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Harry Magdoff

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THE PURPOSE AND METHOD OF MEASURING PRODUCTIVITY*

By Harry Magdoff
National Research Project
Works Progress Administration

Productivity measures may serve various purposes and the method of measurement will depend upon the purpose of the analytical inquiry or the social policy to be formulated or administered. The measures of productivity which will be discussed in this paper were developed in the course of a study of unemployment conducted by the National Research Project of the WPA. The central question concerning unemployment today revolves around the possibility that the current unemployment problem is of a different nature from those of the past. The problem is in part one of the changing structure of the economy and the relationship of this factor to the prospects of future employment. Within the context of this problem arises the question concerning the bearing of the changing productivity of labor on the total volume of labor utilized.[1]

The effect of changes in productivity on the total volume of labor time employed depends on the volume of production and on the types of goods produced. In order to analyze the economic relations involved in the volume of labor time utilized it is, therefore, necessary to construct measures of both production and of labor productivity for each of the several commodities produced.

In addition to problems of analysis, the extent and duration of unemployment today raises a number of questions of government policy. Considerations of the responsibility of government to provide for the needy, the tremendous social cost involved in the waste of human skills and energy, and the resulting lack of purchasing power, direct public attention to the development of a long-term program to provide aid and economic security to all. To plan such a program intelligently, it is necessary to know the relevant facts concerning previous volumes of unemployment and to estimate the probable future volumes of unemployment. Should the concrete program dictated by public policy take the form of providing work relief for all the unemployed in order

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[1] Changes in productivity are the result not only of changes in machine technology, but in the organization of the productive process which affects the plant layout, division of labor, increase in the speed of operation of individual employees, etc., but also of such changes as the relative importance of plants having a higher ratio of output per man-hour and the percentage utilization of capacity. Hence, in order to fully explain the reasons for changing productivity in a given industry, it is necessary to make a detailed study of the economics and technology of that industry.

to utilize their experience and to maintain their skills on useful projects, then the inquiry would have to be directed to the question: Where are the unemployed and who are they? There are therefore two lines of inquiry with which such a government program would be concerned, one with the future *volumes* of employment and unemployment, and another with the geographic distribution of the unemployed labor force according to their skills and occupational characteristics.

We are here dealing with only the first of these problems, which centers on the answers to the following questions: How much employment and unemployment would there be if we again attained the production levels of 1929? How much production is necessary in order to employ the 1929 or the 1938 labor supply? In more generalized form these questions are of the following two types:

1. What relative volumes of labor time are required to produce a given composite of products at different times?
2. What relative volumes of production of a given composite of products are obtainable at different times with a given amount of labor time?

These two questions determine the required statistical measures of unit labor requirements and productivity. The statistical data necessary to answer these questions are (1) the quantities of each product produced and (2) the corresponding man-hours utilized in their production.[2] The answer to the first question can be obtained by computing a ratio of the aggregated labor requirements for a given composite of products at different times. This gives us a measure of average unit labor requirements.

The second question refers to the production that can be obtained with a given labor supply, and defines the desired statistical measurement of labor productivity. The assumption implicit in the use of this question is that there exists a sufficiently large and diverse unemployed labor supply which would be reemployed if production increased. Hence interest centers only on *volumes* of employment and unemployment; and qualitative differences in skills, occupations and efficiency of the individual employees need not be taken into consideration. Labor may be considered as homogeneous, and its unit of measurement as an hour of undifferentiated labor. The measure of the volume of labor time is, therefore, the total man-hours utilized in industry.

Since the question is to what extent the unemployed would be reem-

[2] We are not concerned in this paper with the technical problems of measurement arising from the lack of necessary statistical data and the inadequacy of the available data. It is assumed that the required comparable data on quantities and man-hours are available in sufficient detail.

ployed under conditions of rising production and increasing productivity,[3] the volume of production of individual commodities becomes significant only in so far as more or less labor is required to produce them. Moreover, since labor time may be considered homogeneous for our purpose, it is possible to measure quantitatively the relative changes in the volume of a specified group of diverse products in terms of man-hours. This approach is analogous to that required in the construction of measures of production and prices for the purpose of analyzing fluctuations in the volume of trade. For that purpose the ultimate unit for measuring production is a pecuniary one.[4] We, on the other hand, are interested in the volume of production as related to the volume of labor utilized, hence the logical measure of production for our purpose is in terms of labor time.

The necessity of clearly defining the criterion for measuring the relative importance of diverse products can be seen in the following illustrations for the Cigars and Cigarettes industries. The index of unit labor requirements for the two industries combined, when derived by use of a production index based on value weights is in 1926 higher than either the unit labor requirements of the Cigars industry or the Cigarettes industry separately; after 1929, the index of average unit labor requirements of the composite is lower than that for either industry. Since our problem is to determine the volume of labor required to produce cigars and cigarettes at different levels of production and productivity, the composite index of production derived by using value weights is misleading. For this index results in a measure of unit labor requirements which understates the labor required after 1929 to produce the 1929 volume of cigars and cigarettes. On the other hand, the composite unit labor requirements index obtained by weighting production with man-hours, measures relatives of the total labor required in any one year to produce the 1929 output.

The index of unit labor requirements is conceptually very simple. It answers a specific question concerning the relative volumes of labor time and comprises ratios of *aggregates of labor time.* However, the fact that the different products are measured in diverse physical units pre-

[3] The term "labor productivity" as used in this paper has a definite technical meaning, confined to the ratio of production to labor time utilized. Though the ultimate unit of measurement of labor time is one hour, there are questions concerning the productivity of labor which may require the use of other labor time units, such as a man-day or man-week. In this paper we refer to only two measures of productivity: output per man-hour and output per wage earner.

[4] See, for instance, Arthur F. Burns, "The Measurement of the Physical Volume of Production," *Quarterly Journal of Economics*, Vol. 44, p. 251; Edward E. Lewis, "Some Basic Problems in Index-Number Theory," *Economic Essays in Honor of Wesley Clair Mitchell* (New York: Columbia University Press, 1935), pp. 271–278; Gottfried Haberler, *Der Sinn der Indexzahlen* (Tübingen: J. C. B. Mohr, 1927), pp. 64–68.

cludes the direct measurement of aggregate production or productivity in a similar manner. We have already shown that the criterion of comparing the relative importance of different products is, for our purpose, the number of man-hours required to produce a unit of each product.

TABLE 1

INDEXES OF UNIT LABOR REQUIREMENTS FOR CIGARS, CIGARETTES, AND FOR CIGARS AND CIGARETTES COMBINED, 1919–36

(1929 = 100)

Year	Cigars	Cigarettes	Cigars and cigarettes: number based on composite production indexes constructed with	
			Value weights	Man-hour weights
1919	122.9	323.3	222.0	150.8
1920	110.0	348.2	233.1	143.2
1921	125.9	259.2	214.6	144.3
1922	123.7	227.4	200.5	138.1
1923	121.7	182.4	176.4	130.1
1924	116.4	164.5	158.2	123.1
1925	116.1	145.7	144.9	120.3
1926	109.8	123.8	128.1	111.7
1927	112.5	129.4	127.3	114.8
1928	109.2	129.7	117.8	112.1
1929	100.0	100.0	100.0	100.0
1930	101.5	95.0	94.5	100.7
1931	86.7	92.6	80.2	87.6
1932	95.4	89.9	81.3	94.6
1933	88.2	81.6	70.9	87.3
1934	79.2	98.3	64.3	81.9
1935	66.5	88.6	52.8	69.6
1936	63.9	73.3	47.9	65.2

However, the method of using these man-hours as weights and the type of average must be determined in relationship to a more specific definition of the purpose. The measures we seek should be consistent with aggregates of labor time and should satisfy the questions posed above. Hence the necessary index of production is one which, when divided into the relatives of total man-hours, will yield an index of unit labor requirements which measures "the relative changes in the volume of labor required to produce a given composite of products." Thus the same measure of the average unit labor requirements should be obtained either by (1) aggregating the labor requirements for the indi-

vidual items in a given composite of products and reducing these aggregates to relatives or (2) dividing the relatives of total man-hours by the proper index of production. Then $L = M/Q$, where L represents the index of unit labor requirements, M the relatives of total man-hours and Q the production index.

Likewise, the same measure of productivity (which is the reciprocal of the measure of unit labor requirements) should be obtained whether (1) the indexes of productivity for each product are averaged with appropriate weights or (2) the index of production is divided by the relatives of total man-hours. Then $P' = Q/M$, where P' represents the index of productivity.

Now, changes in the labor requirements per unit for a group of products arise out of the joint operation of two factors: changes in the labor requirements per unit of output of the several products and changes in the relative volume of output of the several products. Thus, in order to analyze changes in the unit labor requirements for a group of products, it is necessary to eliminate the factor of changing composition of production and to formulate questions only in terms of a "*given* composite of production."

The selection of the "given composite" for which unit labor requirements are to be measured does not represent a statistical problem but one which depends upon the purposes to be served by the economic analysis. We have chosen two alternative composites, (1) a base year composite of production and (2) the current year's composite of production. Two sets of formulas therefore had to be developed for measuring production, productivity, and unit labor requirements; one using base year weights and the other current year weights. Then on the basis of the two questions posed above and the criterion that $L = M/Q$, the following alternative sets of formulas were derived:[5]

		Base year production composite		Current year production composite
Unit labor requirements	(1)	$\frac{\sum l_i q_0}{\sum l_0 q_0}$	(2)	$\frac{\sum l_i q_i}{\sum l_0 q_i}$
Productivity	(3)	$\frac{\sum l_0 q_0}{\sum l_i q_0}$	(4)	$\frac{\sum l_0 q_i}{\sum l_i q_i}$

In order to construct production measures suitable for the computation

[5] The derivation of these formulas and the discussion of their meaning will be found in the introduction to a forthcoming report of the National Research Project—Production, Employment and Productivity in Manufacturing Industries, 1919–36.

of the above measures for the base year and current year composites formulas (5) and (6) would have to be applied.

Production (5) $\frac{\sum q_i l_i}{\sum q_0 l_i}$ (6) $\frac{\sum q_i l_0}{\sum q_0 l_0}$

q represents the quantities of each product produced, l the unit labor requirements, which is the ratio of man-hours utilized to the quantities produced; and the subscripts 0 and i designate base year and current year respectively.

The selection of the composite to be used depends upon the characteristics of the period under consideration. Thus the use of a base year composite has greater value under relatively stable conditions of production. In general, the use of a base year composite has more significance when dealing with relatively short periods of time. There are, however, certain times when the use of a base year composite may nevertheless be significant even in periods characterized by shifts in the composition of production. For instance, we are interested in the answer to the question, How much labor would be required if we again attained the 1929 volume and composition of production? Aware of the changed importance of the consumers goods and capital goods sections, one may yet assume that when 1929 volumes of production are again attained the composition of production would revert to one similar to that of 1929. Such an assumption would then permit the construction of measures using the 1929 production composite as a system of fixed weights. Should, however, analysis of present conditions indicate that the composition of production today is likely to be typical of the future, then the questions would have to be formulated in terms of the 1938 composition of production, or in terms of a changing composition of production. When the changing composition of production is in a definable direction, not random, then the question put in terms of the current year composite is a more fruitful one.

Since the composition of production is always changing, the question is: How does one determine whether a changing composition of production is significant from the standpoint of measuring productivity? When both measures are constructed, one using a base year composite and the other a current year composite, the difference between the two results constitutes a measure of the effect of changing composition of production and can be used as a guide.[6]

[6] The differences in the results obtained by two such measures and the effect of correlation between the weights and relatives have often been analyzed in index number literature with reference to price indexes and value-weighted production indexes. See, for instance, Staehle, *International Comparisons of Cost of Living* (International Labor Office, 1934); L. von Bortkiewicz, "Die Kaufkraft des Geldes und ihre Messung," *Nordic Statistical Journal*, Vol. 4 (1932), parts 1–2, pp. 1–68; Lewis, *op. cit.*, pp. 292–293; Warren M. Persons, *The Construction of Index Numbers* (Harvard Economic Society, Inc., 1928), pp. 33–36.

The differences between the results of the two alternative measures are most pronounced when there is a distinct correlation in the relative changes of production and productivity of the individual products. For instance, should productivity increase more rapidly for those products which show a more rapid rise in production, the productivity index with reference to the current year composite will be higher than the index referring to the base year composite. This is illustrated in Table 2. Using Dr. Mills' indexes of output per wage earner for 32 manufacturing industries from 1899 to 1914, we have constructed two composites—one with 1899 and the other with current year employment weights. The important differences between the two indexes occur in the years 1909 and 1914, and are due to the rapid changes in the

TABLE 2

COMPOSITE INDEXES OF OUTPUT PER WAGE EARNER FOR 32 MANUFACTURING INDUSTRIES, 1899–1914*

(1899 = 100)

Year	Index of output per wage earner with	
	Base year employment weights	Current year employment weights
1899	100.0	100.0
1904	104.1	105.4
1909	103.5	110.0
1914	111.7	127.9

* The composite indexes were derived from the indexes of output per wage earner for individual industries presented by Frederick C. Mills in *Economic Tendencies in the United States* (New York: National Bureau of Economic Research, 1932), p. 33. Mills presents data for 35 industries. For three of these, however, index numbers are not shown for each of the census years in the 1899–1914 period; all computations, therefore, are based upon data for 32 industries only. Corresponding wage earner figures, which were used as weights, are from the *Census of Manufactures*.

structure of the manufacturing economy. The difference in 1914 reflects to a large extent the rapid growth of the Automobiles industry since 1909. This can be readily seen when the Automobiles industry is excluded from the composite indexes (see Table 3). Since the Automobiles industry was insignificant in 1899 (0.1 per cent of total employment of the industries covered by Mills' composite) and this index presents relative changes in the productivity for the production schedule of 1899, it does not reflect the effect of the growth and rapidly increasing productivity of the Automobiles industry. On the other hand, when the Automobiles industry was given its changing relative weight each year in the index with current year weights, this index reflected the effect of its rapidly rising productivity in 1914, the year in which the Automobiles industry assumed importance. Even when the Automobiles industry is excluded we notice that there is still a consid-

erable difference between the results obtained by the two formulas for the years 1909 and 1914. These differences result from the fact that production increased most rapidly in those industries which had the highest rates of productivity increase.

TABLE 3

COMPOSITE INDEXES OF OUTPUT PER WAGE EARNER FOR 31 MANUFACTURING INDUSTRIES (AUTOMOBILES EXCLUDED), 1899–1914*

(1899=100)

Year	Index of output per wage earner with	
	Base year employment weights	Current year employment weights
1899	100.0	100.0
1904	104.1	105.4
1909	103.5	110.0
1914	111.6	118.8

* Based on same data as Table 2, with the Automobiles industry excluded.

TABLE 4

COMPOSITE INDEXES OF OUTPUT PER MAN-HOUR FOR 59 MANUFACTURING INDUSTRIES, 1919–36*

(1929=100)

Year	Base year production composite	Current year production composite
1919	63.5	69.1
1920	67.3	72.3
1921	71.7	77.4
1922	77.2	80.3
1923	81.3	82.9
1924	84.0	85.7
1925	88.4	89.4
1926	91.4	92.0
1927	92.5	93.3
1928	97.0	97.3
1929	100.0	100.0
1930	100.9	101.1
1931	104.1	106.1
1932	103.1	107.5
1933	107.6	113.4
1934	110.8	113.7
1935	118.3	122.2
1936	121.6	123.9

* Based on preliminary indexes of output per man-hour for 59 manufacturing industries. The indexes upon which this composite is based will be presented in a forthcoming report of the National Research Project—*Production, Employment and Productivity in Manufacturing Industries, 1919–36.*

This can be illustrated further with reference to the period 1919–36, for which we, on the National Research Project, have constructed indexes of production and productivity for 59 different manufacturing industries. These have been combined into two indexes, one using 1929 and the other current year man-hour weights. (See Table 4.) The differences in the results obtained by using the two indexes are relatively minor, but the character of the divergence is instructive. For the period 1919–29 we note that the productivity for the 1929 production schedule increases more rapidly than that for the current year production composite. The reason is that productivity increased more rapidly in those industries where production increased more rapidly. However, the production increases in these industries have not been large enough to result in as wide a divergence as for the period 1899–1914. From 1929 to 1936 it is interesting to note that the direction of the differences is reversed. During this period the capital goods and durable goods industries declined more precipitously than did the non-durable consumption goods industries. It is also in the durable goods industries that declines in productivity during the period of falling production are found more frequently than in the non-durable goods industries. As a matter of fact, in most of the consumption goods industries, the output per man-hour increased even during the years of declining production after 1929, and when production began to rise the productivity of the non-durable consumption goods industries increased more rapidly. The index constructed with current year weights, which reflects these changes in the composition of production, therefore shows a greater increase in productivity than the index using the base year (1929) weights.[7]

The value of using both formulas together lies in the fact that while each measure answers a different, specific question, together they give added significance to the analysis of productivity changes because they reflect the magnitude of the differences resulting from the changing composition of production. It might be suggested that a "compromise" formula, for instance a geometric average of the two formulas, could have overcome the seeming paradox of two different measures describing what appears to be the same concept. Such a "compromise" formula has been avoided, however, for a definite reason. The position taken here is that there is no "true" measure of productivity or produc-

[7] In using the data on productivity for the purpose of estimating future labor requirements, it is of course important not to compare the figure for one year simply with that of any other single year, but to interpret the annual data in the light of the historical trend. In doing so it is possible to take into account the effect of such factors as percentage utilization of capacity, the survival of the most efficient and the mortality of the least efficient plants on the productivity changes for a given period. This is particularly important in periods characterized by wide fluctuations in production.

tion for a group of diverse products; that measures of production and productivity should therefore not be considered "approximations" to an ideal "reality;" and that a clear understanding of the specific purposes for which they are to be used and of the questions that are being answered must dictate the method used to construct them. The more clearly the purposes and the meaning of these measures are understood, the more valuable they are.

Had the basic purposes of measuring production and productivity been directed to other ends, the formulas discussed here would, of course, not be relevant. For instance, if it were desired to utilize the entire labor supply and to distribute this man-power in production activities according to a defined scheme of economic development, say the achievement of a steadily increasing standard of living, then the significant measure of labor would be not the aggregate of undifferentiated labor as used by us, but a distribution of available man-power by industry, occupation, skill, location, mobility, etc. Furthermore, since the selection of different types of productive activity and the allocation of economic resources would be determined by the requirements of the given purpose, namely, increasing the standard of living, the criteria for measuring the relative importance of diverse types of products would also be determined in terms of that given social objective. The question, What volumes of production are obtainable with a given labor supply?, though superficially analogous to our former question, could not be answered for this particular purpose either by the measures designed by us or by any other production or productivity index commonly used. The problem with which we were confronted arose from an already existing allocation of human and natural resources which was determined through the operations of the market. The criteria for comparing the relative significance of diverse products under such conditions were thus dictated by the existing methods of labor utilization and the existing patterns of production, and were defined in accordance with the specific purpose of our analysis.