1933. The capacity of furnaces in blast during Period II was about 47 percent higher than during period I. The increase in marginal productivity shown by the shift in the parameter of the statistical input-output function was of almost exactly the same magnitude. But although average daily capacity of furnaces in blast during period III was only about ten percent higher than during period II, the marginal productivity of labor again rose by about forty-seven percent.

The increase in productivity following 1933, then arose to a greater extent out of the increased use of auxiliary equipment rather than ~~to~~ from changes in basic capacity.

Steel Works and Rolling Mills

The measurement of steelproduction posed a problem in that the number of products is large and monthly series for many of them are not available. The index finally selected was a monthly series of gross tons of steel ingots. While this measure is subject to the deficiency that it takes no account of changes in the output "mix", no satisfactory substitute could be obtained. The series employed was published in connection with testimony presented by the United

[6] "Labor Productivity in the Merchant Blast Furnace Industry." p.5

States Steel Corporation before the Temporary National Economic Committee.[7] For convenience in computation, the output index was reduced to percentages of 1929 average monthly output.

The index of man-hours was compiled from Census monthly employment multiplied by the series for average hours per week employed above.

Regressions were computed for four periods: I - 1921-23, II - 1925-29,[8] III - 1931-37, and IV - 1939. The scatters are plotted in Figure 7.4 and the statistical results appear in Table 7.2

Table 7.2

Statistically Determined Parameters of the Aggregative Input-Output Function $Y = aX + b$, Steel Works and Rolling Mills, Four Periods

Period		a	σ_a	b	-b/a	r
I	1921-23	.454	.018	-22.72	50.	.9
II	1925-29	.920	.058	-100.96	111.	.9
III	1931-37	.596	.029	-17.42	29.	.9
IV	1939	.972	.078	-28.49	30.	.9

In contrast to the Blast Furnace industry, Steel Works and Rolling Mills are characterized by a substantial overhead. Furthermore the increase in marginal productivity shown in the shift from function I to II occurred at the expense of a sizable increase in overhead.

[7] "Iron and Steel Industry, United States Steel Corporation Studies" Hearings before the Temporary National Economic Committee, part 26, p. 13684

[8] Census monthly employment data for 1927 are not available; the regression II covers only the months of 1925 and 1929.

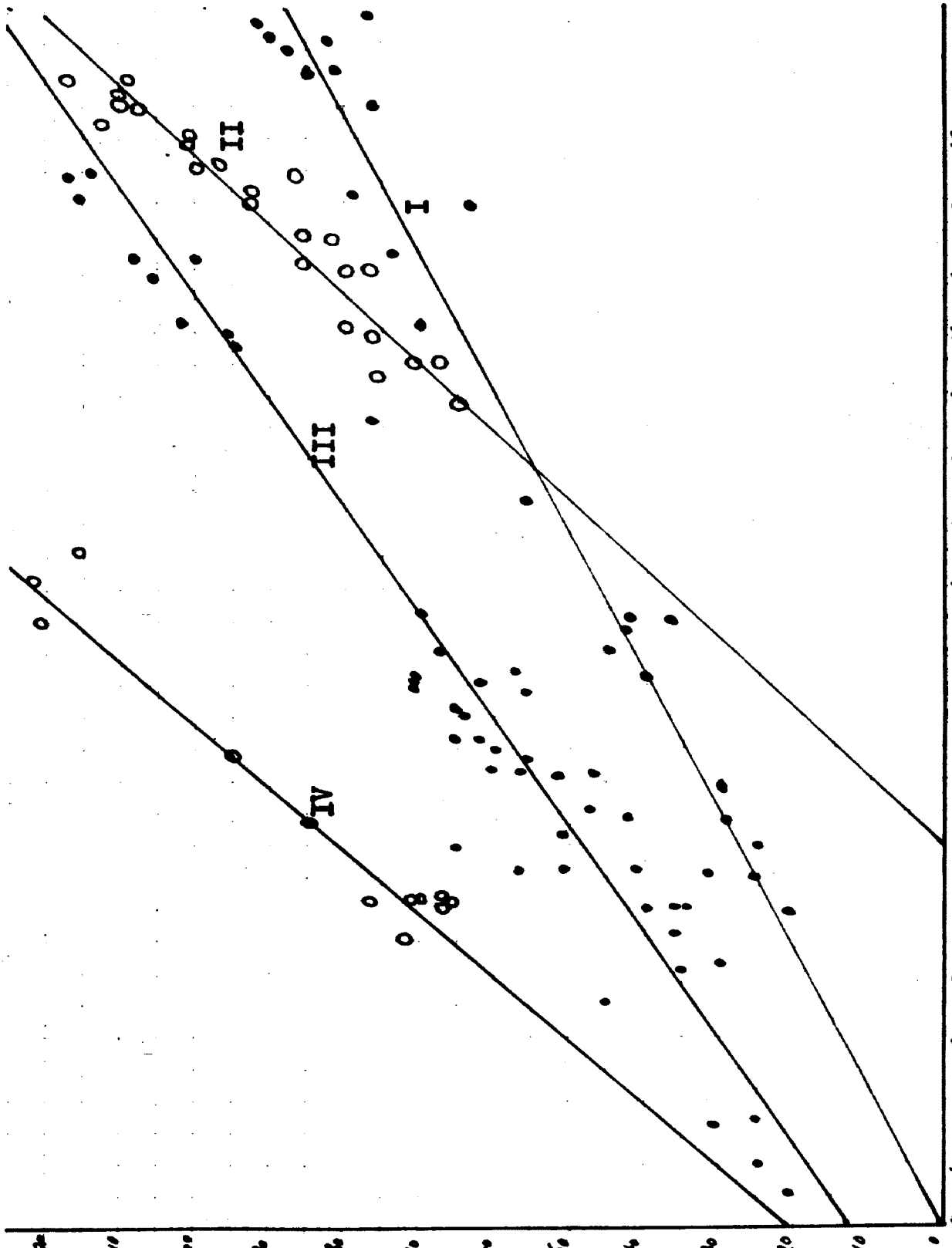


Figure 7.4 Steel Works and Rolling Mills, Regressions of Monthly Output on Monthly Man-hours of Labor Input

The existence of this overhead has two important consequences for our analysis. First, the fact that average productivity is not equal to marginal productivity, but lies below it, implies that average output becomes sensitive to changes in the level of output, rising and falling as employment increases and decreases. Moreover, the rate at which productivity rises as employment increases varies directly as the absolute magnitude of the parameter b and inversely as the square of employment.[9]

Secondly, since capital expenditure and the passage of time are accompanied by changes in two parameters, rather than one, we can no longer evaluate the effectiveness of capital expenditure in simple terms. Since no substantial overhead appears in the Blast Furnace industry, marginal and average productivity are practically equal. A glance at Table 7.1 indicates that the shift from function I to II resulted in an increase in productivity of about .9 index points while the shift from II to III increased productivity 1.3 index points. No such statement can be derived from Table 7.2 for Steel Works and Rolling Mills. What concise expression can be used to compare, for example the shift in the input-output schedule of Table 7.2 from I to II, (in which a large increase in marginal productivity is accompanied by a large increase in overhead), with the shift from II to III, (in which a fall in marginal productivity is accompanied by a fall in overhead)?

[9] That is, $Y = ax + b$

and $P = \frac{Y}{x} = a + \frac{b}{x}$ hence $\frac{dP}{dx} = -\frac{b}{x^2}$

The increase in output, level of employment given, resulting from a shift in the input-output function depends upon the level of employment assumed. A shift in the parameter b affects output at all levels of employment in the same way; the effect of a shift in marginal productivity is proportional to the level of employment.[10] It follows, therefore, that the effectiveness of expenditure depends upon the level of employment that is assumed. If we use the measure of expenditure effectiveness, therefore, to determine the increase in output which must accompany a given capital expenditure if employment in the industry is not to fall, the answer will depend in part upon the level of employment to be maintained.

It is apparent then, why the effectiveness of capital expenditure in the steel industry measured in terms of annual average productivity should appear lower during the thirties than during the period of the twenties.[11] Since the trend measure of productivity makes no allowance for the level of employment, the depression activity of the steel industry would make any capital expenditure appear to be associated with a lower level of productivity.

When, however, the results of capital expenditure are measured in terms of shifts in the input-output function, it becomes evident

[10] That is, since

$$Y = ax + b$$

therefore,

$$\frac{\partial Y}{\partial b} = 1 \quad ; \quad \frac{\partial Y}{\partial a} = x$$

[11] See Chapter V, Table 5.2

that if account is taken of the level of employment, capital expenditure was probably more effective during the depression rather than less. For the result of the activity after 1929 appears to have been a reduction of the overhead of the steel industry by a substantial amount. That is to say, the activity of the depression period can be seen as directed toward getting immediate results in face of a low level of employment and output.

For example, to produce the average 1929 output (100) required 217 index man-hours on function II, but only 195 index man-hours on function III. Thus the effect of the shift in the function was to require about ten percent less labor to produce outputs typical of 1929. On the other hand to produce the average 1931-37 output (60) required 178 index man-hours on function II but only 131 index man-hours on function III. Thus at the range of operation that was typical of 1931-37, about twenty-five percent less labor was required than would have been needed for the same output in the earlier period. If lower levels of operation are compared the results are even more striking. To produce a monthly index output of fifty, for example, would presumably required about a third less labor on schedule III than on schedule II.[12]

[12] The labor X_3 required on schedule III to produce the same output as amount of labor X_2 on schedule II is given by

$$X_3 = 1.53X_2 - 138.$$

It must be borne in mind, however, that for levels of X_2 below the range of actual observation the reliability of such a relationship is open to question.

These results are quite the opposite of those arising from a comparison of schedule I with schedule II. Since II involves higher marginal productivity and higher overhead than I, comparisons at higher levels of output will show a higher effectiveness of expenditure than comparisons at lower levels.

The most significant development in the steel industry during the period covered by the data was the introduction of the continuous strip rolling mill. Although the American Rolling Mill Company had begun a continuous strip mill in 1924, large scale adoption of the continuous rolling technique did not occur until after 1929. Of the total continuous rolling capacity of more than thirteen million tons installed by 1937, less than two million was in plants started before 1929.[13] An estimate prepared by the Steel Workers' Organizing Committee set a figure of 38,470 as the number of workers displaced by continuous rolling mills between 1929 and 1939.[14]

It would, therefore appear that the greatest factor underlying the depression shift in the input-output function of the Steel Works and Rolling Mills industry was the introduction of improvement in basic capacity. In this respect it appears in contrast to the other industries studied.

Rubber Tires and Tubes

The Federal Reserve Board index of Tire and Tube production was taken as the index of output for the industry. The index of monthly

[13] Exhibit No. 2460, submitted by the American Rolling Mill Co. to the Temporary National Economic Committee, Hearings, Part 30, p. 17326.

[14] Exhibit No. 2479, submitted by the Steel Workers' Organizing Committee, ibid. pp. 17339-17341.

man-hours was obtained by multiplying Census monthly employment by the National Industrial Conference Board monthly series of average weekly hours in Rubber manufacturing (1921-1931) and the Bureau of Labor Statistics series for Rubber Tires and Tubes (1933-1939).

Four significantly different periods were selected for analysis: I, 1921-1923 (24 months), II, 1925 (12 months) III, 1927-1929 (24 months), IV, 1931-1939 (60 months). The scatters appear in Figure 7.5. The parameters of the regression equations fitted to these respective periods are given in Table 7.3

Table 7.3

Statistically Determined Parameters of the Aggregate Input-Output Function, Rubber Tire and Tube Industry, Four Selected Periods.

Period		a	σ_a	b	-b/a	$\bar{r}$
I	1921-23	.332	.022	-25.5	68.0	.95
II	1925	.370	.066	-18.8	50.5	.91
III	1927-29	.604	.082	-92.5	153.0	.98
IV	1931-39	.700	.053	-34.9	50.0	.84

From I to II the aggregative function shifted to a higher level, but without a significant change in slope. From II to III, marginal productivity doubled, the improvement in productivity being in part offset by a substantial increase in overhead. From III to IV overhead was again reduced without any significant change in marginal productivity.

As was true of the steel industry, there is no evidence of any significant change in productivity during the thirties. The twenty percent increase in the index of annual average productivity indicated

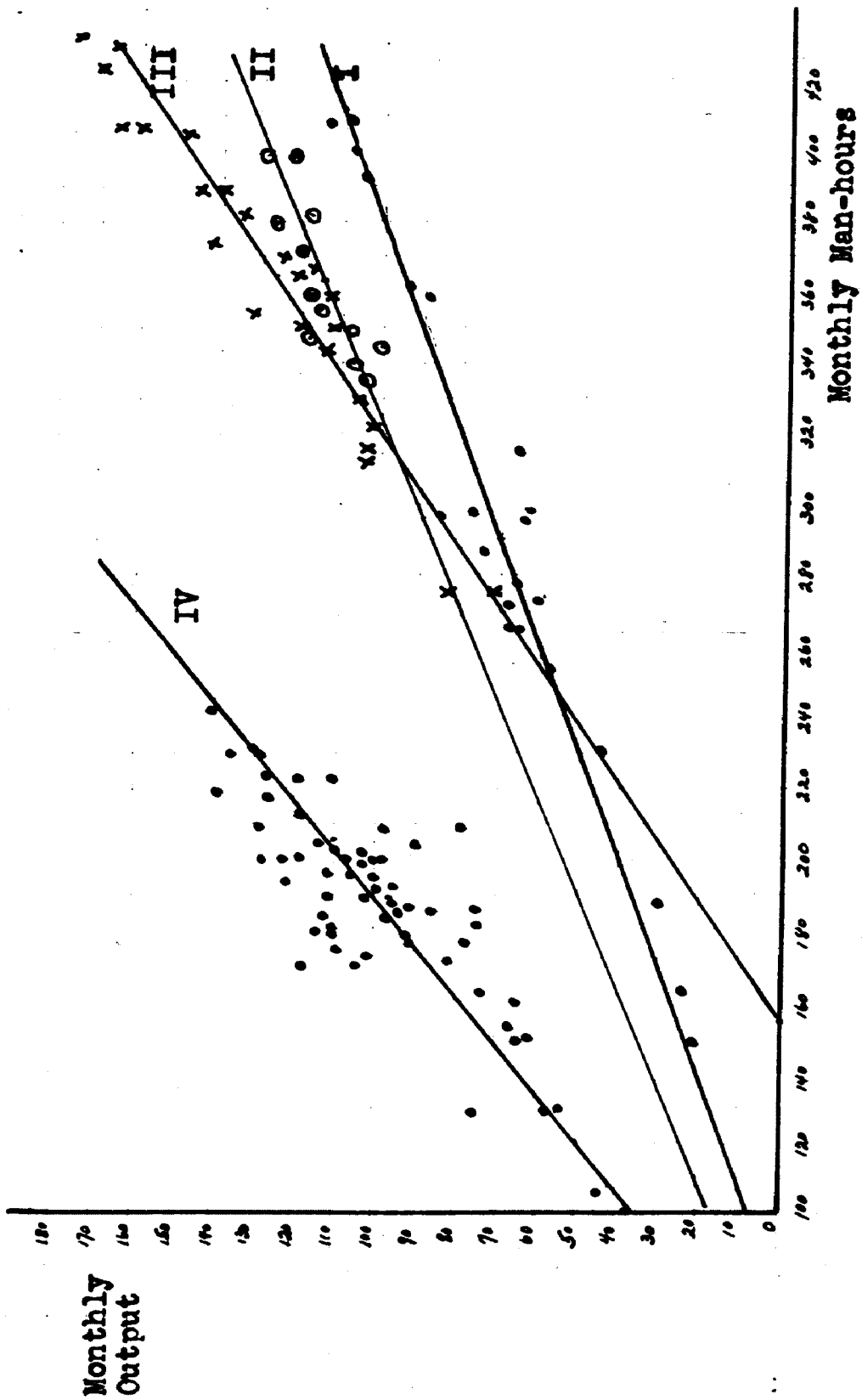


Figure 7.5 Rubber Tire and Tube Industry, Regressions of Monthly Output on Monthly Man-hours of Labor Input.

for the Rubber industry as a whole between 1931 and 1939,[15] is almost entirely attributable to the increasing rate of output. On the other hand, the shift in the input-output function was so sharp between 1929 and 1931 that average productivity rose twenty-two percent in spite of the fall in output.

Separate estimates of capital expenditure by the Tire and Tube segment of the Rubber Products industry are not available, but the shifts in the input-output function can be identified with the type of expenditure which was being made.

Between 1919 and 1925 (during which period the rise in productivity was not substantial) no significant changes occurred in the production of tires. Most capital expenditure during this period was designed to expand output to meet the post-war demand for automobiles. Some firms, however, had initiated the flat-drum process as early as 1919, but by 1925 it was still not in general use.[16] During 1926 there was a general adoption of the process and by 1927 it had become practically universal in the industry.[17] This change in technique is associated with the substantial rise in marginal productivity and the remarkable increase in overhead which characterized the movement of the input-output function from II to III.

Although some improvement in the organization of production occurred during the twenties, the introduction of improved equipment

[15] See Table 3.1 of Chapter III.

[16] Material in this section, unless otherwise noted, is drawn from Boris Stern, "Labor Productivity in the Automobile Tire Industry", Bureau of Labor Statistics Bulletin, no. 585, July, 1933.

[17] ibid. p. 20.

was of minor importance until t
equipment during the three year
automatic feeding equipment, po
so forth, was extensively dealt
Automobile Tire industry. A br
innovations in one department o
labor required for production h
is presented in Table 7.4. The
and 1931.

Table 7.4

Labor Saved by Auxiliary Equipme

Item	
New cutter for crude rubber bale	
2 Banbury Mixers with conveyors	
Spray cooled Banbury mixer & 3 s sheeting mills with acces	
3 tred calenders with automatic	
Tandem calenders with push-butto	

Source: Boris Stern, op. cit.

This general adoption of au
associated with the striking shi
III to IV. It is notable that t
change in marginal productivity
In other words, as was found to
Mills industry the shift of the

esale adoption of auxiliary

, 1928-31. The introduction of

veyers, superior controls, and

y Mr. Stern in his study of the

mary of some of the significant

lant and their effects on the

adapted from his report and

s were all adopted between 1928

oted by an Automobile Tire Plant.

	Labor Saved (man-hrs./day)
	16
	960
uipment	480
	48
ols	32

auxiliary equipment is

he input-output function from

ft involved no significant

uced overhead by two thirds.

of the Steel Works and Rolling

utput function of the Tire

industry was exactly the behavior which would yield immediate saving in cost at low levels of operation.

Cement

The Department of Commerce monthly series for cement production was takenas the index of output of the Cement industry. Monthly Census employment was used and was multiplied by a series of average weekly hours to obtain an index of man-hours. For the years 1933-39 the Bureau of Labor Statistics series was emplcyed for this purpose. For earlier years, annual average weekly hours were computed from the employment and man-hour data used in the estimation of annual average productivity.[18] The use of annual hours does not allow the input index to reflect monthly variations in labor input to the same degree of accuracy that characterizes the use of monthly hours data. It does, however, keep the regressions for the early years comparable to those of the later periods.

It appears from the scatter (Figure 7.6) that the input-output function for the Cement industry shifted so rapidly that separate regressions were computed for each 12 month period. The statistically determined parameters appear in Table 7.5.

From 1925 to 1927 the function exhibited an increase in marginal productivity with no change in overhead. Between 1927 and 1929, a smaller rise in marginal productivity was accompanied by a decline in overhead. The decline in overhead was substantial between 1929 and 1931, and between 1931 and 1933, although during the latter period marginal productivity fell to a significantly lower level.

Between 1933 and 1935 the aggregate input-output function shifted

[18] See Appendix D.

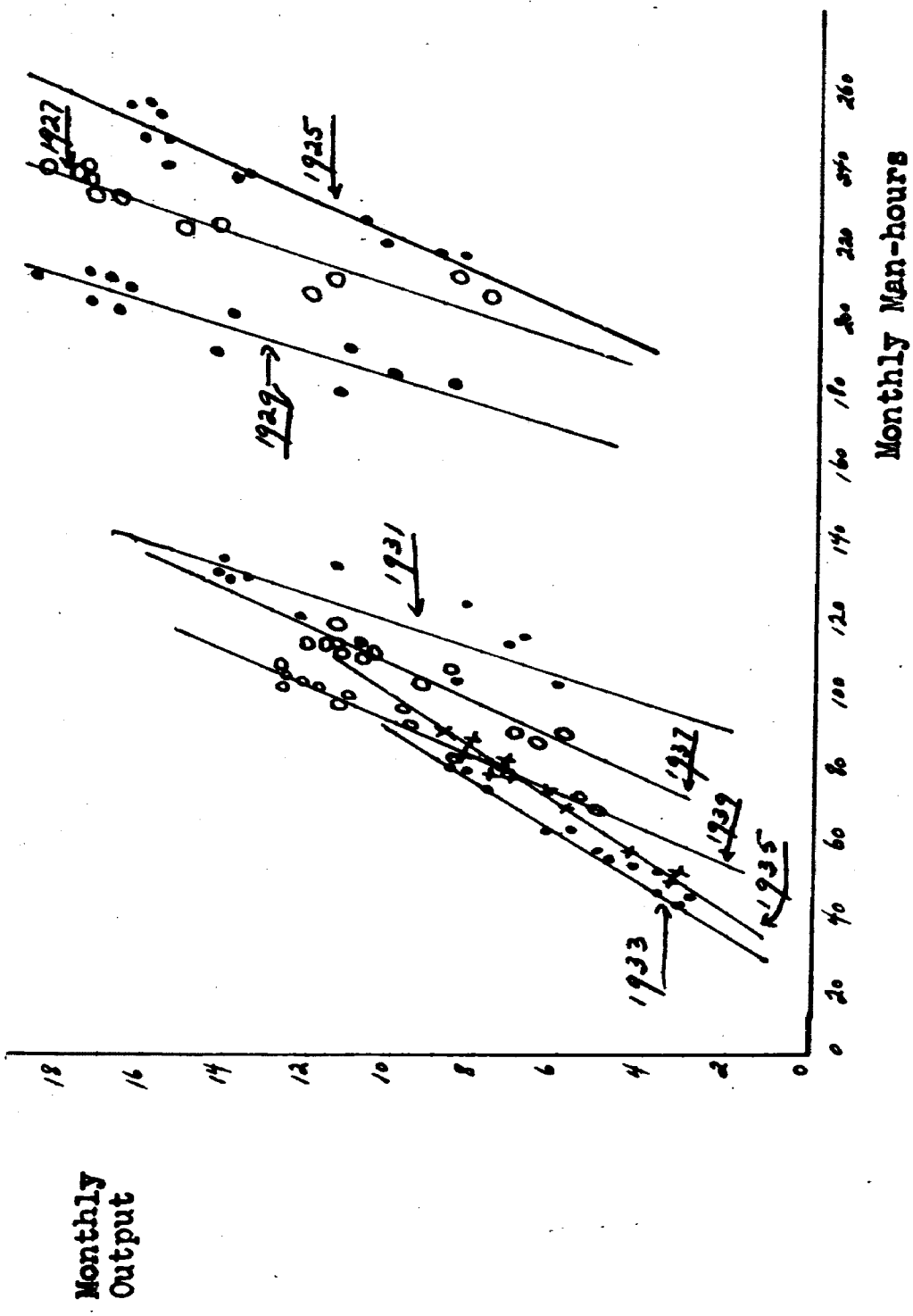


Figure 7.6 Cement Industry, Regressions of Monthly Output on Monthly Man-hours of Labor Input.

in the direction of lower productivity with a decrease in marginal prductivity and an increase in overhead. This downward shift was repeated in 1937 with a further increase in overhead in only small part offset by higher marginal productivity.

Table 7.5

Statistically Determined Parameters of the Aggregate Input-Output Function, Cement Industry, Eight Selected Years.

Year	a	σ_a	b	-b/a	$\bar{r}$
1925	1.896	.019	-312.18	165	.94
1927	2.479	.010	-409.0	165	.98
1929	2.712	.040	-387.8	143	.89
1931	2.286	.202	-167.6	73	.68
1933	1.732	.060	-40.3	23	.98
1935	1.439	.007	-37.6	26	.98
1937	1.846	.019	-90.95	49	.95
1939	2.162	.029	-94.8	44	.98

Although there is, as was true of the industries studied above, certain qualitative evidence as to the type of capital expenditure which characterized the cement industry at various periods, it is difficult to associate this evidence with observable shifts in the input-output function. This is particularly true for the period 1931-39, since the most important element in the behavior of the function during this period was the shifting market function. The striking rise in productivity in the industry from 1929 to 1933 is primarily to be associated with the fact that during this period

cement production was concentrated in the more efficient plants. 163 cement plants reported production during 1929. By 1931 only 158 plants were reporting operations, while the number had fallen to 143 by 1933.[19] The downward shift in productivity in the industry after 1933 was primarily due to the fact that the plants taken out of operation during the low output years of the depression were reopened as conditions improved.

Probably the best index of the extent to which an upward shift in productivity occurred independent of the market function lies in a comparison of the input-output schedules of 1931 and 1937. The return to higher levels of output lowered the productivity schedule of the industry to the 1937 level, but did not return it to the 1931 level.

The capital expenditure history of the Cement industry reflects much the same trends as those examined above. The basic technique of modern cement production was introduced between 1900 and 1920. The most important innovation that occurred during this period was the introduction of the rotary kiln to replace the old dome kiln.[20] The primary advantage in the rotary kiln lay in the fact that it permitted continuous operation. Power shovels and mechanical handling replaced hand shovels and wheelbarrows in the quarrying department, and so forth.

The period of 1921-1929 was one of extending the new mechanized

19 Figures are from the Bureau of Mines, Statistical Appendix to the Minerals Year Book, appropriate years.

20 "Labor Requirements for Construction Materials. Part I - Portland Cement", Bureau of Labor Statistics, Bulletin No. 888.1, 1947, p.3.

technique to all cement plants and the adoption of improved equipment. 51 new plants were built during the period and existing plants replaced much of their equipment with more efficient and larger units.[21] Thus the period of the twenties was one of increase in capacity and the adaption of capacity equipment to new techniques.

In contrast the expenditure for capital equipment during the thirties was largely concentrated on auxiliary equipment. During the period 1930-36 the sales of such equipment were three and a half times as high as during the period 1920-24; at the same time, the sales of major operating units were one third lower.[22] Thus, although it is difficult to measure the exact effect of expenditure on productivity during this period we can assert with confidence that the change in productivity due to capital expenditure arose primarily from the introduction of new auxiliary equipment.

SUMMARY

The statistical input-output functions for the industries studied are characterized by constant marginal productivity and a level of overhead. These two characteristics combined produce changes in average productivity with changes in the level of employment and output, productivity being higher at higher levels of output. The fluctuations of productivity due to fluctuations in output will tend to distort the observed relationship between capital expenditure and productivity; in periods of rising output expenditure will appear to be highly effective; in periods of falling output, expenditure will

[21] "Technological Changes and Labor Productivity in the Cement Industry", Monthly Labor Review, Vol. 51, no. 1, July 1940, p. 49.

[22] ibid. p. 50.

appear to be associated with smaller increases, or even with decreases in productivity.

If the effectiveness of capital expenditure is to be estimated, therefore, account must be taken of the shift in the input-output function and the measurement must be made as of a given level of employment or output. Even so, shifts in the input-output function which are not related to capital expenditure will introduce spurious elements into the result. Thus in the Cement industry, the allocation of given levels of output over fewer plants yields higher productivity than when the same outputs are produced by a larger number of plants. This result naturally follows from the existence of overhead labor requirements in each of the plants in the industry.

The shifts in input-output function which were observed before 1929 involved increases in marginal productivity at the expense of larger overhead requirements. This type of shift tends to produce substantial increases in productivity at the higher levels of production but provides little improvement at the lower levels. Indeed the productivity of labor at low levels of production may be lowered by the change. This shift was associated with expenditure for basic capacity both in the adaptation of capacity equipment to new production techniques and in the introduction of new capacity to reach new levels of output.

The most striking feature of all the schedules following 1929 lies in the fact that the most substantial changes occurred in the magnitude of overhead requirements. This is the sort of shift one would expect to occur when management is bent upon reducing the cost of production at low levels of output. With the exception of the

Rolling Mill industry, the depression shift in input-output functions was associated with the concentration of capital expenditure on auxiliary equipment.

A second striking feature of the behavior of the schedules after 1929 lies in the fact that while there are a number of distinct schedules observable during the period 1919-1929, the function having shifted after 1929 appears to have remained stable, at least until 1939. The sole exception to this rule was, of course, the Cement industry, where the shifting market law makes it impossible to assess the effect of change in technique.

The fact that the technique did not shift significantly after 1931 or 1933 does not, of course, imply that average productivity did not change. Since productivity typically rises in these industries with increases in output, the cyclical rise in production up to 1937 brought increases in productivity with it. In the Tire and Tube industry the gains in productivity at the higher levels of output were even greater than at the lower levels since the shift of the function had involved not only lower overhead, but somewhat higher marginal productivity. In Steel Works and Rolling Mills, on the other hand, the gains inproductivity were greater at the lower levels. This is likewise true of the Cement industry, the decline in marginal productivity being reenforced in this respect by the backward shift of the function as output rose.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The role of capital expenditure in raising the productivity of labor, and the importance of productivity for the well-being of society have long been recognized by economists. The study of the relationship of capital expenditure to the change in productivity over a particular period in the past would, therefore, be considered, by even the most classical economist, an important empirical study. But immediately the relationship between the level of capital expenditure and the level of employment is recognized the study takes on important additional significance. If the free enterprise economy is left without interference it must grow if it is to avoid collapse. Its growth must be an accelerating one in which the rate of acceleration depends upon the propensity of the society to save and the extent to which current investment outlays result in higher productivity.

The effort to determine the effectiveness of capital expenditure is hampered by the fact that there exists no technique for the measurement of productivity which corresponds to the concept as defined by the economist. The unit labor cost measure of productivity leaves out of account the fact that labor in one industry can be substituted for labor in another, either by using labor in industry A to conserve materials bought from industry B, or by using inputs from B to replace labor in A. Furthermore the unit labor cost measure of productivity does not allow for improvement in the product to increase the utility of consumption.

Although the concept of value added per man-hour would appear to be free of these difficulties, it is subject to fluctuations due to changes in both the general level of prices and the relative price of the output of the particular industry under study. When adjustment is made for these factors, the index no longer measures the relative utility of the product. Although the deflated value added per man-hour measure of productivity makes some allowance for substitution of labor between industries, it is unstable in its year to year behavior due to the influence of changes in the price of inputs relative to output prices.

Although these measures are imperfect, the behavior of their trends gives us a good idea of the rate of improvement in the utilization of labor.

All the industries examined exhibited rising trends of productivity during the period studied, but the variation among the trends was substantial. The positive correlation between average capital expenditure per man-year and rate of increase in productivity indicates that the variations in trend were to some extent associated with variations

in the magnitudes of expenditure. But the effectiveness of capital expenditure varied widely from industry to industry.

Variation in capital expenditure effectiveness were attributed to the action of six factors: 1) the extent to which "non-capital" elements were involved in the increase in productivity; 2) the existing capital intensity of the industry; 3) the type of technical improvements available to firms - basic capacity expansion or "auxiliary" equipment; 4) the extent to which basic capacity is expanded; 5) the degree to which the industry depends upon exhausting resources; and 6) the rate at which improved technical possibilities were being made available. Although no quantitative variation in these factors could be related to productivity behavior, the qualitative evidence seems to indicate that the shift in expenditure to auxiliary equipment, as distinguished from basic production units, was an important factor in the contrast in productivity behavior during the period of the thirties as compared with the earlier period.

The statistical evidence indicates that the effectiveness of capital expenditures made after 1929 was somewhat higher than that of those made before 1929, but measurements of effectiveness in terms of average productivity take no account of the effect of low rates of output on productivity. When the behavior of productivity is analyzed in terms of shifting input-output schedules, more can be said as to the relationship of expenditure for plant and equipment and productivity.

In the four industries for which input-output functions were analyzed productivity varied directly with the rate of output although the sensitivity of average productivity to such variations depends

upon the magnitude of the "overhead" requirements of the industry. In one case, Blast Furnaces, the sensitivity was low.

The input-output functions of the industries examined exhibited similar behavior patterns. During the period 1919-1929 the functions moved in the direction of higher marginal productivity, generally at the cost of additional overhead requirements. While the result was increased productivity at high levels of output, the cost of operations at lower levels did not fall correspondingly, and in some cases appeared to have risen.

After the down-turn in activity following 1929 the functions shifted in the direction of lower overhead. The result of the shift was to produce immediate cost reduction at lower levels of output. It is remarkable, however, that this shift was completed by 1931 or 1933 and that although the productivity of labor improved thereafter as the rate of output rose, no further changes in the productivity schedule occurred at least until 1939. This was not the case in the cement industry, but the behavior of the input-output function of this industry is to be associated with the changes in the market behavior of the industry rather than changes in productive technique.

The behavior of the input-output functions examined appears to have been related to the type of investment activity characterizing the separate periods. The 1919-1929 period was one of extending and improving basic capacity equipment. The later period was characterized by the substantially increased proportion of capital expenditure going for auxiliary equipment.

The estimates of capital expenditure, upon which our measure of expenditure effectiveness were based, were necessarily crude.

Furthermore, as has been pointed out, some part of the improvement in productivity is not related to the expenditures made by firms for plant and equipment. But if we accept our measure of expenditure effectiveness as lying in the neighborhood of a "true" value, we may hazard a guess as to the rate at which capital expenditure should have risen if stable employment were to have been maintained over the period 1919-1939.

As we indicated at the outset, the rate at which investment activity must grow, as formulated by Domar, is given by $\alpha\sigma$ where α is the average propensity to save and σ the increase in productive capacity per dollar of investment.[1] In Chapter V we pointed out the formal similarity between σ and the effectivenessof capital expenditure:[2]

$$(1) \qquad \sigma = \frac{\frac{\Delta P}{P}}{\frac{I}{N}} = e$$

where e is the measure of capital expenditure effectiveness.

Before we can use the measure of capital expenditure effectiveness developed in Chapter V as the e of the above expression we must translate the change in index productivity into an absolute change in productive capacity. Our measure of the annual average increase in productivity ($\frac{\Delta P}{P}$) was based upon a productivity index (1929 = 100). Thus to obtain a measure of capital expenditure effectiveness the units of which correspond to those of σ we must multiply the average annual increase in productivity by base year output per man, i.e., average value added per man, 1929.

[1] See p. 8

[2] P. 67

Then:

(2) $e' = ep'$

where e is the index measure of capital expenditure effectiveness and p' is the value added per man in the base year.

It must further be noted that while σ is related to some "net" expenditure for plant and equipment, e' is based on actual (gross) expenditure. The propensity to save which must be used with e' must therefore be a gross concept. In place of α, which represents the average propensity to save out of "net" income (in the peculiar Domar sense, i.e., out of the income remaining after sufficient investment has been made to maintain productivity) we must, therefore, use α', the propensity of society to save out of gross product.

The magnitude of α' depends upon the propensity of income receivers to save disposable income, but also depends upon the dividend policies of firms, the structure of tax rates, governmental budgets and expenditure policies, and so forth. As a measure of α' for the entire economy we may take the ratio of private expenditure on plant and equipment to the Gross National Product. At high levels of employment this has been about ten percent.

For the economy as a whole the rate of growth in capital expenditure required to maintain a given level of labor employment is thus given by

(3) $r = e'\alpha'$

We have not attempted to compute e' for the economy as a whole, but if the e' of manufacturing can be taken as typical,

$$e' = .000147 \times 3700 = .54$$

(i.e., the (value productivity) measure of capital expenditure effectiveness in manufacturing was .0147 percent of 1929 value added per man in

manufactures; the latter was approximately $3700.) And:

$$r = .1 \times .54 = .054$$

That is, if the average effectiveness of expenditure for plant and equipment in the entire economy approximates the effectiveness of expenditure by manufacturing firms, the maintenance of a stable level of employment during the period 1919-1939 would have required that annual gross capital expenditure grow at a rate (r) of about five percent per year. At this rate, annual capital expenditure would be required to double once every fifteen years.

On the basis of our study it would appear that e' for manufacturing is somewhat higher than the average for the entire economy and the rate of five percent may be an exaggeration. The levels of e' appropriate to some of the non-manufacturing industries studied are given in Table 8.1.

Table 8.1

Estimated e' For Selected Non-Manufacturing Industries

Industry	Estimated e'
Agriculture	.2
Electric Light and Power	.5
Mining and Quarrying (excluding Petroleum and Natural Gas)	.2
Petroleum and Natural Gas	.9
Railroads	.2

It should be noted that we have taken no account of the change in productivity in the service industries and trade, and that e'

for the economy as a whole may be higher than the levels for the selected non-manufacturing industries would seem to indicate. In any case we are safe in concluding that the rate of increase in capital expenditure which would have been required to maintain full employment over the period 1919-1939 was somewhere between three and five percent.

This conclusion requires considerable qualification, however. Our measures were made over a period during which capital expenditure did not grow at this rate. The observed effectiveness of capital expenditure applies only to the level of capital expenditure actually made. If expenditure on plant and equipment had somehow been forced to the indicated level it might well be true that the average effectiveness would have been substantially lower. If the marginal productivity of capital diminishes with increases in the stock of equipment this would necessarily be true. Indeed, the very fact that expenditure did not behave in the "required" fashion is partial evidence that the productivity of further additions to capital was not sufficiently high to justify the outlay.[3]

It is in just this point that the difficulty lies. When capital expenditure has high effectiveness in raising the productivity of labor, the maintenance of employment requires that the annual expenditure rise at a high compound rate. As the effectiveness of expenditure

[3] It is obviously true that firms did not expect the rewards from additional expenditure to be sufficient. The expectations of individual firms, however, are conditioned by the general outlook. Thus it is clear that expenditures of very high effectiveness may be foregone during periods of depression. For this reason the past behavior of firms can never be accepted as complete proof as to the effectiveness of capital expenditures which would have appeared had the expenditures been made.

declines the rate at which capital expenditure must increase declines but other things equal the lower the effectiveness of capital expenditure becomes, the less inducement there is for expenditure for plant and equipment and the more difficult it is to maintain any level of capital expenditure. With the failure to maintain the level of expenditure required to maintain the level of employment the latter must decline.

The "double-edged" nature of expenditure effectiveness is most apparent if we concentrate our attention on the problem of recovery from depression. In Chapter VII we saw how the introduction of the continuous strip rolling mill inthe steel industry, and the purchase of auxiliary equipment by the Blast Furnace and the Rubber Tire and Tube industries were associated with striking upward shifts in the output resulting from given labor inputs in these industries. Had the technical possibility of reducing costs by these expenditures not been available, the magnitude of capital expenditure and hence the level of employment would have been lower than it was. But the fact that these expenditures were made served in part to raise the level of employment, and in part to further complicate the problem of recovery by decreasing the volume of employment associated with any given level of income.

Thus the concept of capital expenditure effectiveness is important, not only for the understanding of the long-run behavior of the economy, but also for analysis of the problems of cyclical fluctuation. The employment multiplier of investment depends not only upon the input-output function of the economy as a whole, but also depends upon shifts in that function generated by investment activity.

Finally the nature of the relationship between capital expenditure and productivity points up the ultimate problem of economic policy. We may look at the relationship in two ways. On the one hand we may say that the expenditure activity which creates jobs is, from another point of view, the activity which destroys employment opportunity. On the other hand, we may say that the sacrifice of present leisure creates the opportunity for future leisure. Whether a decline in the amount of labor effort expended in production is a social problem or a social blessing depends upon whether it is voluntary. It is obvious from past experience that our economic institutions do not automatically lead us to a rational social choice of the balance to be struck between the enjoyment of leisure, the enjoyment of present consumption, and the additions to be made to productive power for future enjoyment. At one time we find ourselves in periods of unemployment suffering from an <u>embaras de richesse;</u> another time our eagerness to have both present and future enjoyment in greater amount than available resources can provide results in the irrational rationing process of inflation. The study we have concluded does not indicate what combination of economic institutions is required for social rationality. It does, however, indicate something of the magnitude of one of the problems to be solved.

APPENDIX A

SOURCES AND DESCRIPTION OF UNIT REAL LABOR COST PRODUCTIVITY INDEXES.

Non-manufacturing Industries

1. Agriculture

Source: Productivity in Agriculture, Bureau of Labor Statistics, report LS49-1525, mimeo, Nov., 1948.

The index of output used in the compilation of this index of productivity weights individual farm products by unit man-hour weights. The series is an extension of one originally prepared by the National Research Project. The N.R.P. weights were average unit man-hour requirements 1924-29.

2. Coal Mining

Source: Productivity indexes for bituminous and anthracite coal are given separately by V. E. Spencer, Production, Employment, and Productivity in the Mineral Extractive Industries 1880-1938, W.P.A., N.R.P. report no. S-2. The indexes of output used in each case were, of course, simply aggregate tonnage. The two productivity indexes were combined by the present writer by constructing an index of aggregate output with weights equal to 1929 unit man-hour requirements.

3. Electric Light and Power

Source: Jacob M. Gould, Output and Productivity in the Electric and Gas Utilities, 1899-1942, National Bureau of Economic Research, New York, 1946.

Mr. Gould's output index is an aggregate of kilowatt-hours generated by class of user, weighted by class prices. It does not appear, however, that the results would be significantly changed if an unweighted aggregate of kilowatt hours were employed.

4. Mining and Quarrying (excluding Crude Petroleum and Natural Gas).

Source: Spencer, op. cit.

As noted in the text, this index is the harmonic mean of productivity indexes of the individual mining industries, weighted by base year man-hour requirements. Where weighted aggregates were necessary in the measurement of the output of individual industries, however, Spencer used base year unit labor costs as weights in some cases and unit values in others.

5. Crude Petroleum and Natural Gas.

Source: ibid.

The weights employed in measuring output were man-shifts per unit, 1935. Annual data were available only since 1935, the remaining figures represent Spencer's linear interpolations of decenial census data.

6. Railroads.

Source: Solomon Fabricant "Labor Savings in American Industry, 1899-1939", National Bureau of Economic Research Occasional Paper 23, New York, 1945. The index was prepared by researchers of the National Bureau and its nature is not indicated. The behavior of the index is essentially the same as that of one compiled by the present writer in which the index of output was an average of quantity relatives of annual freight ton-miles and passenger miles weighted by total revenues from the respective services.

7. Telephone.

Source: ibid.

No description is given of the index. It was compiled at the National Bureau from data furnished by the American Telephone and Telegraph Co.

Manufacturing Industries

Source: "Productivity and Unit Labor Cost in Selected Manufacturing Industries, 1919-1940", Bureau of Labor Statistics, February, 1942.

These indexes are extensions of those compiled by the National Research Project (Irving H. Siegal and others, "Production, Employment, and Productivity in 59 Manufacturing Industries," 3 parts, W.P.A., N.R.P. report no. S-1, 1939). Productivity is measured by the use of output indexes in some of which unit man-hour requirements are used as weights, in others unit product values or unit value added are used as weights.

No extension of the index for Manufactured Ice was available and the N.R.P. index was employed.

APPENDIX B

BASIC DATA AND COMPUTATION OF VALUE PRODUCTIVITY INDEXES.

The procedure employed in computing value productivity indexes was as follows. Census employment was multiplied by annual average weekly hours, and reduced to an index of man-hours (1929 = 100). This index was divided into the Census figure for value added and the result reduced to an index of value added per man-hour, current prices. The "current price" index was then reduced to 1929 output prices by deflating by an index of output values.

Since the 1939 Census employment figure for many industries is not comparable to earlier data, the procedure was followed of interpolating the 1939 figure on the basis of movements of the B.L.S. index of employment for the industry in question. In some cases, however, better results were obtained by estimating the 1939 employment figure from the movements of the Census total of "factory" and "non-factory" employment for the industry in question.

The basic data and computed value productivity indexes are given in the following tables.

TABLE B-1

AUTOMOBILES AND AUTOMOBILE EQUIPMENT, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	343	45.9	75.0	1,139	74.6	44.4
1921	213	44.7	45.4	758	83.5	52.5
1923	405	47.7	92.1	1,465	79.1	60.8
1925	426	47.3	96.1	1,750	90.9	66.2
1927	369	46.4	81.9	1,469	89.1	73.0
1929	447	46.8	100	2,002	100	100
1931	286	36.9	50.3	952	94.2	106.0
1933	244	35.2	40.9	648	79.1	104.9
1935	388	37.3	69.1	1,122	81.0	110.1
1937	479	35.9	82.6	1,507	91.0	119.0
1939	444	35.5	76.0	1,258	82.7	101.2

Sources: Col. (1) Census of Manufactures
(2) 1921-1931, National Industrial Conference Board; 1933-1939, Bureau Labor Statistics; 1919 interpolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2)
(4) Census
(5) Computed from (3) and (4)
(6) 1919-1923, (5) divided by an index of prices derived by the writer from Census production and value data; 1925-1939, (5) divided by price per pound of automobiles published by the Automobile Manufacturers Association, Automobile Facts and Figures.

TABLE B-2

BLAST FURNACES, STEEL WORKS, AND ROLLING MILLS, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	419	63.7	120.8	1,322	67.1	49.0
1921	254	51.9	59.7	535	57.0	49.6
1923	425	55.4	106.5	1,290	74.2	58.1
1925	400	51.5	93.1	1,282	85.0	79.0
1927	389	51.0	89.8	1,220	84.0	84.5
1929	420	52.7	100	1,623	100	100
1931	278	41.7	52.4	623	73.8	84.0
1933	289	32.5	42.5	482	67.9	81.5
1935	375	34.9	59.1	894	93.2	102.0
1937	502	38.7	88.0	1,624	114.0	110.5
1939	436	35.5	69.9	1,332	117.6	113.2

Sources: Col. (1) Census of Manufactures
(2) 1920-1931, National Industrial Conference Board; 1933-1939, Bureau of Labor Statistics. 1919 interpolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by B.L.S. index of steel prices.

TABLE B-3

BOOTS AND SHOES, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Hours Per Week	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	211	45.8	106.3	440	91.6	72.4
1921	184	45.7	92.2	389	93.5	89.3
1923	225	45.6	113.1	473	92.5	99.4
1925	207	45.8	104.2	444	93.3	98.9
1927	203	45.2	101.2	450	98.5	99.3
1929	206	44.2	100	451	100	100
1931	181	44.5	88.8	316	79.0	86.9
1933	191	39.6	83.2	267	71.1	115.2
1935	202	37.1	82.5	310	83.4	124.6
1937	215	38.3	90.5	352	86.3	115.2
1939	204	36.0	80.7	346	86.0	127.0

Sources: Col. (1) Census of Manufactures
(2) 1920-39, National Industrial Conference Board. 1919 interpolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by an index of shoe prices derived by the writer from Census physical production and value data for years 1927-39. Earlier years, (5) divided by B.L.S. index of wholesale shoe prices.

TABLE B-4

BREAD AND BAKERY PRODUCTS, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	142	50.3	69.6	439	80.4	82.2
1921	149	50.5	73.4	491	85.0	82.6
1923	163	50.6	80.4	548	86.5	93.3
1925	160	50.7	79.4	600	94.8	90.5
1927	172	50.9	85.5	701	104.0	102.5
1929	201	51.0	100	789	100	100
1931	183	48.1	85.9	685	101.0	118.7
1933	182	44.4	79.1	492	78.8	98.8
1935	218	40.5	86.3	565	83.0	91.9
1937	239	42.6	99.5	699	88.8	92.7
1939	231	41.7	94.1	762	102.0	112.0

Sources: Col. (1) Census of Manufactures
(2) 1919, 1923, 1929, Census prevailing hours. 1932-39, Bureau of Labor Statistics. Remaining years by linear interpolation.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by B.L.S. Index of wholesale prices, Bread, for 1919-21; 1923-39, (5) divided by an index of Bread and Bakery Product prices compiled by the writer from Census Physical Production and Value data.

TABLE B-5

CANNING AND PRESERVING, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	90	54.2	81.4	216	84.2	64.5
1921	60	53.5	53.8	142	83.7	68.0
1923	82	53.7	74.0	236	100.9	97.5
1925	93	53.4	83.8	252	95.4	95.5
1927	94	53.2	83.8	239	90.5	94.8
1929	113	52.9	100	316	100	100
1931	89	45.0	67.1	205	96.8	124.2
1933	94	38.1	60.5	186	97.4	135.8
1935	132	35.9	79.6	260	103.1	150.0
1937	153	37.9	97.7	314	101.6	132.2
1939	138	36.9	83.4	311	118.0	171.8

Sources: Col. (1) Census of Manufactures
(2) 1919, 1921, 1923, 1929, Census prevailing hours; 1933-39, Bureau of Labor Statistics; remaining years by linear interpolation.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by an index of prices of canned products compiled by the writer from Census production and value data.

TABLE B-6

CEMENT, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100) Current $	1929 Output Prices
1919	25.5	n.a.	79.6	95.8	70.5	63.6
1921	26.2	n.a.	80.5	101.3	72.9	57.1
1923	35.1	n.a.	104.1	163.3	90.9	70.9
1925	38.4	n.a.	109.4	186.7	98.8	80.5
1927	36.3	n.a.	111.6	173.6	90.2	81.5
1929	33.4	n.a.	100	172.3	100	100
1931	24.3	n.a.	60.8	92.7	88.0	129.5
1933	15.8	34.1	31.6	60.8	110.0	126.9
1935	20.7	33.9	39.5	77.3	112.5	110.0
1937	26.4	38.8	57.6	113.2	115.9	115.8
1939	22.8	38.2	49.0	124.1	147.0	147.6

Sources: Col. (1) Census of Manufactures
(2) Bureau of Labor Statistics
(3) 1919-1935, W.P.A., National Research Project, Production, Employment and Productivity in 59 Manufacturing Industries, Part II, p. 35; 1937-39, computed from (1) and (2).
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by an index of cement prices compiled by the writer from Census physical production and value data.

TABLE B-7

CLAY PRODUCTS (OTHER THAN POTTERY), DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	76.9	46.8	77.0	140.9	85.1	73.6
1921	68.8	48.8	71.9	126.1	81.8	71.0
1923	102.7	48.9	108.2	230.1	98.6	85.1
1925	102.8	49.2	108.1	233.7	100.1	94.4
1927	101.0	49.5	107.1	220.0	95.4	92.7
1929	93.7	49.8	100	215.1	100	100
1931	51.1	41.5	46.5	90.4	92.1	102.8
1933	31.9	35.9	24.6	44.6	84.4	97.0
1935	44.6	35.4	33.9	73.2	100.5	105.8
1937	65.2	37.1	51.8	128.2	114.8	111.2
1939	61.8	35.2	46.6	133.4	133.0	113.1

Sources: Col. (1) Census of Manufactures (1939 by B.L.S. index, Brick and Tile employment)
(2) 1919, 1921, 1923, 1929, Census prevailing hours; 1933-1939, B.L.S.; remaining years by linear interpolation.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by an index of clay product prices compiled by the writer from Census physical production and value data.

TABLE B-8

CONFECTIONERY INDUSTRY, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	76.5	51.1	121.6	195	90.3	63.6
1921	61.0	50.2	95.3	140	81.9	81.5
1923	63.5	51.0	100.7	164	91.2	87.2
1925	63.6	50.6	100.1	173	97.2	91.1
1927	63.2	50.6	99.4	174	98.2	93.7
1929	63.5	50.6	100	178	100	100
1931	51.3	44.4	70.7	139	110.8	117.1
1933	50.6	37.2	58.5	98	96.1	144.4
1935	52.1	36.7	59.5	106	102.5	158.2
1937	53.7	39.3	65.5	123	108.0	154.0
1939	53.1	38.1	62.9	127	113.4	170.0

Sources: Col. (1) Census of Manufactures, 1919-1937; 1939 based on B.L.S. index of employment.
(2) 1919, 1921, 1923, 1929, Census prevailing hours; 1933-39, Bureau of Labor Statistics. Remaining years by linear interpolation.
(3) Computed from (1) and (2)
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by an index of confectionery prices compiled by the writer from Census physical production and value data, 1925-39. The index was extrapolated to 1919 on the basis of the B.L.S. wholesale price index.

TABLE B-9

FLOUR AND GRAIN MILL PRODUCTS, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	45.5	50.6	173.1	253	76.6	43.5
1921	35.4	50.2	134.9	186	72.1	60.1
1923	35.2	50.2	133.0	163	64.2	68.4
1925	32.0	49.8	120.0	173	75.5	61.3
1927	30.0	49.5	111.7	176	82.6	74.7
1929	27.0	49.2	100	191	100	100
1931	22.8	48.7	83.7	137	85.8	136.9
1933	23.2	43.4	75.8	134	92.8	136.0
1935	26.5	37.4	71.9	137	100.0	99.4
1937	26.4	44.3	82.3	134	85.4	88.7
1939	26.7	42.3	85.9	144	87.8	131.2

Sources: Col (1) Census of Manufactures, 1919-37; 1939 by B.L.S. employment index.
(2) 1919-35, W.P.A., National Research Project loc. cit. Part III p. 54.
(3) Computed from (1) and (2).
(4) Census of Manufactures
(5) Computed from (3) and (4).
(6) (5) divided by an index of flour and grain mill product prices compiled by the writer from Census physical production and value data.

TABLE B-10

GLASS INDUSTRY, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	77.5	49.4	113.5	171	75.0	44.8
1921	54.7	49.2	80.4	127	78.7	45.7
1923	73.3	48.9	106.3	196	91.7	53.5
1925	69.4	49.2	101.2	182	89.5	78.2
1927	65.8	49.5	97.0	172	88.4	86.0
1929	67.5	49.8	100	201	100	100
1931	49.9	41.5	61.6	143	115.5	132.5
1933	49.8	35.9	53.2	129	120.9	145.2
1935	67.1	35.4	70.9	174	123.0	148.0
1937	79.1	37.1	87.4	247	141.0	159.2
1939	67.1	35.2	70.4	227	160.5	182.3

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. index of employment.
(2) 1919, 1921, 1923, 1929, Census prevailing hours. 1933-39, Bureau of Labor Statistics. Remaining years by linear interpolation.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by an index of glass product prices compiled by the writer from Census physical output and value data.

TABLE B-11

ICE CREAM INDUSTRY, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	19.1	54.9	85.1	73	49.8	35.2
1921	20.2	55.3	90.4	92	58.4	58.6
1923	23.1	55.8	104.4	115	63.8	62.2
1925	23.0	55.6	103.6	145	81.5	78.6
1927	21.9	55.4	98.3	151	89.3	85.5
1929	22.4	55.2	100	173	100	100
1931	17.8	52.9	75.9	158	120.7	122.2
1933	14.3	47.6	55.3	92	96.6	110.0
1935	17.3	45.4	63.5	108	98.0	122.7
1937	18.7	47.9	72.2	138	110.8	137.0
1939	17.7	46.2	67.1	140	121.1	160.1

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. employment index.
(2) 1919, 1921, 1923, 1929, Census prevailing hours; 1933-1939, Bureau of Labor Statistics. Remaining years by linear interpolation.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4)
(6) (5) divided by an index of ice cream prices compiled by the writer from Census physical output and value data, 1923-1939, extrapolated to 1919 on the basis of the B.L.S. index of wholesale prices.

TABLE B-12

LEATHER TANNING AND FINISHING, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	72.5	49.4	151.0	282	130.0	78.6
1921	49.0	46.6	96.2	105	114.2	116.0
1923	59.7	47.6	119.8	167	97.5	106.0
1925	52.3	47.5	104.7	155	102.7	110.8
1927	52.9	45.8	102.0	162	110.6	114.1
1929	49.9	47.6	100	144	100	100
1931	42.0	45.2	80.1	98	85.6	112.2
1933	44.2	41.8	78.0	99	88.8	140.4
1935	50.9	38.1	81.8	109	92.4	130.3
1937	50.7	38.2	81.8	114	96.6	113.0
1939	47.6	38.6	77.6	117	105.2	136.0

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. employment index.
(2) 1921-39, National Industrial Conference Board; 1919 extrapolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2).
(4) Census of Manufactures
(5) Computed from (3) and (4).
(6) (5) divided by B.L.S. index of wholesale leather prices.

TABLE B-13

LUMBER AND LUMBER PRODUCTS, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	864	48.2	93.5	1745	93.0	80.0
1921	703	45.7	71.5	1259	87.6	80.8
1923	932	52.3	108.1	1967	90.5	75.9
1925	921	52.6	107.6	1963	90.6	85.0
1927	865	52.0	100.0	1826	90.9	91.0
1929	876	51.4	100	2006	100	100
1931	517	43.2	49.7	904	90.4	116.2
1933	457	40.4	41.5	632	75.5	105.6
1935	570	38.1	48.2	869	89.7	114.1
1937	684	42.4	64.3	1270	98.4	107.3
1939	597	38.9	51.7	1245	119.6	141.9

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. employment index.
(2) Weighted average of average weekly hours, furniture and lumber industries. Individual series given in W.P.A., National Research Project study cited above (Table B-6, source note), 1919-1935; 1937-9, Bureau of Labor Statistics series were employed.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by an index of lumber and lumber product prices compiled by the writer from B.L.S. index of furniture prices and Census lumber and lumber products production and value data.

TABLE B-14

MANUFACTURED ICE, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	30.2	57.0	93.2	94.1	59.0	54.3
1921	24.1	57.1	74.3	107.7	85.7	76.8
1923	26.9	57.0	82.6	118.0	83.4	83.3
1925	24.9	57.2	77.0	142.2	108.0	106.2
1927	22.1	57.3	68.5	144.0	122.8	122.8
1929	32.1	57.5	100	171.1	100	100
1931	25.2	53.6	73.1	156.9	125.2	131.5
1933	21.3	49.7	57.3	112.3	114.8	129.2
1935	19.0	49.2	50.6	100.3	116.1	137.2
1937	18.7	51.6	52.3	109.0	124.0	144.2
1939	15.9	50.5	43.4	104.0	140.2	169.0

Sources: Col. (1) Census of Manufactures (no adjustment for 1939).
(2) 1919, 1921, 1923, 1929, Census prevailing hours. 1933, 1935, Census actual hours. Other years interpolated.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by an index of manufactured ice prices compiled by the writer from census production and value data.

TABLE B-15

PETROLEUM REFINING, DATA AND COMPUTATION OF INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	58.9	50.5	71.9	385	88.2	49.3
1921	63.2	50.7	77.5	345	71.9	49.0
1923	66.7	50.1	80.9	369	75.1	64.9
1925	65.3	50.5	79.8	487	100.2	75.8
1927	71.2	50.9	87.7	390	73.2	71.9
1929	80.6	51.3	100	608	100	100
1931	68.8	46.3	77.1	314	66.8	120.0
1933	69.0	38.9	65.0	314	79.1	138.0
1935	77.4	35.0	66.4	357	88.0	122.1
1937	83.2	36.0	73.5	482	106.5	125.6
1939	83.5	36.1	73.7	528	111.6	151.5

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 estimated from the movement of the total of "factory" and "non-factory" employees reported by the industry in the Census, 1937 and 1939.
(2) 1921-31, National Industrial Conference Board; 1933-39, Bureau of Labor Statistics; 1919 extrapolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by B.L.S. index of wholesale petroleum and petroleum product prices.

TABLE B-16

PULP AND PAPER, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	209	52.7	99.0	531	67.1	51.9
1921	185	49.0	81.4	403	62.0	51.3
1923	219	47.4	93.2	578	77.5	63.5
1925	222	46.8	93.3	627	84.1	71.3
1927	224	47.2	95.0	704	92.8	88.0
1929	233	47.8	100	800	100	100
1931	195	40.3	84.4	600	88.8	95.1
1933	196	38.6	80.6	518	79.2	92.0
1935	236	38.9	82.5	637	96.7	107.1
1937	264	41.0	97.3	853	109.6	116.5
1939	251	40.3	90.6	860	118.5	127.8

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. employment index.
(2) 1919-35, W.P.A. National Research Project, op. cit.; 1937-39, Bureau of Labor Statistics.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by B.L.S. index of wholesale paper and pulp prices.

TABLE B-17

RUBBER PRODUCTS, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	158	49.4	109.0	544	92.8	45.5
1921	103	47.2	68.0	327	89.2	56.6
1923	138	47.9	92.5	457	91.2	75.1
1925	142	47.4	93.9	539	106.5	79.7
1927	142	48.5	96.1	565	109.2	90.0
1929	149	48.0	100	539	100	100
1931	99	40.4	55.8	361	120.5	152.6
1933	106	35.2	52.3	261	92.1	152.7
1925	115	34.7	55.8	309	103.1	134.0
1937	130	34.5	64.4	369	106.2	118.2
1939	130	36.9	67.1	406	112.1	131.6

Sources: Col. (1) Census of Manufactures, 1919-37; 1939 figure computed on the basis of movements in reported total of "factory" and "non-factory" employees, Rubber Products industry, 1937, 1939.
(2) 1920-33, National Industrial Conference Board; 1935-37, Bureau of Labor Statistics; 1919 extrapolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2).
(4) Census of Manufactures
(5) Computed from (3) and (4).
(6) (5) divided by an index of prices of rubber products compiled by the writer from Census production and value data.

TABLE B-18

SLAUGHTERING AND MEAT PACKING, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (millions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	161	48.4	122.6	463	82.0	59.8
1921	117	46.9	87.3	333	82.8	98.5
1923	133	49.7	105.1	410	84.6	109.0
1925	120	49.6	95.6	425	96.3	98.1
1927	119	50.2	95.8	393	89.0	96.5
1929	123	50.6	100	461	100	100
1931	107	59.0	85.2	342	87.0	119.4
1933	113	44.0	82.0	288	76.1	169.0
1935	117	40.4	78.2	332	92.0	106.0
1937	127	41.0	83.6	400	103.7	118.0
1939	127	40.6	82.9	422	110.4	153.0

Sources: col. (1) Census of Manufactures, 1919-37; 1939 based on B.L.S. employment index.
(2) 1921-33, National Industrial Conference Board; 1935-39, Bureau of Labor Statistics; 1919 extrapolated on the basis of Census prevailing hours.
(3) Computed from (1) and (2).
(4) Census of Manufactures.
(5) Computed from (3) and (4).
(6) (5) divided by an index of meat prices compiled by the writer from Census production and value data.

TABLE B-19

MANUFACTURES AS A WHOLE, DATA AND COMPUTED INDEX OF VALUE PRODUCTIVITY

Year	Employment (thousands)	Average Weekly Hours	Index of Man-hours	Value Added (billions of $)	Index of Value Added per Man-hour (1929 = 100)	
					Current $	1929 Output Prices
1919	8,423	43.8	99.7	23.7	77.7	58
1921	6,475	41.8	73.2	17.2	70.0	69
1923	8,194	45.6	101.0	24.6	78.6	77
1925	7,871	44.5	99.2	25.7	84.5	84
1927	7,848	45.0	95.7	26.3	90.0	92
1929	8,370	44.2	100	30.6	100	100
1931	6,163	40.5	67.6	18.6	90.0	116
1933	5,788	38.1	59.5	14.0	77.0	111
1935	7,204	36.6	71.5	18.6	85.0	100
1937	8,569	38.6	89.5	25.2	92.3	102
1939	8,405	37.7	85.5	24.7	94.2	125

Sources: Col. (1) Census of Manufactures, 1919-1937; 1939 based on B.L.S. index of employment.
(2) 1923-39, Bureau of Labor Statistics; 1921 extrapolated on the basis of N.I.C.B. series for manufacturing industries; 1919 based on Census prevailing hours.
(3) Computed from (1) and (2).
(4) Census of Manufactures
(5) Computed from (3) and (4)
(6) (5) divided by B.L.S. index of wholesale prices of manufactured products.

APPENDIX C

CAPITAL EXPENDITURE ESTIMATES

MINES AND QUARRIES (NOT INCLUDING CRUDE PETROLEUM AND NATURAL GAS EXTRACTION)

In estimating the expenditure for new plant and equipment by mining and quarrying establishments, the sizable outlays for development were included. These development expenditures include the cost of exploration, test shafts, sinking mine shafts, running drifts, timbering, stripping overburden in the case of open pit or strip mining, and similar expenditures which must precede the actual exploitation of the mineral deposits.

For estimating the magnitude of this expenditure two bench marks were available. The Census of Mines and Quarries of 1919 and 1929 furnished a report of the total cost charged to development by operators in each of the minerals industries covered. These bench marks were applied to the value of factory construction to obtain annual estimates of development expenditure.

The resulting estimates, while not entirely satisfactory seem to be the best that could be made. The difficulty lies not only with the method of interpolation, but with the base-year development cost figures themselves. A portion of expenditure for development in the minerals industries is charged to current account. This is in part due to the fact that such costs are rapidly expensed with the extraction of the mineral uncovered, and in part to the fact that the line between development expenditures which should be properly included in capital account and those which should be included in current expense is in large part an arbitrary one. The difficulty of obtaining consistent and meaningful data are therefore great.

For the estimation of expenditure for machinery and equipment, bench-marks were available in the Census of Mines and Quarries, 1929, and in the Census of Mineral Industries, 1939. The two figures needed adjustment before they were comparable. The Census of 1939 embodied a complete survey of expenditures for machinery, segregating the purchase of new machinery from that purchased "in a used condition". Since the Census of 1929 made no such distinction, it was necessary to reduce the 1929 figure by the percentage of used machinery in total machinery purchased in 1939.

Secondly, the 1929 figures excluded, while the 1939 data included, installation cost. Such costs have been estimated[1] at roughly fifteen percent of all expenditures for machinery and equipment, and the 1929 figure was raised by that amount. Thirdly, the 1929 figure did not include data for certain industries which were included in the 1939 coverage. In the case of very minor operations, or, as in the case of potash mining, where operations were not substantial before 1929, no adjustment was felt necessary. The 1929 figure was raised, however, to account for the omission from coverage of the clay-mining operations of brick, tile, terra-cotta and other producers of products from common clay. This adjustment was made on the basis of the volume of such common-clay mining operations during 1929 as compared to the volume mined by operators covered by the census.

The resulting adjusted figures for expenditure for machinery and equipment were then applied to the estimated annual "net" production

[1] Terborgh, George, "Estimated Expenditure for New Durable Goods, 1919-1938", Federal Reserve Bulletin, Sept. 1939, p. 735.

of mining machinery. The estimated "net" production series was obtained by adding the value of mining machinery produced to the value of mine cars produced as reported by the Census of Manufactures. These census year values were interpolated for intercensal years by using the movements of the gross income of machinery firms producing "Miscellaneous Machinery - Building, Construction, Gas, Mining Machinery and Equipment," obtained from the Statistics of Income for the years 1927-1937. The value for 1938 was estimated on the basis of movements of the gross income of machinery firms producing "Construction and Mining Machinery" as reported by the Statistics of Income. The earlier years were interpolated on the basis of the movements of Kuznets' series for the total value of mining and oil-field machinery produced.[2] The resulting series for the annual production of mining machinery was then converted to "net" annual production by deducting the export of mining machinery as reported by the Bureau of Foreign and Domestic Commerce in Foreign Commerce and Navigation of the United States. An allowance of ten percent was substracted from the reported value of exports to cover crates, transportation to port and other exporting costs.

The estimate of building construction was based on the reported expenditure for building and major repairs, Census of Minerals Industries, 1939. The 1939 figure was carried back on the basis of movements of estimated expenditure for machinery and equipment.

[2] Kuznets, Simon, Commodity Flow and Capital Formation, Vol. I, National Bureau of Economic Research, 1938, Table II-3 p.137.

TABLE C-1

MINERAL INDUSTRIES, EXPENDITURE FOR DEVELOPMENT,

1919 AND 1929

Industry	Expenditure for Development (thousands of dollars)	
	1919	1929
Coal		
Bituminous	30,044	16,646
Pennsylvania Anthracite	6,190	7,902
Metals		
Iron Ore	14,658	9,886
Major Non-ferrous Ores	25,434	36,040
Other Non-ferrous Ores	763	1,258
Stone, total	1,252	3,618
Other Non-metals	2,079	1,507
Crude Petroleum and Natural Gas	230,867	n.a.

Sources: *Census of Mines and Quarries, 1919* and *1929*.

TABLE C-2

MINERAL INDUSTRIES, EXPENDITURE FOR MACHINERY AND EQUIPMENT, 1929 AND 1939

(figures in thousands of dollars)

Industry	Expenditure for Machinery		
	1929	1939	
		New	"Used"
Crude Petroleum and Natural Gas	n.a.	127,717	12,429
Coal			
Bituminous	34,947	22,315	2,942
Pennsylvania Anthracite	1,753	2,874	322
Lignite	n.a.	73	20
Metallic Ores			
Iron Ore	3,594	3,410	193
Major Non-ferrous Ores	18,703	10,055	2,862
Other Non-ferrous Metals	1,109	874	174
Stone, total	8,228	4,245	1,127
Sand and Gravel, total	7,173	4,238	1,064
Clay and Shale			
Kaolin, Ball Clay and Fire Clay	459	1,070	100
Common Clay and Shale	n.a.	137	81
Fullers Earth	140	61	7
Bentonite	n.a.	63	40
All Other Minerals, total	4,852	2,628	352

Sources: Census of Mines and Quarries, 1929, and Census of Mineral Industries, 1939.

TABLE C-3

MINERAL INDUSTRIES, EXPENDITURE FOR NEW PLANT AND MAJOR REPAIRS, 1939

Industry	Expenditure for New Plant and Major Repairs (thousands of dollars)
Crude Petroleum and Natural Gas	11,840
Coal, total	7,056
Metallic Ores, total	5,248
Stone, total	1,203
Sand and Gravel, total	1,030
Clay and Shale, total	308
All Other Minerals, total	1,704

Source: Census of Mineral Industries, 1939

TABLE C-4

MINING AND QUARRYING (EXCLUDING CRUDE PETROLEUM AND NATURAL GAS), DATA AND ESTIMATED CAPITAL EXPENDITURE, 1919-1939

(figures in millions of dollars)

Year	Mining Machinery Production	Mining Machinery Exports	Total U.S. Factory Construct.	Estimated Expenditure For Machinery	Building	Development	Total
1919	54	8	780	121	33	80	234
1920	56	8	889	128	35	87	250
1921	34	7	464	72	19	45	136
1922	48	6	378	112	30	37	142
1923	58	9	444	130	35	44	209
1924	44	10	372	91	24	36	151
1925	48	11	415	98	27	41	166
1926	58	13	588	120	32	58	210
1927	46	12	563	90	24	56	170
1928	45	13	649	85	23	65	173
1929	49	16	761	88	24	76	188
1930	31	14	498	45	12	50	107
1931	13	9	228	10	3	23	36
1932	8	4	95	10	3	10	23
1933	9	4	134	12	3	13	28
1934	20	7	160	32	9	16	57
1935	25	9	149	39	12	15	66
1936	33	9	225	58	17	25	100
1937	36	15	330*	50	15	33	98
1938	37	13	220*	56	17	22	95
1939	38	13	240*	57	18	24	99

Sources: Col. (1) Odd numbered years, Census of Manufactures; even numbered years interpolated as explained in text.
(2) Foreign Commerce and Navigation of the U.S.
(3) L.J. Chawner, Construction Activity in the United States, Department of Commerce. Starred figures estimated on the basis of non-resi-

COAL MINING

The estimate of capital expenditures by the anthracite and bituminous coal industry was made by taking the percentage of each expenditure series attributable to coal mining operations in the base years and applying it to the estimated series. For machinery and equipment, expenditures for coal mining constituted roughly twenty-five percent in both 1929 and 1939, and this figure was used throughout the entire period from 1919 to 1939. The building expenditures of coal mining operators were roughly twenty-five percent of total building in mining and quarrying in 1939 and this figure was used throughout the period. The expenditures for development by coal mine operators constituted roughly forty-five percent of the total development expenditure in mining and quarrying operations in 1919 and roughly a third in 1929. The percentage was interpolated linearly from 1919 to 1929 and the flat one third was used from 1929 to 1930.

This estimate of capital expenditure is necessarily more crude than the others, but no separate series for the production of coal mining machinery was available.

TABLE C-5

COAL MINING, ESTIMATED CAPITAL EXPENDITURE, 1919-1939

(figures in millions of dollars)

Year	Estimated Expenditure			
	Machinery	Buildings	Development	Total
1919	30	8	36	74
1920	32	9	37	78
1921	18	5	19	42
1922	28	7	15	50
1923	33	9	18	60
1924	22	6	14	42
1925	24	7	14	45
1926	30	8	15	53
1927	23	6	20	49
1928	21	6	22	49
1929	22	6	26	54
1930	11	3	16	30
1931	3	1	8	12
1932	3	1	3	7
1933	3	1	4	8
1934	8	2	5	15
1935	9	3	5	17
1936	15	4	8	27
1937	12	4	11	27
1938	14	4	7	25
1939	14	5	8	27

Sources: See text.

CRUDE PETROLEUM AND NATURAL GAS

Buildings and Expenditure for Machinery and Equipment other than Well Machinery.

The expenditure for building and for equipment other than machinery and equipment for wells drilled was estimated by applying the figure for the total of such expenditure, 1939, to the estimated production of oil field machinery and equipment, net of exports. The latter series was prepared in the same way as the estimate of production of mining machinery. The 1939 figure for buildings was given in the Census of Mineral Industries, 1939. The figure for other machinery and equipment was obtained by subtracting the Census reported expenditure for machinery and equipment for new wells from reported total expenditure for machinery and equipment.

Drilling and Equiping New Wells

The greater part of expenditure for new capital in the petroleum and Natural Gas industries is involved in the drilling and equiping of new wells. Annual data for the number of petroleum and natural gas wells and dry holes drilled were available in Petroleum Facts and Figures, and the estimate of drilling and equiping expenditure was made by obtaining an average figure for the cost of drilling and equiping wells, including dry holes, and multiplying it by the number drilled in each year.

Estimates of average cost per well for drilling and equiping were available for five individual years. The Census of Mineral Industries, 1939 indicated a figure of $17,900 based on the drilling

and equiping expenditures reported by producing and contracting firms covered. The expenditures reported included those made directly by producers and those made in the form of fees to contractors. An estimate for the year 1935, prepared[1] from Bureau of Mines data gave an average cost of $18,500. Figures for the other three years were reported by the American Petroleum Institute as follows: $19,300 for the year 1926[2], $22,400 for the year 1928[3] and $22,000 for the year 1930.[4] For the remaining years between 1926 and 1939 the average cost per well of drilling and equipment were obtained by linear interpolation. There are no estimates available for years prior to 1926 and the figure $19,000 was adopted.

[1] Kiessling, O. E. and others, Technology, Employment, and Output per Man in Petroleum and Natural Gas Production, W.P.A. National Research Project Study #E-10, 1939, p. 199.

[2] Petroleum Facts and Figures, first edition, 1928, p. 124.

[3] Ibid., second edition, 1929, p. 115.

[4] Ibid., fourth edition, 1931, p. 88.

TABLE C-6

CRUDE PETROLEUM AND NATURAL GAS, DATA AND ESTIMATED EXPENDITURE FOR BUILDINGS AND FOR MACHINERY AND EQUIPMENT OTHER THAN FOR EQUIPPING NEW WELLS.

(figures in millions of dollars)

Year	Production of Oil Field Machinery	Export of Machinery	Expenditure Made For Building	Non-well Machinery
1919	28	3	5	27
1920	31	6	5	27
1921	27	10	3	18
1922	38	4	7	37
1923	52	6	10	50
1924	41	6	9	49
1925	47	9	8	41
1926	67	14	11	57
1927	62	15	10	51
1928	71	15	12	61
1929	89	23	14	72
1930	60	22	8	41
1931	23	10	3	14
1932	17	4	3	14
1933	21	6	3	18
1934	40	12	6	30
1935	54	14	8	43
1936	91	17	15	80
1937	121	32	19	97
1938	80	37	9	47
1939	82	33	10	52

Sources: Col. (1) Odd numbered years, Census of Manufactures; Even numbered years, interpolated as explained in text.
(2) Foreign Commerce and Navigation.
(3) and (4) Estimated as explained in text.

TABLE C-7

CRUDE PETROLEUM AND NATURAL GAS, ESTIMATED EXPENDITURE, DRILLING AND EQUIPPING WELLS, 1919 - 1939

Year	Number of Wells Drilled	Average Cost per Well (dollars)	Total Expenditure Drilling and Equipping Wells (millions of dollars)
1919	29,173	19,000	554
1920	33,911	19,000	644
1921	21,937	19,000	417
1922	24,689	19,000	469
1923	24,438	19,000	464
1924	21,888	19,000	416
1925	25,623	19,000	487
1926	29,319	19,300	566
1927	24,143	20,800	502
1928	22,331	22,400	500
1929	26,356	22,200	585
1930	21,240	22,000	467
1931	12,342	21,300	263
1932	15,040	20,600	310
1933	12,312	19,900	245
1934	18,197	19,200	349
1935	21,420	18,500	396
1936	25,890	18,300	474
1937	33,075	18,200	602
1938	27,493	18,000	495
1939	26,347	17,900	472

Sources: See text.

MANUFACTURING - SELECTED INDUSTRIES

The method employed in preparing the estimates of expenditure for new plant and equipment in the remaining manufacturing industries was essentially the same as that used for estimating the minerals industries as a whole. The general procedure followed was to obtain values of the output of machinery used in the particular industry from the Census of Manufactures for census years, and to apply the reported expenditure for new plant and equipment in 1939 as a benchmark. If values of exports were available, they were deducted from the census value of production and expenditure for plant and equipment in 1939 was applied to "net" production. In general, to interpolate values for the intercensal years, the movement of the Chawner estimates for the entire industrial group of which the particular industry is a member were used.

Special note should be taken of the following cases in which the general procedure was modified.

Tobacco Products

Since no figures are available for the production of tobacco-manufacturing machinery for the censal years 1919 and 1921, an estimate was made of the expenditure for plant and equipment in the tobacco products industry by analyzing the relationship between the estimated expenditure for new plant and equipment during the other censal years and changes in the value of the investment in the tobacco products industry. A careful study of the value of the investment in the tobacco industry had been made by the Federal Trade Commission

in connection with its report on profits in the industry.[1] The study attempted to eliminate, insofar as possible, changes in the value of investments due to writing up of assets, etc. In the absence of any other method of estimate, the use of the F.T.C. data were employed.

Manufactured Ice

The Census of Manufactures reported a separate figure for ice making machinery prior to 1931. For 1931 and the following years, ice making machinery was combined with refrigerating machinery in the classification "Refrigerating and Ice-making Machinery." The value of ice-making machinery was estimated by using the ratio of the two classifications as reported in the Census of Manufactures, 1929. This estimate probably tends to exaggerate the expenditure for plant and equipment by ice-manufacturing establishments, since it is quite probable that the proportion of ice-making machinery in the total tended to decline with the decline of the ice industry. In the absence of specific information no adjustment could be made.

Shoe Machinery

Since most shoe machinery is leased by shoe manufacturers rather than purchased, the unqualified application of the general method of estimating expenditure of shoe manufacturers for new plant and equipment would understate the amount of new plant and equipment actually put in use by the shoe industry. The bench-mark figure was, therefore, arrived at by subtracting the reported

[1] Investments, Profits and Rates of Return for Selected Industries, T.N.E.C., Hearings Part 31, p. 17662, Table 1.

expenditure for new plant and equipment by other Leather and Leather Products establishments from Chawner's estimate for the expenditure for new plant and equipment in the Leather and Leather Products group, 1939.

Clay Products (other than Pottery)

The estimates for the clay products group were made in two parts. Estimates for the brick and tile portion of the group were based on a series of estimated sales of clay working machinery to brick and tile producers.[2]

Capital expenditure by the rest of the clay products industry were estimated on the basis of the difference between Census reported production of Clay working machinery and the estimated sales to brick and tile producers.

[2] See Table C-15

TABLE C-8

ESTIMATED CAPITAL EXPENDITURE, THREE MANUFACTURING GROUPS

(figures in millions of dollars)

Year	Food and Kindred Products	Stone, Clay, and Glass Products	Leather and Leather Products
1919	137	95	29
1920	354	168	23
1921	214	115	14
1922	257	130	18
1923	248	198	17
1924	234	157	15
1925	272	181	16
1926	371	234	20
1927	343	202	17
1928	423	283	17
1929	378	241	17
1930	267	120	12
1931	171	76	11
1932	131	38	10
1933	207	28	10
1934	195	43	11
1935	185	65	13
1936	268	99	15
1937	320	99	15
1938	217	68	14
1939	240	68	15

Source: L. J. Chawner, "Capital Expenditure in Selected Manufacturing Industries", loc. cit.

TABLE C-9

EXPENDITURE FOR NEW PLANT AND EQUIPMENT, SELECTED MANUFACTURING INDUSTRIES, 1939

(figures in thousands of dollars)

Industry	Expenditure	
	New Plant	New Equipment
Boots and Shoes	1,431	3,811
Bread and Bakery Products	9,337	27,517
Canning and Preserving	3,012	7,858
Cement	2,850	4,731
Confectionery	1,220	3,357
Clay Products (other than Pottery)	2,764	2,977
Flour and Grain Mill Products	2,523	3,392
Glass	4,335	9,347
Ice Cream	2,996	9,807
Leather Tanning and Finishing	801	1,781
Manufactured Ice	2,563	3,410
Slaughtering and Meat Packing	8,425	8,953
Tobacco Products	2,027	4,994

Source: Census of Manufactures, 1939

TABLE C-10

PRODUCTION AND EXPORT OF SHOE MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, BOOT AND SHOE INDUSTRY, 1919-1939

Year	Machinery Production (thousands of $)	Machinery Export (thousands of $)	Estimated Expenditure Plant and Equipment (millions of dollars)
1919	16,261	2,840	16.6
1920	n.a.	-	14.0
1921	9,482	1,797	9.5
1922	n.a.	-	12.2
1923	10,663	1,324	11.5
1924	n.a.	-	11.1
1925	11,769	1,370	12.8
1926	n.a.	-	15.6
1927	12,334	1,718	13.1
1928	n.a.	-	12.9
1929	12,317	1,988	12.7
1930	n.a.	-	10.1
1931	9,755	1,000	10.8
1932	n.a.	-	9.6
1933	8,130	609	9.3
1934	n.a.	-	10.1
1935	10,245	653	11.8
1936	n.a.	-	12.3
1937	10,903	889	11.2
1938	n.a.	-	10.7
1939	10,603	894	12.0

Sources: Col. (1) Census of Manufactures
(2) Foreign Commerce and Navigation
(3) 1939, Chawner's estimate of capital expenditure by Leather and Leather Products group less Census reported expenditure by non-shoe portion of the group, (see text). Remaining odd numbered years extended on the basis of (1) less (2). Even numbered years interpolated by reference to estimated expenditure by the group.

TABLE C-11

PRODUCTION AND EXPORT OF BAKING MACHINERY, AND ESTIMATED CAPITAL EXPENDITURE, BREAD AND BAKERY PRODUCTS INDUSTRY, 1919-1939

Year	Machinery Production (thousands of $)	Machinery Export (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	9,359	n.a.	21.8
1920	n.a.	-	45.6
1921	10,560	n.a.	23.5
1922	n.a.	-	30.9
1923	14,451	n.a.	32.0
1924	n.a.	-	32.0
1925	17,212	n.a.	38.1
1926	n.a.	-	49.7
1927	20,015	487	44.4
1928	n.a.	-	53.0
1929	21,730	1,002	46.0
1930	n.a.	-	33.9
1931	10,876	466	23.6
1932	n.a.	-	13.7
1933	7,332	180	15.9
1934	n.a.	-	20.8
1935	11,869	403	26.0
1936	n.a.	-	21.0
1937	18,120	661	39.6
1938	n.a.	-	30.0
1939	17,583	967	37.8

Sources: Col. (1) Census of Manufactures
(2) Foreign Commerce and Navigation
(3) 1939, Census of Manufactures, 1939; 1927-37, odd numbered years, carried back on the basis of (1) less (2); remaining odd numbered years, based on (1); even numbered years interpolated on the basis of capital expenditure by the Food and Kindred Products group.

TABLE C-12

PRODUCTION OF CANNING MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, CANNING AND PRESERVING INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	n.a.	8.0
1920	n.a.	20.8
1921	5,139	12.6
1922	n.a.	20.2
1923	9,691	23.7
1924	n.a.	21.4
1925	9,766	23.9
1926	n.a.	25.2
1927	7,339	17.9
1928	n.a.	22.8
1929	8,535	20.9
1930	n.a.	15.0
1931	4,065	9.9
1932	n.a.	6.1
1933	3,139	7.7
1934	n.a.	14.8
1935	8,271	22.1
1936	n.a.	27.1
1937	11,840	28.9
1938	n.a.	15.1
1939	4,103	10.1

Sources: (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years except 1919, extended on the basis of (1); remaining years based on estimated capital expenditure, Food and Kindred Products group.

TABLE C-13

PRODUCTION OF CEMENT-MAKING MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, CEMENT INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of 4)
1919	n.a.	4.9
1920	n.a.	8.7
1921	n.a.	5.9
1922	n.a.	6.7
1923	3,680	9.2
1924	n.a.	8.1
1925	4,146	10.4
1926	n.a.	8.9
1927	4,619	11.6
1928	n.a.	14.5
1929	4,387	11.0
1930	n.a.	5.7
1931	1,579	3.9
1932	n.a.	1.9
1933	545	1.4
1934	n.a.	2.6
1935	1,640	4.1
1936	n.a.	5.5
1937	2,065	5.1
1938	n.a.	5.1
1939	3,035	7.6

Sources: Col. (1) Census of Manufactures.
(2) 1939, Census of Manufactures; odd numbered years except 1919 and 1921 extended on the basis of (1). Remaining years interpolated on the basis of estimated capital expenditure, Stone, Clay, and Glass Products group.

TABLE C-14

PRODUCTION OF CONFECTIONERY AND ICE-CREAM MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, CONFECTIONERY INDUSTRY, 1919 - 1939.

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	9,341	6.1
1920	n.a.	5.7
1921	5,157	3.4
1922	n.a.	3.7
1923	5,029	3.3
1924	n.a.	3.0
1925	5,143	3.4
1926	n.a.	4.3
1927	5,682	3.6
1928	n.a.	3.6
1929	3,674	2.4
1930	n.a.	2.4
1931	3,809	2.5
1932	n.a.	1.5
1933	2,667	1.8
1934	n.a.	2.5
1935	5,052	3.3
1936	n.a.	4.3
1937	7,217	4.7
1938	n.a.	3.6
1939	6,985	4.6

Sources: Col. (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years, extended on the basis of (1); even numbered years, interpolated on the basis of Estimated Capital Expenditure, Food and Kindred Products group.

TABLE C-15

PRODUCTION OF CLAY-WORKING MACHINERY, ESTIMATED SALES OF CLAY-WORKING MACHINERY TO BRICK AND TILE PRODUCERS, AND ESTIMATED CAPITAL EXPENDITURE, BRICK AND TILE, 1919 - 1939

Year	Machinery Production (thousands of $)	Sales of Machinery (thousands of $)	Estimated Capital Expenditure (millions of $)
1919	3,187	n.a.	6.1
1920	n.a.	2,039	10.8
1921	3,772	1,343	7.3
1922	n.a.	2,180	11.6
1923	5,508	2,785	14.9
1924	n.a.	2,344	12.4
1925	5,298	2,474	13.2
1926	n.a.	2,453	13.1
1927	4,308	1,791	9.5
1928	n.a.	1,801	9.6
1929	4,402	1,959	10.4
1930	n.a.	986	5.3
1931	1,671	643	3.5
1932	n.a.	193	1.0
1933	591	248	1.3
1934	n.a.	247	1.3
1935	1,071	452	2.4
1936	n.a.	674	3.6
1937	2,727	n.a.	4.3
1938	n.a.	n.a.	3.0
1939	2,059	n.a.	3.2

Sources: Col. (1) Census of Manufactures
(2) M.E. West, op. cit., pp. 89 and 93.
(3) 1939, Census of Manufactures; 1919, 1935, 1937 interpolated on the basis of (1); remaining years interpolated on the basis of (2).

TABLE C-16

ESTIMATED SALES OF CLAY-WORKING MACHINERY, (OTHER THAN SALES TO BRICK AND TILE PRODUCERS), AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, CLAY PRODUCTS (OTHER THAN BRICK, TILE, AND POTTERY), 1919 - 1939

Year	Estimated Machinery Sales (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	n.a.	3.3
1920	n.a.	5.7
1921	1,575	3.1
1922	n.a.	4.0
1923	3,300	6.5
1924	n.a.	5.3
1925	3,356	6.7
1926	n.a.	5.5
1927	3,846	7.6
1928	n.a.	9.7
1929	3,751	7.4
1930	n.a.	3.7
1931	1,110	2.2
1932	n.a.	1.3
1933	362	.7
1934	n.a.	.9
1935	651	1.3
1936	n.a.	2.8
1937	n.a.	3.3
1938	n.a.	2.3
1939	n.a.	2.5

Sources: Col. (1) Table C-15: col.(1) less col. (2).
(2) 1939, Census of Manufactures; 1919, 1935, 1937 estimated on the basis of col. (1) of Table C-15; remaining odd numbered years estimated on the basis of (1) above. Even numbered years interpolated by reference to estimated capital expenditure, Stone, Clay, and Glass Products group.

TABLE C-17

PRODUCTION AND EXPORT OF FLOUR AND GRAIN MILL MACHINERY, AND ESTIMATED CAPITAL EXPENDITURE, FLOUR AND GRAIN MILL PRODUCTS INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Machinery Export (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	19,981	2,376	17.8
1920	n.a.	-	12.2
1921	8,663	1,612	7.2
1922	n.a.	-	8.5
1923	9,084	1,155	8.1
1924	n.a.	-	6.8
1925	7,946	889	7.6
1926	n.a.	-	8.8
1927	7,967	626	7.8
1928	n.a.	-	8.9
1929	8,286	686	7.7
1930	n.a.	-	5.8
1931	4,342	250	4.1
1932	n.a.	-	2.2
1933	2,354	162	2.2
1934	n.a.	-	3.6
1935	5,167	153	5.1
1936	n.a.	-	5.6
1937	6,916	207	6.7
1938	n.a.	-	4.9
1939	6,087	245	5.9

Sources: Col. (1) Census of Manufactures
(2) Foreign Commerce and Navigation
(3) 1939, Census of Manufactures; remaining odd numbered years on the basis of (1) less (2); even numbered years interpolated on the basis of estimated capital expenditure, Food and Kindred Products group.

TABLE C-18

PRODUCTION OF GLASS-MAKING MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, GLASS PRODUCTS INDUSTRY, 1919 - 1939.

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	3,316	10.2
1920	n.a.	18.2
1921	4,088	12.6
1922	n.a.	8.6
1923	2,651	8.2
1924	n.a.	6.8
1925	2,666	8.2
1926	n.a.	11.4
1927	3,085	9.5
1928	n.a.	13.3
1929	3,688	11.3
1930	n.a.	7.2
1931	2,545	7.8
1932	n.a.	3.9
1933	1,895	5.8
1934	n.a.	7.7
1935	3,543	10.9
1936	n.a.	15.2
1937	4,729	14.5
1938	n.a.	11.5
1939	4,459	13.7

Sources: Col. (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years on the basis of (1); even numbered years interpolated on the basis of estimated capital expenditure, Stone, Clay and Glass Products group.

TABLE C-19

PRODUCTION OF CONFECTIONERY AND ICE-CREAM MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, ICE CREAM INDUSTRY, 1919 - 1939.

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	9,341	17.2
1920	n.a.	16.0
1921	5,157	9.5
1922	n.a.	10.5
1923	5,029	9.0
1924	n.a.	8.4
1925	5,143	9.5
1926	n.a.	12.0
1927	5,682	10.5
1928	n.a.	10.1
1929	3,674	6.7
1930	n.a.	6.7
1931	3,809	7.0
1932	n.a.	4.1
1933	2,667	5.0
1934	n.a.	7.1
1935	5,052	9.3
1936	n.a.	12.1
1937	7,217	13.3
1938	n.a.	10.2
1939	6,985	12.9

Sources: Col. (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years, on the basis of (1); even numbered years interpolated on the basis of estimated capital expenditure, Food and Kindred Products group.

TABLE C-20

MANUFACTURE OF LEATHER WORKING MACHINERY (OTHER THAN SHOE MACHINERY), AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, LEATHER TANNING AND FINISHING INDUSTRY, 1919-1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	4,691	9.6
1920	n.a.	7.9
1921	2,526	5.2
1922	n.a.	6.1
1923	2,575	5.3
1924	n.a.	4.5
1925	2,222	4.6
1926	n.a.	5.3
1927	2,000	4.1
1928	n.a.	3.4
1929	1,249	2.6
1930	n.a.	1.8
1931	816	1.7
1932	n.a.	1.5
1933	747	1.5
1934	n.a.	1.7
1935	1,005	2.1
1936	n.a.	2.5
1937	1,220	2.5
1938	n.a.	2.3
1939	1,265	2.6

Sources: Col. (1) Census of Manufactures

(2) 1939, Census of Manufactures; remaining odd numbered years on the basis of (1); even numbered years interpolated on the basis of estimated capital expenditure Leather and Leather Products group.

TABLE C-21

PRODUCTION OF ICE-MAKING MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, MANUFACTURED ICE INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	15,665	23.4
1920	n.a.	46.0
1921	14,805	22.0
1922	n.a.	26.5
1923	17,245	25.6
1924	n.a.	21.7
1925	15,296	22.8
1926	n.a.	33.1
1927	21,681	32.2
1928	n.a.	42.0
1929	26,579	39.6
1930	n.a.	26.6
1931	10,500	15.1
1932	n.a.	6.5
1933	2,520	3.8
1934	n.a.	4.9
1935	4,040	6.0
1936	n.a.	8.2
1937	5,850	8.8
1938	n.a.	5.7
1939	4,010	6.0

Sources: Col. (1) 1919-1929, Census of Manufactures reported production of Ice-Making machinery; 1931-1939, estimated from the relationship of production of Ice-Making machinery to the total of Refrigerating and Ice-Making machinery, 1929, and data for the latter, Census of Manufactures, 1929-39.

(2) 1939, Census of Manufactures; remaining odd numbered years, estimated on the basis of (1); even numbered years, interpolation on the basis of estimated capital expenditure, Food and Kindred Products group.

TABLE C-22

PRODUCTION OF PACKING HOUSE MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, SLAUGHTERING AND MEAT PACKING INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	n.a.	8.1
1920	n.a.	21.2
1921	4,133	11.8
1922	n.a.	15.2
1923	5,411	15.6
1924	n.a.	13.9
1925	5,370	15.4
1926	n.a.	24.7
1927	8,918	25.6
1928	n.a.	26.2
1929	6,663	19.1
1930	n.a.	15.8
1931	4,622	13.3
1932	n.a.	7.4
1933	2,756	7.9
1934	n.a.	11.6
1935	5,317	15.3
1936	n.a.	19.6
1937	7,029	20.2
1938	n.a.	14.6
1939	6,023	17.4

Sources: Col. (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years except 1919 interpolated on the basis of (1); remaining years interpolated on the basis of estimated capital expenditure, Food and Kindred Products group.

TABLE C-23

PRODUCTION OF TOBACCO MANUFACTURING MACHINERY, AND ESTIMATED EXPENDITURE FOR NEW PLANT AND EQUIPMENT, TOBACCO PRODUCTS INDUSTRY, 1919 - 1939

Year	Machinery Production (thousands of $)	Estimated Expenditure Plant and Equipment (millions of $)
1919	n.a.	12.0
1920	n.a.	16.0
1921	n.a.	7.6
1922	n.a.	7.3
1923	3,647	7.5
1924	n.a.	7.4
1925	3,818	8.0
1926	n.a.	10.7
1927	4,970	10.5
1928	n.a.	10.0
1929	5,018	10.6
1930	n.a.	9.3
1931	3,471	7.3
1932	n.a.	3.3
1933	1,106	2.3
1934	n.a.	2.8
1935	1,693	3.5
1936	n.a.	5.5
1937	3,679	7.7
1938	n.a.	5.5
1939	3,337	7.0

Source: Col. (1) Census of Manufactures
(2) 1939, Census of Manufactures; remaining odd numbered years except 1919 and 1921 interpolated on the basis of (1); even numbered years interpolated by reference to estimated capital expenditure, Manufacturing as a whole; for procedure in estimating 1919 and 1921, see text.

APPENDIX D

BASIC DATA EMPLOYED IN THE COMPUTATION OF STATISTICAL INPUT-OUTPUT FUNCTIONS

TABLE D-1

BLAST FURNACE INDUSTRY, MONTHLY EMPLOYMENT

(thousands of workers)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	30.8	25.8	22.1	17.9	16.7	16.6	14.0	13.9	14.7	16.2	17.5	18.2
1923	31.8	33.6	34.8	36.3	38.5	39.8	39.3	38.7	38.5	36.9	36.4	36.0
1925	31.9	32.4	32.1	30.9	29.1	27.0	27.2	26.8	27.1	27.9	28.4	29.0
1927	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1929	24.9	24.7	24.6	24.8	25.3	25.3	25.3	25.4	25.1	25.9	24.8	22.2
1931	15.8	16.0	15.7	15.5	15.4	14.0	13.1	12.2	11.8	11.7	11.3	10.4
1933	9.0	9.3	8.7	8.5	9.2	11.3	13.8	15.5	15.6	15.5	14.6	14.0
1935	13.2	14.5	14.5	14.8	15.2	15.1	14.9	15.6	15.9	16.1	16.2	16.1
1937	21.0	21.5	22.5	23.6	24.7	23.0	25.0	25.4	25.2	24.3	21.8	18.9
1939	17.5	17.6	17.9	17.6	16.5	17.7	18.1	18.6	20.9	24.0	24.1	23.9

Source: Census of Manufactures

TABLE D-2

BLAST FURNACES, STEEL WORKS, AND ROLLING MILLS, MONTHLY ESTIMATED AVERAGE WEEKLY HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	55.7	50.6	54.0	53.7	47.3	49.5	53.3	55.1	54.2	60.9	56.6	58.0
1923	61.3	60.2	60.4	60.2	60.0	59.3	61.9	57.0	51.4	53.3	50.5	56.8
1925	56.0	53.5	54.6	53.0	51.4	51.3	52.4	51.8	54.9	54.4	54.7	55.6
1927	-	-	-	-	-	-	-	-	-	-	-	-
1929	56.0	55.4	55.7	55.6	55.2	55.7	54.8	54.9	55.5	56.4	52.6	51.0
1931	45.3	45.6	45.5	44.5	42.3	42.6	44.5	41.0	42.8	41.8	44.5	40.9
1933	27.0	30.4	26.8	30.3	35.4	39.4	42.4	39.3	35.9	36.0	31.2	33.3
1935	32.2	35.9	35.2	34.7	34.2	32.4	30.2	34.1	36.0	36.5	36.4	38.9
1937	42.7	42.9	43.5	42.6	41.3	40.2	38.1	40.5	37.5	35.7	30.7	27.3
1939	33.7	32.4	34.4	33.6	32.8	33.6	32.1	35.7	35.2	40.0	39.2	39.0

Sources: 1921-35, M. Ada Beney, Wages, Hours, and Employment in the United States, 1914-1936, National Industrial Conference Board, N.Y., 1936, Table 19; 1937-39, Bureau of Labor Statistics.

TABLE D-3

BLAST FURNACES, INDEX OF MONTHLY MAN-HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	172.5	130.5	119.0	96.0	79.1	82.3	74.4	76.7	79.7	98.6	99.0	105.0
1923	194.9	202.0	210.0	218.0	231.0	236.0	243.9	220.5	197.9	196.8	183.3	204.3
1925	178.6	173.2	175.1	164.8	151.6	138.3	142.6	139.0	148.8	152.0	155.1	161.2
1927	-	-	-	-	-	-	-	-	-	-	-	-
1929	139.4	138.0	137.0	137.0	138.1	142.0	138.9	139.4	139.2	146.0	146.5	113.8
1931	71.5	72.9	71.6	69.0	65.0	59.5	58.2	50.2	50.5	48.9	50.4	42.5
1933	24.2	28.3	23.4	25.8	32.4	44.8	57.4	60.9	56.0	55.3	46.0	46.9
1935	41.9	52.0	51.0	51.5	51.7	49.0	45.1	54.5	57.0	58.8	59.1	62.6
1937	90.0	92.1	98.0	100.1	101.5	92.5	95.2	102.8	94.0	86.8	67.0	51.6
1939	59.0	59.9	61.6	59.1	54.0	60.0	58.1	66.4	73.6	96.0	93.1	93.2

Source: Computed from Tables D-1 and D-2.

TABLE D-4

BLAST FURNACES, MONTHLY PIG IRON PRODUCTION

(millions of short tons)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	2.706	2.170	1.787	1.886	1.368	1.193	.968	1.069	1.104	1.396	1.585	1.847
1923	3.617	3.353	3.947	3.976	4.332	4.118	4.120	3.863	3.501	3.527	3.242	3.272
1925	3.775	3.600	3.992	3.650	3.283	2.994	2.984	3.029	3.053	3.386	3.386	3.641
1927	-	-	-	-	-	-	-	-	-	-	-	-
1929	3.855	3.591	4.160	4.102	4.366	4.163	4.239	4.206	3.917	4.019	3.563	3.177
1931	1.920	1.911	2.276	2.262	2.233	1.835	1.639	1.434	1.309	1.314	1.236	1.098
1933	.637	.621	.607	.698	.994	1.417	2.008	2.053	1.705	1.519	1.215	1.324
1935	1.655	1.802	1.982	1.863	1.934	1.739	1.703	1.973	1.990	2.216	2.314	2.359
1937	3.597	3.359	3.875	3.799	3.962	3.480	3.919	4.039	3.820	3.240	2.248	1.669
1939	2.436	2.307	2.682	2.303	1.924	2.373	2.639	2.979	3.224	4.063	4.167	4.221

Source: Dpt. Commerce summary of data compiled by Iron Age, cf. Survey of Current Business, Vol. 20, no. 10, Oct. 1940, p.14.

TABLE D-5

STEEL WORKS AND ROLLING MILLS, MONTHLY EMPLOYMENT, 1921-1939.

(thousands of workers)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	293	276	252	223	222	211	183	205	219	239	252	249
1923	377	376	393	389	397	399	390	398	393	397	382	368
1925	380	382	385	375	367	360	354	354	364	370	375	382
1927	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1929	386	391	400	407	412	410	411	411	398	391	365	350
1931	294	300	308	303	291	269	257	242	233	230	224	224
1933	216	220	204	219	239	270	311	334	337	337	317	318
1935	340	356	361	359	356	351	351	361	362	369	373	378
1937	471	479	496	506	510	469	504	504	500	476	437	399
1939	344	346	347	346	342	344	345	349	375	416	434	439

Source: Census of Manufactures

TABLE D-6

STEEL WORKS AND ROLLING MILLS, INDEX OF MONTHLY MAN-HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	163	140	136	120	105	104	98	113	119	145	143	145
1923	231	226	237	234	238	236	241	231	202	212	193	209
1925	213	204	210	199	188	185	185	183	200	201	205	214
1927	-	-	-	-	-	-	-	-	-	-	-	-
1929	216	217	223	226	228	228	225	226	221	220	192	178
1931	133	137	140	135	123	115	114	99	100	96	100	92
1933	58	67	55	66	85	106	134	131	121	121	90	106
1935	109	127	127	124	122	113	106	123	130	135	136	147
1937	197	203	214	215	211	188	192	201	189	176	143	120
1939	95	100	103	103	103	102	102	113	124	145	152	156

Source: Computed from Tables D-2 and D-5.

TABLE D-7

STEEL WORKS AND ROLLING MILLS, INDEX OF MONTHLY OUTPUT

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	55	44	39	30	32	25	20	28	29	40	42	36
1923	84	76	89	87	92	82	77	81	73	78	69	63
1925	92	82	92	78	76	70	67	75	76	85	85	87
1927	84	84	100	91	89	77	71	77	72	73	69	70
1929	99	96	112	109	117	108	107	109	100	100	79	64
1931	55	56	67	61	56	47	42	38	34	35	35	29
1933	23	24	20	30	44	57	70	64	51	46	34	40
1935	64	62	64	59	59	50	50	65	63	70	70	68
1937	105	98	116	113	115	93	101	108	95	75	48	33
1939	71	66	76	66	65	69	70	84	94	120	121	115

Source: Monthly gross ingot tons expressed as per cent of 1929 average. Tonnage figures were obtained from testimony presented on behalf of the United States Steel Corp. before the T.N.E.C. (Hearings, Part 26, p. 13858).

TABLE D-8

RUBBER TIRE AND TUBE INDUSTRY, MONTHLY EMPLOYMENT

(thousands of workers)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	38.1	40.3	43.1	51.6	59.4	59.8	64.4	68.1	63.3	60.3	58.1	59.4
1923	77.8	82.7	86.3	86.6	85.6	80.3	70.6	64.5	61.1	60.4	64.7	66.9
1925	75.3	76.9	78.4	81.5	84.7	85.5	87.8	88.5	84.8	80.1	77.4	78.8
1927	74.4	75.6	77.0	81.5	84.5	82.8	81.1	80.5	78.0	74.6	71.4	73.0
1929	84.8	86.8	87.6	89.1	90.9	91.8	90.6	86.4	80.8	74.8	69.1	66.5
1931	49.8	49.4	49.6	50.0	51.6	52.0	50.6	49.4	47.8	46.7	46.6	46.5
1933	43.1	43.2	42.3	41.8	47.6	54.1	60.2	64.1	62.5	60.4	58.7	57.8
1935	59.1	59.9	59.6	59.4	58.6	57.7	56.0	55.0	55.3	55.4	54.6	54.9
1937	66.4	67.0	57.8	57.8	67.3	66.7	65.8	65.7	65.4	63.5	59.3	57.1
1939	52.4	52.1	52.5	52.5	52.5	52.5	53.0	54.2	55.7	58.0	56.9	57.2

Source: Census of Manufactures, except 1927; 1927 interpolated on the basis of the B.L.S. index of employment for the industry.

TABLE D-9

RUBBER TIRE AND TUBE INDUSTRY, MONTHLY ESTIMATED AVERAGE WEEKLY HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	39.1	40.2	42.7	44.5	42.8	44.7	46.1	46.5	44.3	44.3	44.0	45.8
1923	46.3	47.8	47.2	46.6	46.6	44.6	42.0	41.3	43.1	43.3	44.2	44.4
1925	45.1	45.1	45.3	44.0	44.8	43.5	45.2	45.0	45.0	43.1	43.4	44.3
1927	46.2	46.2	45.9	46.2	46.0	46.2	45.4	45.6	44.7	44.3	44.0	44.3
1929	46.7	47.0	46.5	47.5	47.5	46.9	44.9	42.7	44.3	41.7	39.8	41.5
1931	37.4	39.6	40.4	40.9	44.5	44.4	38.8	37.5	36.8	32.6	32.0	32.2
1933	29.8	29.6	24.7	30.7	34.7	40.2	40.0	34.8	31.8	33.9	30.9	31.9
1935	33.0	33.7	31.7	33.3	32.9	32.4	30.8	32.2	32.9	32.6	35.2	36.4
1937	33.4	34.3	35.1	34.6	33.2	32.1	31.7	30.9	30.8	29.3	27.2	28.0
1939	34.2	33.2	34.0	33.3	33.2	34.9	35.6	35.5	36.2	37.5	35.1	36.1

Sources: 1921-31, National Industrial Conference Board series for Rubber Manufacturing;
1933-39, Bureau of Labor Statistics series for Tire and Tube industry.

TABLE D-10

RUBBER TIRE AND TUBE INDUSTRY, INDEX OF MONTHLY MAN-HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	149	162	184	230	254	268	296	316	294	267	256	272
1923	360	394	407	404	400	358	296	266	266	262	286	297
1925	340	347	354	359	379	372	397	398	382	346	336	348
1927	344	351	353	376	389	382	368	367	349	330	314	323
1929	396	407	407	424	431	430	406	369	358	312	275	276
1931	186	195	200	202	230	231	196	185	176	152	149	150
1933	128	128	105	128	165	218	241	223	199	204	181	185
1935	195	202	189	198	193	187	172	177	182	177	192	200
1937	222	230	207	200	223	214	209	203	201	186	162	160
1939	179	173	179	175	173	183	189	193	202	218	200	206

Source: Computed from Tables D-8 and D-9

TABLE D-11

RUBBER TIRE AND TUBE INDUSTRY, INDEX OF MONTHLY OUTPUT

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921	22	24	30	45	58	66	85	66	64	65	68	60
1923	92	104	112	109	108	89	62	68	69	69	75	77
1925	108	119	117	118	126	120	122	128	118	100	104	107
1927	113	120	132	141	140	135	118	121	111	106	102	101
1929	145	162	166	170	175	167	139	123	113	103	83	71
1931	86	100	107	113	136	130	111	93	77	67	63	61
1933	54	58	45	76	118	139	140	110	98	79	73	75
1935	106	110	102	103	96	95	81	91	97	91	99	99
1937	119	129	128	129	128	119	98	90	103	91	73	64
1939	110	109	114	104	102	112	111	122	123	126	118	110

Source: Federal Reserve Board

TABLE D-12

CEMENT INDUSTRY, MONTHLY EMPLOYMENT

(thousands of workers)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
1921												
1923												
1925	35.4	35.0	36.7	38.2	38.6	40.1	40.8	40.8	40.8	40.0	38.4	36.4
1927	35.0	34.2	36.2	37.7	38.6	39.6	40.0	40.0	39.6	38.6	37.2	34.8
1929	31.3	30.9	32.5	33.8	35.0	35.6	35.5	35.7	34.6	33.5	32.2	30.0
1931	23.5	23.7	24.8	26.7	26.9	26.5	26.1	25.3	23.9	23.4	20.7	20.2
1933	12.9	12.8	13.0	15.3	16.0	18.3	19.7	20.8	18.9	16.4	16.3	14.6
1935	15.9	16.1	17.7	20.9	23.5	24.6	23.5	22.4	21.7	21.9	21.3	18.8
1937	23.2	23.9	26.2	27.3	27.9	28.1	28.2	28.0	28.0	27.3	25.8	23.1
1939	18.4	19.5	21.7	23.4	24.0	25.7	26.2	26.1	25.6	25.9	25.2	23.7

Sources: Census of Manufactures except 1927 and 1933; 1927 and 1933 interpolated on the basis of the B.L.S. index of cement employment.

TABLE D-13

CEMENT INDUSTRY, MONTHLY ESTIMATED AVERAGE WEEKLY HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921												
1923												
1925	..... average for the year = 61.5											
1927	..... average for the year = 59.5											
1929	..... average for the year = 58.6											
1931	..... average for the year = 48.9											
1933	30.8	32.5	34.0	31.9	37.5	38.7	38.9	35.8	31.5	33.2	32.4	28.5
1935	29.6	30.3	31.6	33.8	34.2	35.4	35.1	35.4	35.0	34.0	34.8	36.0
1937	35.7	36.8	39.1	39.5	39.4	40.6	39.0	41.2	38.7	39.3	38.3	36.1
1939	35.7	36.1	36.9	37.6	38.0	39.1	38.0	38.9	38.3	40.4	38.8	39.0

Sources: 1925-31 averages computed from data of Table B-6; 1933-39, Bureau of Labor Statistics.

TABLE D-14

CEMENT INDUSTRY, INDEX OF MONTHLY MAN-HOURS

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921												
1923												
1925	214	215	216	235	238	247	251	252	252	246	236	224
1927	208	203	206	224	230	236	238	238	236	230	221	204
1929	183	181	190	198	204	208	208	209	203	196	188	176
1931	115	116	121	130	132	129	127	124	117	115	101	99
1933	40	42	44	49	60	71	77	75	60	55	53	42
1935	47	49	56	71	80	87	83	79	76	75	74	68
1937	83	87	102	108	110	114	106	115	108	107	99	84
1939	66	71	80	88	92	100	99	102	98	105	98	93

Source: Computed from the data of Tables D-12 and D-13.

TABLE D-15

CEMENT INDUSTRY, MONTHLY PRODUCTION OF PORTLAND CEMENT

(millions of barrels)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1921												
1923												
1925	8.9	8.3	11.0	13.8	15.5	15.4	15.6	16.4	15.9	16.0	13.7	10.7
1927	8.3	7.4	11.5	14.1	16.7	17.2	17.4	18.3	17.5	17.2	14.5	12.0
1929	9.9	8.5	10.0	13.8	16.2	16.8	17.3	18.6	17.2	16.7	14.1	11.2
1931	6.6	5.9	8.3	11.3	14.0	14.1	13.9	13.6	12.1	10.8	8.2	6.0
1933	3.0	2.8	3.7	4.2	6.3	7.8	8.6	8.2	5.6	5.0	4.7	3.5
1935	3.2	3.1	4.3	6.1	8.2	8.7	8.0	7.2	7.2	7.5	7.1	5.8
1937	6.6	5.8	8.4	10.4	11.6	11.2	11.6	11.9	11.2	11.4	9.3	7.0
1939	5.3	5.5	8.2	9.7	11.2	12.0	12.6	12.4	11.9	12.5	11.0	9.5

Source: Department of Commerce. Data published currently in the Survey of Current Business.

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