PRODUCTIVITY OF LABOR IN AGRICULTURAL PRODUCTION

Folke Dovring

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PRODUCTIVITY OF LABOR IN AGRICULTURAL PRODUCTION

SUMMARY OF METHOD AND FINDINGS

This bulletin presents results from detailed studies of aggregated labor productivity in United States agriculture. This productivity concept is the ratio of farm output for final use over the sum of direct (on-farm) and indirect (off-farm) labor used for agricultural production. Indirect labor is estimated from the amounts of money spent by farmers for farm production requisites (capital goods and current production inputs). Such an estimate gives an approximate measure of the part of the nonfarm labor force that is indirectly contributing to agricultural production.

The research reported here examines some of the effects and interactions of federal support policies for agriculture and their long-run effects on agriculture as an industry, rather than year-to-year effects on farmers' incomes. The index of aggregated labor productivity is specifically designed to measure the advantage to society as a whole from changes in agriculture. This index is directly comparable with the index of national income per worker in the national economy and roughly comparable with the index of per capita national income; it is therefore directly related to the welfare effects of productivity change. Prior to the research now being reported, this type of productivity measurement was discussed to some extent but hardly found any significant application.

In this analysis, agriculture, together with those parts of other industries selling supplies to agriculture, is treated as one "subsystem" in the national economic system — the "agricultural output subsystem."

This new productivity index has been computed for United States agriculture as a whole for the years since 1919 by means of a shortcut method. For certain benchmark years (1919, 1929, 1939, and 1954) parallel estimates were made on the basis of detailed input-output tables, to which an elaborate matrix-algebra procedure was applied. The results of these matrix analyses were in good agreement with those from the shortcut method for these same years, and the soundness of the shortcut method was thus confirmed.

Analogous productivity measures were also computed for a number of major commodities, using as material the annual "Farm Costs and Returns" publications of the USDA. A modified version of the shortcut method used in the national totals since 1919 was applied to these farm-level data, some of which start in 1930 and others in various later years.

The index of aggregated labor productivity in United States agriculture shows that over the period under study, productivity in the agricultural subsystem (under this concept) has risen considerably faster than in the national economy as a whole. Specifically, it is shown that during the period since 1919, the rate of productivity increase has not only been high, but has also been accelerating. The rate of acceleration since 1919 has been constant at 3.5 percent of the rate-of-productivity increment. As a consequence, the average annual rate-of-productivity increase rose from 1.5 percent around 1920 to about 6 percent around 1960. This acceleration is connected, above all, with the accelerated rate of farm exodus, that in the 1950's reached the level of 5 percent per year. The amount of indirect labor used to produce and service farm production requisites rose very moderately, from 1½ million man-years in the 1920's to about 2 million around 1960. During the same period direct farm labor fell from over 10 million to 4 million workers.

For years prior to 1919, detailed data for similar index numbers have not been worked out. However, from summary information referring to decennial years from 1870 to 1910, it appears possible, but not certain, that productivity increases since 1870 have also accelerated at the same annual rate of 3.5 percent.

This acceleration in the productivity of agriculture may have counterparts in other parts of the economy, but conclusive proof is lacking so far. Productivity in the national economy as a whole has been rising at a more steady rate; if there is any tendency toward acceleration in national productivity indexes, it must be by a very low acceleration factor. However, there are several conceptual problems in regard to the index numbers of production in industries and services, and it is therefore possible that a different type of analysis from those so far applied might reveal more progress than has been estimated to date.

The rapid rate of productivity increase in agriculture forms the principal background to the fall in relative prices of farm products and the welfare effects that flow from it — mainly to consumers who get their food at lower real cost. Farmers also share in the benefits from productivity — mainly indirectly, from the higher level of economic well-being to which increased agricultural productivity contributes vigorously.

Commodity-level analyses have supplied separate productivity indexes for wheat, corn, soybeans, peanuts, cotton, tobacco, eggs, milk, hogs, beef, sheep, and wool. Several of these commodities are represented by separate indexes for two or more major production areas. The period covered by these indexes is not always the same. Some of the series for wheat, corn, soybeans, cotton, milk, hogs, beef, sheep, and wool begin in 1930; other series start at various later dates. Another set of estimates for the national agricultural economy was prepared by aggregating the commodity data.

Some of the commodity indexes show the same rate of long-term productivity increase as the national aggregate. Others are moving slower, and a few even more rapidly, over the same period of years, than the national aggregate. Several of the indexes can be interpreted as reflecting the same rate of long-term acceleration (of 3.5 percent per year) as the national aggregate, although with various time lags behind or ahead of the national trend. Productivity-increase rates ahead of the national trend are shown for New Jersey egg farms and the Northwest wheat farms. Close to the national trend are the cash-grain farms of the Corn Belt, some cotton farms, and some dairy farms. Below the national trend are hog farms, most dairy farms, and several cotton farms; even more below are beef farms (both ranches and fattening enterprises) and tobacco farms. Below the national trend also are most wheat farms (without representing the common accelerating trend). There may be instances where the acceleration has ceased and been replaced by a slower rhythm of productivity increase or possibly even a decelerating one.

Several, but not all, of the commodity series reflect the slump in agricultural production that marked part of the early and mid-thirties. Since moving averages have to be used to eliminate year-to-year incidental variation, the start of the series is sometimes difficult to interpret because some of the years of abnormally low output are already included in the first moving average. Apart from this, certain periods can be shown as characteristic of certain commodities.

Thus, productivity in wheat production recovered during the late thirties and regained the precrisis level during the early years of World War II. In the late war years and the early postwar years wheat productivity stayed relatively level. It rose sharply after 1953, with signs of a new lull around 1960. Corn productivity had a similar, but not quite so sharp spurt up to 1944, but during the following years there was no serious interruption in the rather steady uptrend of productivity also continuing to about 1960. Among the cotton farms analyzed, most had a slowdown in productivity improvement during most of the 1940's — roughly the period when wheat production remained constant — followed by a more or less sharp upturn, usually starting some years earlier than in the case of wheat. Tobacco productivity showed some improvement in the late forties (the starting years of the series), thereafter a lull in the early to mid-fifties, and some moderate improvement in subsequent years.

Milk productivity is among the smoothest series, with a steady uptrend during most of the period, but with a lull during the war years and the early postwar years. The series for eggs starts in 1945 and shows one of the steadiest uptrends, at a faster rate than the national trend. Hog productivity suffered a sharp setback in the early thirties, then recovered rapidly and has thereafter proceeded somewhat unevenly, with slowdown periods first in the same period as milk and then again for some years in the early fifties. Beef productivity increase is slow and uneven, with pronounced cyclical peaks around 1945 and 1955 and troughs around 1950 and close to 1960, as well as in the mid-thirties. Sheep and wool productivity follows roughly the same pattern with a sharp rise from the mid-thirties to the mid-forties, then a slump centering around 1950, and thereafter a sustained sharp rise with signs of weakening in the early sixties.

These various differences in trend can be tied in with long-term movements in the agricultural economy. The beef cycle is an extreme case that can be immediately recognized. Other variations in trend can be explained in terms of wartime conditions that favored the increased production of food grains but may have been less favorable to milk, pork, and cotton. It is logical that wartime shortages of machinery and chemicals should have had some negative effects on several lines of production. The rather general uptrend over most of the fifties is related most closely to the accelerating farm exodus.

The differences in the rate of the productivity change can also be explained in part by technical circumstances and in part by farm policy. The slow productivity increase in tobacco production is only in part due to technical necessity; in part at least it must be due to the particular support system applied to tobacco production that created little incentive to substitute capital for labor. The case of beef is more complicated. In the ranching areas, rise in productivity is hampered by the fact that the grass-producing ability of the pastures can hardly be improved, and the scope for substitution of capital for labor is limited. Yet the sheep ranches have shown rapid improvement in their productivity which, admittedly, was low at the start of the period compared to that of certain other sheep-producing countries. But the slow rise in productivity of beef production is not confined to the ranches; it extends also to beef raising and fattening enterprises in the Corn Belt and, to a lesser extent, to hog production in the same area, despite the fact that these productivity indexes reflect both feed crop production and animal husbandry. These cases reflect a late start and as yet a not too rapid adoption of high-productive technology in animal husbandry.

Generally speaking, productivity increases are related to a downward pressure on prices. A wave of productivity increases made possible a fall in the relative price of the commodity — sometimes merely by a failure of the price to rise in times of inflation. The new price level then became associated with a permanent readjustment of the factors of production, particularly the substitution of capital for labor. It is possible that federal support policies have promoted rather than hampered these changes by making the income flow of farmers more dependable and hence reducing the risks associated with a higher level of cash outlays.

Some investigations were made of changes in capital intensity. The "real capital ratio" in the sense of Joan Robinson[1] (capital per worker,

[1] Joan Robinson, *The Accumulation of Capital.* London, 1956.

as a ratio of a worker's annual earnings) in American agriculture did not changed much over the period under study. Because conceptual difficulties attach both to land and to farm-produced forms of capital (such as livestock and crop inventories), the analysis was centered around the more narrow but less controversial concept of machinery capital ratio. This is the value of machinery capital per worker as a ratio of a hired farm worker's annual earnings. Both machinery values and wages are expressed in the current prices of each given year. Even this ratio changed little over the period studied, both in the aggregate and on most farm types. The chief exceptions were among the cotton farms that consistently show a ratio rising roughly at par with productivity. This, however, reflects the slow rise of wages to hired labor in cotton production.

It is thus not quite correct to say that American agriculture has grown more capital intensive if the "real capital ratio" is taken as a measure of capital intensity. When the ratio of farmers' and farm workers' net earnings to total output is falling, this is related more to the growing volume of intermediate products than to the stock value of capital at year's end.

The rate at which labor used for agricultural production produces income, in relation to the earning rates in other parts of the economy, is shown in Figures 14-23. The curves in these diagrams show the number of hours of aggregated labor needed to produce one per capita national income worth of the commodities in question. The labor force in the United States is close to 40 percent of the total population, and the over-all number of hours needed to produce one per capita national income in the whole economy is therefore close to the same percentage of a labor year, that is, about 800 hours.

Since the indications on the figures refer to aggregated labor, they reflect the weighted average of production by both the farm labor and the nonfarm labor involved. When the number of hours required to produce one per capita national income is higher than average for the economy in general, the tendency for farm labor to earn less is understated, because it is averaged in with the nonfarm component, whose earning power is in line with the rest of the economy. Conversely, in those cases where the number of hours needed in some lines of agricultural production is lower than average for the economy, farmers are likely to have higher earnings than workers in industries and services. This advantage may also be understated in our figures.

The data for the national farm economy show a rather steady level up to 1944 (with a temporary, relative improvement from 1932 to 1936, reflecting the absence of unemployment in the farm sector) of approximately 1,500 to 1,600 hours, thus close to twice the average national level. In the mid-forties, the level fell to between 1,000 and 1,100 hours — a sizable improvement. Only part of this improvement may have come to farmers, since the nonfarm component in the aggregated labor force is now so much larger in relative terms, and some part went to the owners of farmland under lease.

Commodities show varying patterns which, however, add up to the national one. Both the temporary improvement of the thirties and the more lasting one of the late forties can be recognized in most of the commodity diagrams. The absolute level of earning power is rather different, both between commodities and also, in some commodities, between farm types producing the same commodity.

The differences in level between commodities reflect the relative prices of the commodities, including the effects of price supports. The most highly productive farm types apparently are the Northwestern wheat farms. The combination of high support prices and high levels of wheat yields accounts for this. With a lower wheat price level these farms would not appear to exceed the earning power of the cash grain farms in the Corn Belt, as they now do. Wheat farms in general are also among those where the earning power of aggregated labor has been high recently, in contrast to their position in the early thirties.

Rates of remuneration better than those for the national (agricultural and nonagricultural) economy as a whole are also seen on the cash grain farms of the central Corn Belt, and the cotton farms in California and some of those in Texas. Better than average rates of remuneration for agriculture are found on most other wheat farms, other Corn Belt farms, and on the ranches. Close to the national average for agriculture are most of the dairy farms, the New Jersey egg farms, and some cotton farms. Other cotton farms are below the average agricultural level, as are most tobacco farms.

Several policy implications can be made from these analyses. The usual contention that federal farm supports have had the effect of slowing down progress in agriculture is not borne out; hypothetically, positive effects may be inferred. Since the general tendency is for farmers' net income to be a smaller fraction of total turnover as the productivity rises, it follows that price sensitivity and the need for price stability will increase rather than decrease as productivity rises further, as it most certainly will, although perhaps not as rapidly as in the recent past. As the farm exodus begins to level off, continued productivity rise in agriculture will depend even more than before on the continued rise in productivity in factories and offices. The prices at which production requisites are supplied to farmers may become a major policy issue as these prices become more and more decisive for the levels of farm prices.

PRODUCTIVITY: CONCEPTS AND MEASUREMENT

Productivity is a measure of the relation between input and output in physical terms. It is not really a measure of economic relations. Nevertheless, changes in productivity are believed to be important to the economic welfare of society. If society at large gets more output from the use of the same resources, then this should normally mean progress. There might be exceptions when basic changes occur in the modes of production and consumption, some types of output becoming obsolescent, some resources becoming exhausted, etc. At the level of specific industries and of individual firms, the connection between productivity and rates of profit is more problematic. When overall productivity of a given commodity rises sharply, a fall in the relative price of the commodity usually follows. Profits, or generally rates of earnings to factors, may therefore not rise as fast as productivity; in some cases they may not rise at all, and more commonly they rise no more than is general in the whole economic system. If a firm has rising productivity, it may still receive a declining rate of profit if the relative price of its output falls more rapidly than its productivity rises, and vice versa. It is in social rather than private or firm-level accounting that productivity has the most direct relevancy to economic welfare.[1] Even there it is the more relevant the more directly it expresses physical relations without implying other economic relations in the way productivity has been defined and measured.

There are several different concepts of productivity, and still more ways of computing these measures.[2] Each productivity measure has certain properties that render it suitable to express some phenomenon that may be relevant to the knowledge of economic processes; each also has its disabilities that render it unsuitable to explain certain phenomena. The present study, because of its orientation, needs a productivity measure that will illustrate the consequences to the whole national economy of such productivity changes as can be discovered.

Productivity measures may be comprehensive or partial. A comprehensive measure should express the relation between all factors of production on the one hand and the entire output of the firm or industry on the other. Partial measures may express the ratio between one production factor, or a group of production factors, and all of the output, or between some factors and that part of the output which these factors are supposed to have generated.

Among the partial measures, output per man (or per man-hour) and output per acre (or area unit in general) both have applications to certain problems in agricultural economics. Clearly, a change in either of

[1] In the competition between firms, some advantage will of course accrue to those who increase their productivity faster than the average for the industry.

[2] Systematic reviews of productivity concepts used in agricultural economics are found in J. Horring, *Concepts of Productivity Measurement in Agriculture on a National Scale,* Paris, O.E.C.D., 1961 (O.E.C.D. Documentation in Agriculture and Food, No. 57), and in C. O. Meiburg and K. Brandt, "Agricultural Productivity in the United States 1870-1960," *Food Research Institute Studies,* Stanford, Calif., May 1962.

these ratios may be economically significant, but its significance cannot be judged in isolation from other circumstances. Another kind of partial measure is typified by the concept of net productivity, which is the ratio between "internal" factors of production and the net output or "value added" of the firm or industry. Against this concept, gross productivity or the ratio between all inputs (both external and internal factors) and all of the industry's or firm's output for final disposal from the industry or firm is often represented as the most comprehensive measure we have.

The concept used in this bulletin is that of aggregated labor productivity. It is less comprehensive than gross productivity but it raises fewer difficulties of concept and interpretation, and it is better suited to the purpose of the present inquiry. Included on the input side are all productive goods and services represented not by their money value but by the amounts of human labor used to generate them.[3] Excluded among conventional inputs are rent on land and interest on capital, both of which represent transfer payments rather than material goods and services. Also excluded are, as in all other productivity measures to date, government services, education, social overheads, and so on. Agriculture and its suppliers are treated as one subsystem of the economy.

The characteristics and the computation of aggregated labor productivity, as well as the properties and the limitations of the most commonly used conventional productivity measures, are examined in the Technical Appendix. The main results are discussed below.

Both gross and net productivity measurements suffer from the classical index-number problem, or the difficulty of aggregating inputs and outputs in terms that retain the same meaning over time. This is not too serious in regard to the aggregate of agriculture's output, which is relatively homogenous over time, with moderate changes in commodity composition as well as quality and relative prices. The difficulty is greater on the input side, especially in times when productivity changes rapidly, because of the effect this has on the relative prices of labor and capital.

Gross productivity has the added disadvantage, which has been unnoticed by most writers, that the rate of change which it is able to show is in part dependent on the level of aggregation. Thus a gross productivity index for an industry is not comparable with any index at the national level (which is always net), nor with those for subaggregates within the industry (e.g., animal husbandry taken separately will not be comparable with agriculture as a whole), nor even over time when structural changes are profound. A net productivity index does not share this fault, but has a drawback for the present inquiry in that it refers to something less than the industry's total output.

[3] The focusing on labor used aims merely at a descriptive account of certain factual relations which exist within the economy. No value theory is implied.

The aggregated labor productivity index avoids both of these difficulties. It is comprehensive with regard to output. On the input side, there is no index-number problem when all conventional inputs (other than rent and interest) have been converted to their counterpart in labor, using the current prices and wages of each year for the conversion.

The new index is less comprehensive in some other ways. Above all, it has not incorporated some important explanatory variables that are usually included in productivity measurement, whether gross or net. It also fails to include, thus far, some elements of overhead cost that to date have only been discussed but never included in any productivity measurement.

The question of why labor becomes as productive as is the case is clearly separate from the questions regarding direction and size of change. Among the production factors not included in the computation of the index is capital as a stock. Capital as a flow is included, as should be clear from the description in the Technical Appendix. After depreciation and new acquisitions plus upkeep and repair costs (the flow elements) have been accounted for, capital (stock) costs are reduced to rent and interest. These are costs at the firm level, not at the national level where they are transfer payments within the system. There are some real costs associated with banking operations, but they are minor. Land used for agricultural production has remained nearly constant in physical terms over the period studied, and variations in its rental value are mainly reflections of productivity changes.

Essentially, rent and interest are instruments for the distributive allocation of product, and for deciding how resources are allocated as between alternative productive uses. These functions are of the greatest importance for the optimization of economic results. They contribute to optimization and thus to explaining some of the reasons of productivity change. They represent human sacrifice in terms of waiting, not of direct effort. Differently expressed, they represent alternatives in the timing of physical inputs as well as of consumption. In a given year, the volume of rental payments does not modify the volume of product, only its distribution between people as consumers and between firms as producers. When the focus is upon the welfare results of productivity change, the size and composition of capital stock is a very important explanatory variable, but its inclusion among inputs would amount to double counting.

Outside the costs of production in this (as in all other productivity studies, to date) are also the "social overheads." These include education, extension, research, public administration, and public works in roads. These services represent considerable amounts of human labor and it would be desirable to include these amounts to the extent that they are relevant to the agricultural production process. The amounts are very difficult to compute, however. The budgets of agencies performing the services are known, but no technique has been found to separate those parts of their activities that could be labeled as production inputs into agriculture. Clearly, some parts are not agricultural at all (e.g., the Forest Service), while some have mixed or dual functions, benefiting both farmers and others. The most difficult part is education in all its forms, which is in fact part investment and part consumption. Expenses of these kinds affecting agricultural production are likely to have increased over the period under consideration; but these changes, had they been included among production costs, would have affected the productivity index only rather slightly.

Another group of inputs that might have been included are federal projects involving land reclamation and new irrigation facilities. Part of these investments could also be charged to agriculture, on condition that a method is found to identify agriculture's share in projects that are, to a great extent, multipurpose in character. This problem area is not of very great significance on the national level, but in certain areas, and for some commodities, its influence may be sizable.

All of the above-mentioned factors must be regarded as explanatory variables. None of them are indispensable for the estimate of indirect labor. The index computed according to the above indications remains an essentially meaningful expression of the trend of productivity change as a contributor to national welfare.

PRODUCTIVITY OF AGGREGATED LABOR: UNITED STATES TOTALS

The index of aggregated labor productivity was worked out for the United States as a whole by the two separate techniques described in the Technical Appendix. In addition, one more series of United States totals was computed by aggregation from commodity-level data. The purpose of this aggregation was chiefly to provide a test on the accuracy and reasonableness of the commodity data; the results are discussed in the next section.

These analyses of the agricultural output subsystem led, first of all, to an approximate measure of that part of the nonagricultural labor force used to produce and service production requisites for agriculture.[1] With some variation, the sum of indirect labor absorbed by agriculture has been surprisingly stable at 1.5 to 2 million man-years per year throughout the whole period from 1919 to 1965. In the years around 1920, the data show a level close to 2 million man-years annually. Even if it is assumed that this is caused by special circumstances in those years, any increase in the use of indirect labor from the middle and late 1920's up until around 1960 would only be from 1.5 million man-years

[1] See W. Gossling and F. Dovring, "Labor Productivity Measurement: The Use of Subsystems in the Interindustry Approach, and Some Approximating Alternatives." Jour. Farm Econ. 48:377. 1966.

Table 1. — Numerical Comparisons of Gossling and Dovring Indexes of Labor Productivity (Output per Man-Year)

Year	Gossling index I			Dovring index II	
	Variant 1[a]	Variant 2[b]	Variant 3[c]	Variant 1[d]	Variant 2[e]
1919	35	35	34	35	35
1929	43	43	42	43	43
1939	48	48	52	52	46
1954	85	85	85	82	82
1957–1959	..	..	..	100	..

[a] Using full-sized input-output tables presented in Appendix C of W. Gossling, "A New Economic Model of Structural Change in U.S. Agriculture and Supporting Industries." Unpublished Ph.D. thesis, University of Illinois. 1965.
[b] Using full-sized input-output tables presented in Series III tables in the Appendix to Gossling, *op. cit.* There are differences of less than a percentage point in variants 1 and 2 of the Gossling index I.
[c] Using two-industry input-output tables presented in Series III tables in the Appendix to Gossling, *op. cit.*
[d] Calculated from United States National Income and Agricultural Statistics.
Note: For sources of data on employment see Appendix G to Gossling, *op. cit.* The index base for columns 1, 2, 3, and 5 uses Dovring's 1957-1959 employment figure. It is assumed that the ratio of external output to "entire output less intra-agricultural output" is the same for 1957-1959 as for 1954.
Source: W. Gossling and F. Dovring, "Labor Productivity Measurement: The Use of Subsystems in the Interindustry Approach, and Some Approximating Alternatives." Jour. Farm. Econ. 48:375. 1966.

to about 2 million. During this same time the agricultural labor force fell from over 10 million in the 1920's to 4 million in 1960 and to even less since then. Substitution of capital for labor has thus been highly remunerative to the economy at large. The industries and services supplying farm requisites have increased their productivity to such a degree that they have been able to supply a vastly increased physical volume of goods and services without using up any correspondingly increased portion of the nation's work force.

In index-number terms, the shortcut method and the matrix method yield indexes that, for convenience, are named the "Dovring index" and the "Gossling index" after their originators. There are several variants of each which are described elsewhere.[2]

The two types of indexes are in substantial agreement as to the magnitude of long-term productivity changes. One set of comparable figures is shown in Table 1. In these figures, the number of hours in a work-year also varies in agriculture. This leads to a somewhat slower productivity rate than that obtained from data in man-hours.

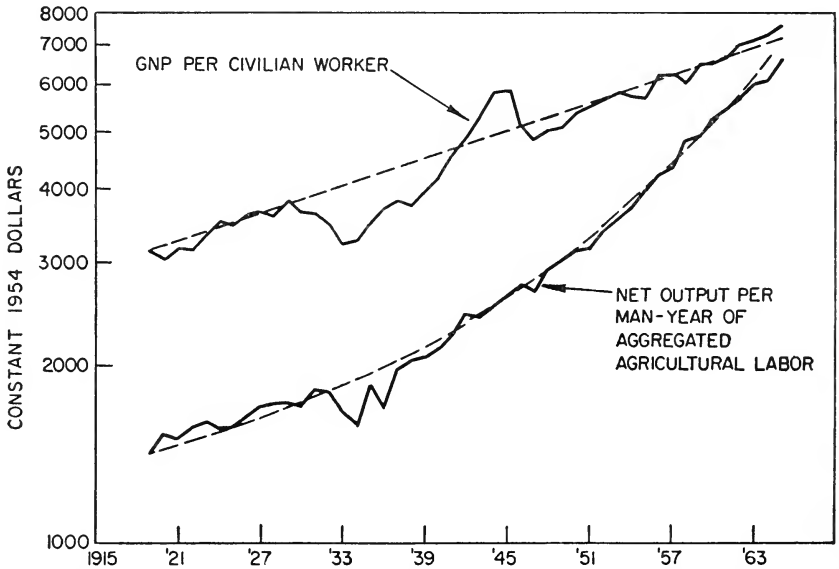
The table indicates that productivity gains tripled over four decades and doubled over the last two. An element of acceleration is crudely visible in these data. The data also show that productivity improvement was slower in the second decade than in the first, thus confirming that the crisis of the 1930's had effects on the medium-term trend. The faster

[2] See W. Gossling, "A New Economic Model of Structural Change in U.S. Agriculture and Supporting Industries." Unpublished Ph.D. thesis, University of Illinois. 1965.

rise after 1939 might to some extent reflect recovery from the aftermath of the crisis.

These conclusions are further illustrated by the year-to-year series as shown in Figure 1. The Dovring index (man-year variant) is here based on the standard assumption of 2,400 hours in an agricultural work-year. Thus in effect it represents the man-hour concept as regards farm labor. This in itself would lead to a somewhat sharper uptrend than if the agricultural work-year is assumed to become shorter over the decades. At the same time the assumed length of the agricultural work-year is on the high side. Thus it reduces the absolute number of agricultural work-years and hence the relative weight of the declining agricultural component in relation to the slightly expanding urban component of the total. Therefore the apparent difference in the rate of productivity increase in comparison with the data in Table 1 is not very large.

More important than any such technical differences is the fact that the data shown in Figure 1 display a distinct pattern of growth. The curve reflects a rather smoothly accelerating rhythm. The rate of acceleration has in fact been constant from 1920 to 1960. It is possible that the rhythm has been decelerating since around 1960 (see page 22). The broken-line curve accompanying the empirical data represents the movement that would have resulted if each year's incremental rate were always 3.5 percent higher than that of the preceding year. At such a rhythm, the rate of gain would double every twenty years, as



Aggregated labor productivity in the United States civilian labor force and the United States agricultural labor force. (Fig. 1)

has indeed been the case. The rate of annual productivity gain was about 1.5 percent around 1920, close to 3 percent around 1940, and 6 percent around 1960. Productivity thus did not just grow by simple compound interest, but the rate of increase did.[3]

The discovering of a growth rate that is accelerating at a constant rate is at first highly surprising. Previous analyses had indicated certain periods with different productivity increase. In gross terms, for instance, there had been some moderate but noticeable rate of increase before 1910, thereafter a more or less static period, and finally a high rate of gain starting in the late 1930's. The data in Figure 1 show the 1920's as improving at a rather steady rate which, in principle, would have made it possible to foresee the even higher rates in subsequent decades. The years of crisis and drouth in the early and mid-thirties now appear merely as an episodic deviation, and from 1941 onwards the real trend again agrees with the result of an extrapolation of the acceleration going on in the twenties. The year 1931 is still on the trend line, 1932 even above it, and only two bad drouth years (1934 and 1936) fall very seriously below it.

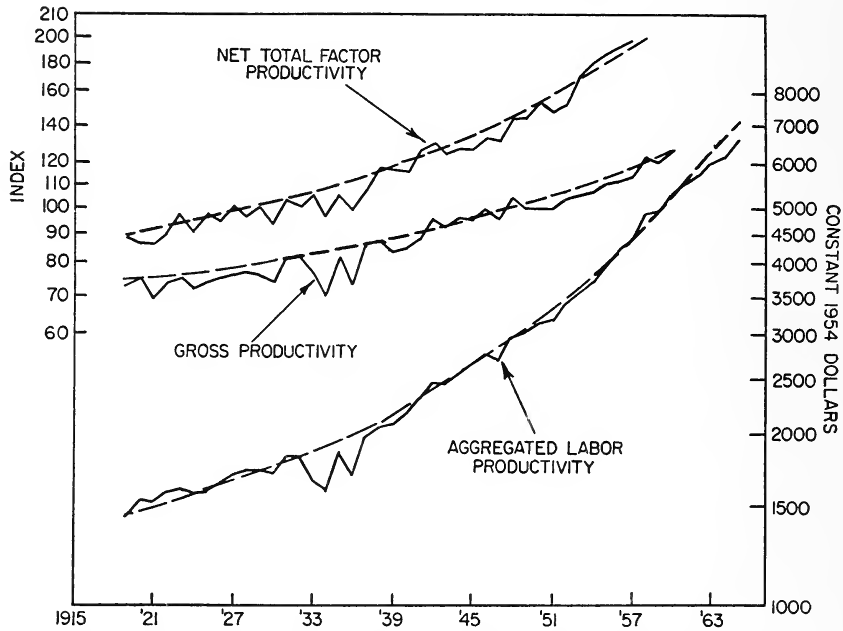
[3] To illustrate the principle of change, the following expressions may be used:

Year	*Output per man-year*
0	a
1	ab
2	abx
3	$ab(x^2)$
. . .	. . .
n	$ab(x^{n-1})$

where a is output per man at the start of the period, b is the incremental rate at the start of the period (in this case 1.015), and x the rate of acceleration (in this case 1.035). The expression can also be written exponentially, assuming each year's productivity increment to be to the x power of that of the preceding one:

Year	*Output per man-year*
0	a
1	ab
2	$a(b^x)$
3	$a(b^{x^2})$
. . .	. . .
n	$a(b^{x^{n-1}})$

On magnitudes such as those represented in this material, the difference is slight. $a(b^{x^{n-1}})$ differs from $ab(x^{n-1})$ by only a slight fraction in values under 1.06. Most of this difference could be removed by a small reduction in the value of x. Only at rates of annual growth considerably in excess of 6 percent would the difference become disturbing; but such high values are practically excluded, as we shall see later. For rates of growth below 1.5 percent per year, the difference between the two types of ratio is too small to be traced in empirical data.



Comparison of productivity indexes for United States agriculture. The net total factor productivity index is taken from Kendrick and the gross productivity index from USDA data. (See footnote below.) (Fig. 2)

Before commenting upon the rate of acceleration, it should be mentioned that the same rate can be traced in the other productivity measures. Figure 2 shows a comparison between the gross, net, and aggregated labor productivity indexes.[4] The indexes have been placed on different absolute levels in order to make them more readable, but the scales are the same and the slopes of the three curves are therefore comparable. The broken lines accompanying the three series of empirical data also have different shapes in this figure, but they are all parts of the same function as described above, reflecting accelerating productivity gains at a constant rate of acceleration of 3.5 percent per year. The elements of the broken-line curve accompanying the diagram for net productivity are the same as those for aggregated labor productivity, but always with a 10-year lag; those of the broken-line curve accompanying the gross productivity diagram are also the same, although with a lag of 26 years in relation to the curve accompanying the aggregated labor productivity diagram. Expressed in different

[4] The gross productivity index is taken from R. A. Loomis and G. T. Barton, *Productivity of Agriculture, United States, 1870-1958.* USDA, 1961. The net productivity index is taken from J. W. Kendrick, *Productivity Trends in the United States.* National Bureau of Economic Research, General Series, No. 71, pp. 363 *sq.* Princeton, 1961.

terms, this means that the yearly incremental rate of net productivity in each given year is always 0.71 times that of aggregated labor productivity; similarly the incremental rate of gross productivity in each given year amounts to 0.41 times that of the aggregated labor productivity incremental rate in the same year. The corresponding proportion between the rates of gross and net productivity increment is 0.58:1.

The fit is satisfactory on all three curves; but if gross productivity data were all we had, the evidence would hardly be convincing. The gross productivity curve taken in isolation could also be read as reflecting two linear trends with a break sometime in the early thirties. The comparison between the three curves establishes beyond any doubt that they all reflect the same constantly accelerating trend of productivity increase with the same acceleration factor of 3.5 percent.

This comparison leads to some further reflections on the nature and merits of the alternative productivity measures. First of all, it places more stress on what they have in common. Since we are looking at essentially the same thing in all three diagrams, it should not be too surprising that they are found to contain basically the same long-term trend. But the capacity of the three indexes to reveal this trend is not the same. The acceleration factor was easiest to discover in the aggregated labor productivity index; in the net productivity diagram, the same trend would be evident once it was discovered, but it was less easy to discover. The gross productivity curve, because of its statistical properties as discussed above and in the Technical Appendix, has so weak a trend that the continuous acceleration could hardly have been discovered, and could certainly not have been regarded as conclusive evidence without the comparison with the other indexes. The gross measure is more likely to lead to conclusions about productivity trends as being erratic or incidental rather than expressing built-in long-range tendencies in the economic system. It is no small merit of the aggregated labor productivity index that it enabled us to make the discovery of the constantly accelerating trend.

The fact of constant relations between the three productivity diagrams may serve to remove some of the objections against the gross and net measures that rely on the index-number problem as regards inputs; but this improvement in their standing may be valid only over the length of period shown and not for even longer periods. For the comparison between gross productivity and aggregated labor productivity, it is clear that the proportion between yearly incremental rates that characterizes the diagrams for the total agricultural economy does not hold for subsytems within agriculture, as will be shown in some detail in the next section. The property of the gross measure to be dependent on the level of aggregation is in no way corrected.

This acceleration of trend raises several questions. How long has this been going on, how does it relate to the tendencies of the economy in general, what are the specific causes for this to happen in agriculture, and how long can the same phenomenon go on in the future? None of these questions can be given a definitive answer here, but some tentative suggestions are offered.

For years prior to 1919, information on purchased farm inputs is less precise and less reliable than for more recent years. The entire statistical basis for calculations of this kind is weaker. At the same time it is obvious, as one follows these older statistics, that the nonfarm indirect labor serving agriculture through external inputs was a smaller absolute quantity as well as a smaller part of total aggregated labor used for agricultural production. Compared to the total nonfarm economy, they were rather a similar fraction, or even a somewhat larger one; but the farther back one searches, the smaller were also the nonfarm sectors, both absolutely and in comparison with the farm sector. The fraction of nonfarm production that went into farm production requisites was about 4 to 5 percent in the 1920's (as compared to only 3 percent recently), and close to 6 percent around 1900; some very weak data indicate that it was 8 percent around 1870. The smaller absolute size of these nonagricultural inputs for agriculture, and their smaller relative size within the agricultural input aggregate, makes any lack of accuracy in their estimation less crucial for the estimates of aggregated labor input, the vast bulk of which was determined in those early decades by the size of the agricultural labor force. Because of this, some idea can be had of the magnitude of output per man-year of aggregated labor for these early decades — in fact with somewhat less uncertainty than is the case with the gross and net productivity measures. Imprecise as these estimates are, they indicate that the same accelerating trend with the same acceleration factor may have been at work for at least a hundred years.[5] If this is true, then the typical annual rate of productivity increment was ¾ percent around 1900, ⅜ percent in 1880, and just over ¼ percent in 1870. The same principle may have been at work even farther back in the economic history of the country; but on that level, annual increments were so low and so far overshadowed by short-run movements that it would be very difficult to make the evidence positive.

In the same way certain indications can be obtained for both gross and net productivity gains since 1870. The decennial estimates from

[5] During the entire second half of the nineteenth century, important productivity gains were made in some lines of agricultural production and very little in others. Gains in the efficiency of direct labor in grain production have been explored by W. N. Parker and Judith L. V. Klein, "Productivity Growth in Grain Production in the United States, 1840-60 and 1900-10," *Output, Employment, and Productivity in the United States after 1800.* National Bureau of Economic Research, Studies in Income and Wealth, Vol. 30, by the Conference on Research in Income and Wealth, pp. 523-580. New York, 1966. Output per man-hour (of direct, on-farm labor only) of wheat, oats, and corn rose about 3.5 to 4 times during the period from 1839 to 1911.

1870 to 1910 are crude and of low reliability and neither confirm nor contradict the hypothesis that the same rate of acceleration may have been at work for a century. The rates of annual productivity increase that must have characterized those early times could be made to fit any one of several alternative formulas for continuous long-term change.

This accelerating productivity trend in agriculture bears an intriguing relation to the growth rates in the rest of the United States economy. Growth of overall productivity has also been accelerating inasmuch as its rate of increase is higher in recent decades than it was prior to World War I. Usually this is interpreted merely as a break in trend around 1919 (possibly as early as 1917), with a lower constant rate before this break and a higher one thereafter.[6] The possibility that the whole movement might have been one of accelerating rise in productivity has been discussed. The difficulty is that if there is any continuous acceleration in national product per man as conventionally defined, then the acceleration factor must have been very much lower than in agriculture in recent decades. It might also be possible that the break in trend came from agriculture which is usually included with the rest of the national economy in these calculations. The years around 1920 were in fact those when the rate of productivity increase in agriculture began to catch up with that of the economy in general. It also appears that, when agriculture is subtracted, the rest of the economy shows no discernible acceleration since 1920.

All of this assumes implicitly that the productivity of agriculture and industry are fully comparable. Between the two there exists an important difference, however. In agriculture, as already pointed out in the preceding section, the index-number problem is of small consequence for the output index. Farm output has continued to consist of essentially the same commodities, in roughly similar proportions between them since 1870. The addition of commodities such as soybeans and grain sorghum had little impact, since these new products are substitutes for farm commodities that were already being produced, and since they are produced by essentially the same types of technology. Introduction of entirely new crops for entirely new uses and produced by essentially new techniques occurred much earlier when tobacco, cotton, etc., became staple products on American farms, but there has been no comparable upheaval in the farm output aggregate during the last hundred years.

The same cannot be said of industry, or of services using industrially produced equipment. Industry is continuously generating entirely new products, some of which serve entirely new purposes, while some others serve old purposes in such radically different ways that the change is difficult to incorporate into conventional output indexes. The

[6] J. W. Kendrick, *op. cit.*, pp. 65-71.

change in the efficiency of mail carriage through use of railroads, airplanes, and the telegraph is not measured by comparisons with the cost of carrying the mail by men on horseback or by stagecoach; it is measured in comparison with alternate uses of the same industrial resources. The industrial cost of building and servicing the telegraph system is what goes into the national income accounts, not the use value of the new means of conveyance in terms of the number of men on horseback who would have been needed to carry the same number of messages over the same distances. The gain in time often has no counterpart at all, since instant delivery was not physically possible before. To send a letter across the United States would have required many man-days of work in the prerailroad age; now it can be done very quickly and inexpensively. No one has ever calculated the astronomical gain in productivity of this in terms of the final commodity or the final service. Similarly, the contribution to national income from building and servicing electronic computers is estimated on the basis of the cost of doing so based on conventional inputs used in the process. The use-value would include the number of clerks handling previously used means of computation that would be needed for the tasks now handled by the new computers. Such a measure of productivity increase would show much sharper gains than result from conventional national income data, but the attempt has hardly been made to compute productivity in such terms. Yet this is what would be needed to make real comparisons with agriculture.

Productivity trends can be said to be comparable only to the extent that the final output is essentially similar in character over the time period studied. American agriculture comes into this category, and so might some other raw-material industries such as coal mining. In most lines of industrial production there are important discontinuities, as discussed above, that the index numbers fail to reflect. It is therefore premature to state that productivity has not been accelerating in other sectors of the economy. The indications set forth above suggest that all the conventional productivity measures understate the real gains in commodity production and hence tend to depress the index and possibly to conceal some inherent accelerating tendencies. It is of course also possible that some of these gains are neutralized by the increasing overhead costs in services that are immune to productivity change or even retrograde. The net effect for single commodities or for homogeneous commodity groups might be discovered by analyses similar to those presented above for agriculture.

Unless there were built-in accelerating tendencies in the industrial economy, it is hard to see how even agriculture could have displayed as much acceleration as it has. Most of this movement has come from the greater efficiency of industrially produced and scientifically based means of production. It is industry and science that have supplied the increased leverage of labor used for agricultural production reflected in the indexes above. In the industrial sectors of national income accounts, the machinery, chemicals, etc., supplied to agriculture are entered at their costs of production; radical innovations remain buried in the index numbers and are not seen. It is when these inputs are linked up directly with the agricultural sector, as in the present analysis, that the effect is really seen in full. Here the effect of industrial improvements becomes measured in terms of labor displaced in relation to a final output of more or less unchanged character. This will be even more evident in the commodity-level analyses where we can see, for instance, the number of man-years needed to produce a given quantity of wheat at various points in time. The index-number problem is eliminated. This gives a true measure of the increasing efficiency of basic industrial technology. The accelerating trend of agricultural productivity thus allows us to infer an accelerating trend in industrial productivity that the index-number problem prevents us from seeing clearly in most branches of industry.

There are of course many causes of these spectacular changes. Superficially, one could point to the accelerating exodus of people from agriculture and the continuing substitution of capital for labor. However, this is merely a restatement in different terms of the descriptive starting point. Increase in the productivity of aggregated labor consists of a rising ratio of output to labor used. Given the relatively slow rate at which agricultural output may increase, reduction of manpower is the obvious prerequisite for rapid productivity increase. This rapid exodus is not an explanation of the process; it is the main part of the process. Repeating this over again in different ways will not explain it.

Behind the rate of farm exodus, as a process of productivity improvement, there are different causes that may be invoked at different levels of analysis. The increasing efficiency of mechanical, chemical, and biological means of production is an obvious prerequisite, and in a certain sense the rate of productivity increase may be said to reflect rates of advancement in technology. It also reflects rates of adoption and competent application of technology. The time trend is thus influenced by things such as diffusion of knowledge, build-up of technical competency at the farm-operator level, and the ability and willingness to obtain the financing that may be necessary to bring the more efficient means of production into application in quantity. The time trend, if we can call it that, is then a result of both the trend in technology (increasing leverage of more and more systematic knowledge allowing a more efficient approach to the problems of mastering nature) and of educational, financial, and other allied factors that together promote or retard the application of new technology. Even though it is obvious that there is a lag between invention and broad application, it does not follow that the rate of productivity increase is much slower than technological trends alone would make possible, since later phases receive booster effects when the delayed technology arrives to full application.

The acceleration of productivity in agriculture possibly reflects accelerating tendencies in the economic system as a whole. The timing of this acceleration in agriculture is, in any event, also a function of the relative sector proportions between agriculture and other industries. The very rapid exodus of people from agriculture that occurred in the 1950's could hardly have happened much earlier, because in each earlier decade the farm sector was relatively larger and the difficulty of absorbing whatever surplus manpower it might have had was correspondingly greater. By the same token, the possibilities of supplying and financing industrially produced means of production were correspondingly smaller. As shown above, the percentage of the nonagricultural production of the country that went to agriculture as production inputs has always been small and, if anything, it has grown gradually smaller. The recent very high rates of increase in agricultural productivity are thus also a function of the stage of economic development in which the country finds itself.

If acceleration as such can be read as a function of technological and general economic development, at least its timing may to some extent have been affected by the details of economic policy during the period under study. As will be shown in some detail in the following section, the rate of productivity increase has not been uniform and its variations are to some extent related to price levels, including the levels of support price that have been in effect. The trend shown for the agricultural economy as a whole has some features that suggest an almost automatic process; but it cannot really be accepted as entirely automatic. Inadequate economic policies or incidental catastrophies might have hindered it to an extent that the crisis of the early thirties did not. On the other hand, it is difficult to see how the trend could possibly have been much more rapid.

This leads to the question of how long such a trend may continue. Not forever. This follows from the principle of acceleration, for eventually the rates of change and levels of productivity would be absurd. Any continuously accelerating trend has to break sometime. It may even be that it already has broken, sometime close to 1960, as suggested by the data shown in Figure 1. If the rate of annual productivity increase were to continue to double every twenty years, it would reach 12 percent annually around 1980, which is highly unlikely, and 24 percent around the year 2000, which is certainly not possible. Within the next ten to twenty years the rate of acceleration will have to slow down. What pattern and rate of growth in agricultural productivity will follow cannot now be foreseen. Data from recent years indicate the possibility (unconfirmed because the new trend is as yet too short) of a deceleration at 3.5 percent per year since 1960 or perhaps 1958. Such a trend would have the rate of productivity gain fall to half in 20 years, but it would still result in very substantial gains in the decades to come.

The break in trend, whether it has already happened or is only impending in the near future, can be discussed from at least two mutually complementing angles.

For one thing, a situation will eventually come about where the amount of direct labor in agriculture becomes smaller than the amount of indirect labor used to produce and service its production requisites. In such a situation, any continued decline in the use of direct on-farm labor will have less incidence on the rate of productivity change than before. At some point the agricultural labor force will have become so small that its absolute size is of minor importance both for the cost budget of agriculture and even more for the consumer prices of farm-based goods such as food and clothing. At this "indifference point" it will no longer be necessary to maintain those income pressures that have been the driving force in the rapid farm exodus of recent decades.

In addition, when external capital ceases to displace farm labor, its rates of utilization and depreciation will become more crucial than they have been so far. Further sharp rises in the productivity of aggregated labor used for agricultural production would then depend chiefly on further rising productivity in the factories that produce these machines, chemicals, etc. Even though such productivity improvements may turn out to be spectacular in automated factories, the servicing aspects of farm requisites may remain more labor intensive.

All of this points toward the conclusion that, in regard to agriculture, essentially different types of economic policy will be necessary in the medium-term, if not already in the short-term future.

A point can be made in regard to relative income. Figure 1 shows, among other things, that output per man-year in agricultural production has risen sharply in recent years, and seemingly much faster than in the economy as a whole. Even though this may in part be an illusion because of the index-number problem in industry previously mentioned, it is quite likely that productivity in the agricultural subsystem has risen more than in the general economy.[7] In the dollar terms used in the diagram, which refers to 1954 prices for both series, it would appear that agriculture was, at long last, about to catch up with the rest

[7] One further reservation, although of minor importance during the period under study, relates to the increasing specialization of farm labor on farming alone. In older times, the labor force working on farms did a great deal of work other than farming — in processing the farm products intended for use by the household and sometimes others as well, in making and repairing tools, and even in building houses, making shoes, etc. The gradual disappearance of these activities is a partial offset against the rise in farm productivity which may be sizable in the phases of transition between a traditional, mainly agricultural economy, and a modern industrial economy. In the United States, over the period under study, the modifications which could be brought in by considering this aspect are certain to be minor, however.

of the economy in the relative ability to earn income. This has not occurred to the extent indicated by the diagram, for farm prices have continued to fall relative to prices in general, and the gap in earning ability is still larger than the diagram would indicate. Such a change in relative prices is to be expected when one sector improves its productivity more rapidly than others. Nevertheless, as productivity change in agriculture slows down, there has to be an adjustment of prices and earnings so that finally all factors used for agricultural production arrive at a similar rate of returns as similar factors earn elsewhere in the economy. This conclusion, too, will call for some reorientation of economic policy in regard to agriculture.

COMMODITY ANALYSES

The analyses discussed in the preceding section were made on United States agriculture as a whole. Working with an aggregate of that size, it is very likely that one obtains a general picture in which numerous significant features are balancing each other. Disaggregation into meaningful subsystems is clearly desirable in order to obtain material for more detailed conclusions and thereby to better characterize the aggregate and its changes.

Productivity indexes for several commodities were computed from data on commercial farms by type and location which are published annually by the USDA.[1] Some of these farm-type data series begin in 1930, others at various later dates; several of the series were started in the mid-forties, a few only in the 1950's. A few were changed as to their type recently, causing the homogeneous series to be discontinued.

Several of these farm types are close to being one-product firms and can be analyzed accordingly. Data about the share of marketing receipts coming from the major product on the various farm types under study are shown in Table 2.

Where there is only one major product and where other products are negligible, there is obviously no index-number problem on the output side. Output can then be specified in physical rather than monetary terms. This is the case with the New Jersey poultry farms (egg producers) and some of the cattle ranches. Some other farm types have a secondary product which is of so little importance that the assumption that the main product takes its share of the costs in proportion to its share in sale value entails very little potential error; these cases can also safely be treated as if they were one-product farms. Such is the case of at least one of the dairy-farm types (central Northeast) and some of the tobacco farms.

[1] An example of the computation procedure is shown in Appendix Table 2. Details of the procedure may be found in Chapter 3 of J. V. Leunis, "Productivity of Accumulated Labor in U.S. Agriculture: Analyses by Farm Types." Unpublished M.S. thesis, University of Illinois, 1965.

Table 2. — Percentage of Marketing Receipts From the Major Product on Different Farm Types, Average 1930-1934 and 1956-1960

Farm types	Periods	
	1930–1934	1956–1960
Dairy farms	60–80	60–85
Poultry farms	.....	97
Corn Belt farms	.....	.....
Cotton farms	70–85	60–80
Tobacco farms	50–85	40–80
Wheat farms	40–70	40–70
Cattle ranches	80–95	75–95
Sheep ranches	85–90	80–85

Source: Estimates are based on data in "Costs and Returns on Commercial Farms." USDA Statistical Bulletin 297 and sequels.

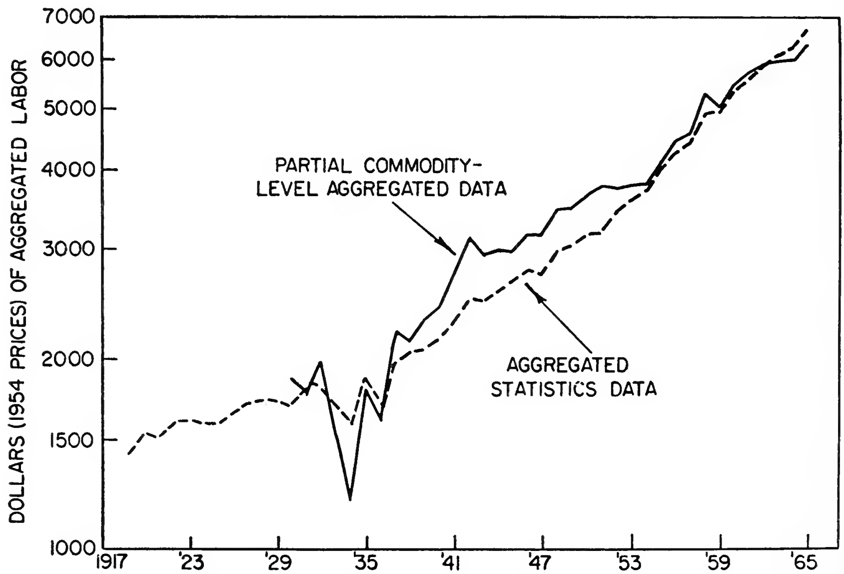
The same principle can in fact be also applied on farm types where the main product is less dominant. Where the balance of the output consists of several minor products, it is reasonable to assume that each product absorbs inputs in proportion to its share in total output value. Where there are two main products of similar proportions, the treatment may appear less evident at first glance, and an element of index-number problem comes into the picture. The problem is solved practically by treating such farm types as one-product farms alternatively for one and for the other of the two main products. The indexes that come out of such calculations usually resemble those obtained for the same commodities from farm types which come closer to being really one-product farms. For instance, a tobacco-dairy farm in Kentucky yields a productivity index for tobacco that has a similar level and a similarly slow movement to indexes derived from other tobacco farms; its dairy component yields a productivity index for milk that rises at a similar rapid rate to indexes obtained from other dairy farms, and has only a slightly lower absolute level of output per unit of aggregated labor than these. The contrast between the slow movement of productivity in tobacco, and the much more rapid one in milk, in a case like this, is balanced by the contrary movements of the relative prices of the two commodities, as will be shown in some detail in a later section. The equimarginal principle takes expression in these relations to such an extent that productivity indexes can also be computed, with some reserve, for the two main products of an outspoken two-product farm. To what extent this can be done even when the second product is of considerably smaller importance than the leading one is in part a matter of judgment. The sheep ranches form a special case because of the way in which the two products are associated.

Another set of estimates for the whole of U.S. agriculture was computed from commodity-level data as described in the Technical

Appendix. The result is shown in Figure 3. On the whole, the differences between the index computed through aggregation of farm-type data and that computed directly on the basis of aggregate national data are such as could be expected from the procedure. They are in line with the differences in the statistical properties of the two series. The total use of direct labor fell more sharply in the late 1930's, by these indications, than according to aggregate USDA data; in the early 1950's the two series are again in better agreement. As a consequence, productivity appears higher in these data, during the period from 1938 to 1953, than in those computed from aggregate statistics; but the rise in productivity appears to be slower from 1940 to 1950. The limitation to commercial farms, and among these to those most highly mechanized, is the obvious explanation.

This exercise confirms that the commodity-level indexes are reasonably comparable with the national index as well as with each other. The national series computed by means of aggregation from farm-type data would have to be refined in several ways before it could be used to substitute for the series computed directly on the basis of aggregate national data.

Commodity data are shown in Figures 4 through 13, sometimes with two charts for one commodity in order to make the figures more readable. In most cases, moving five-year averages are used to reduce the year-to-year variation reflecting weather. Since the longest series start in 1930, there is a weakness in the data in that the first five-year averages



Aggregated labor productivity in United States agriculture. **(Fig. 3)**

already include some of the worst depression years with their combination of drouth and reduced economic activity. To correct for the impression of very large productivity increases in subsequent years, some of the figures show the annual data for 1930 to 1932 in a small separate graph with a symbol for the average of that three-year period.

As illustrative examples, diagrams for gross productivity are also shown in two of the figures (corn, Fig. 5, and eggs, Fig. 9).

Wheat. Figures 4a and 4b show productivity indexes for six different wheat-producing farm types, representing three principal wheat-producing areas: the northern Great Plains, the southern Great Plains, and the Northwest wheat area.

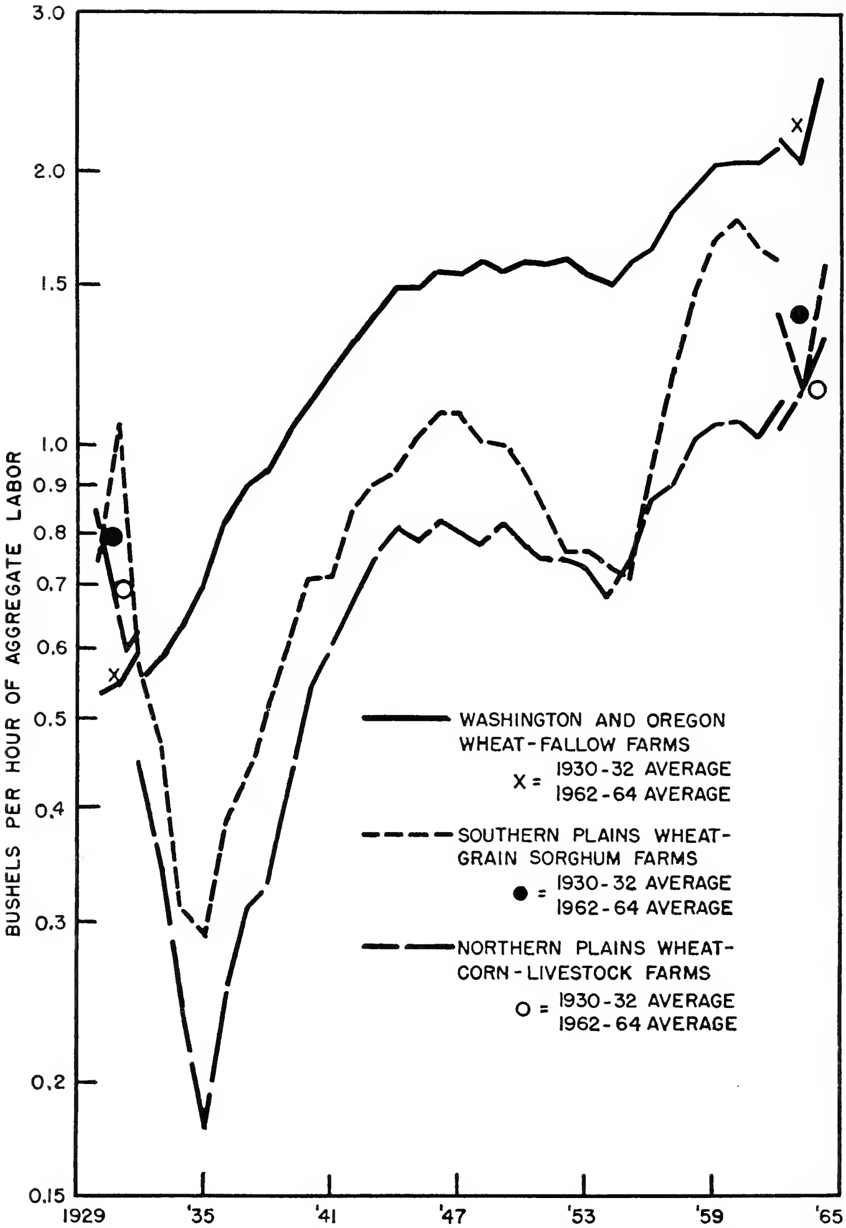
Total variation in productivity has been enormous, especially on the Great Plains, but most of this variation was caused by the catastrophic decline in production during certain years of the 1930's. When precrisis levels are considered (and they represent wheat yields that were rather typical of the preceding decade), total productivity increase from 1930 to 1960 has been rather moderate on the southern Plains and somewhat greater on the northern Plains where the yield level at the beginning of the period was even lower. The "plateau" shown from the early forties to the early fifties is in fact not much higher than the precrisis level, and most of the productivity increase has therefore been achieved since the mid-1950's.

The Northwest wheat farms show a partly different picture. The sharp rise in productivity throughout the thirties is real, as there was no drop in the crisis years, and the precrisis level (which was lower here than in the Great Plains) represents acre yields that are on line with those of the 1920's in the same area. The lull in productivity increase during most of the 1940's and the early 1950's also occurs here, and the renewed productivity increase since the mid-1950's is hardly more striking than on the Great Plains.

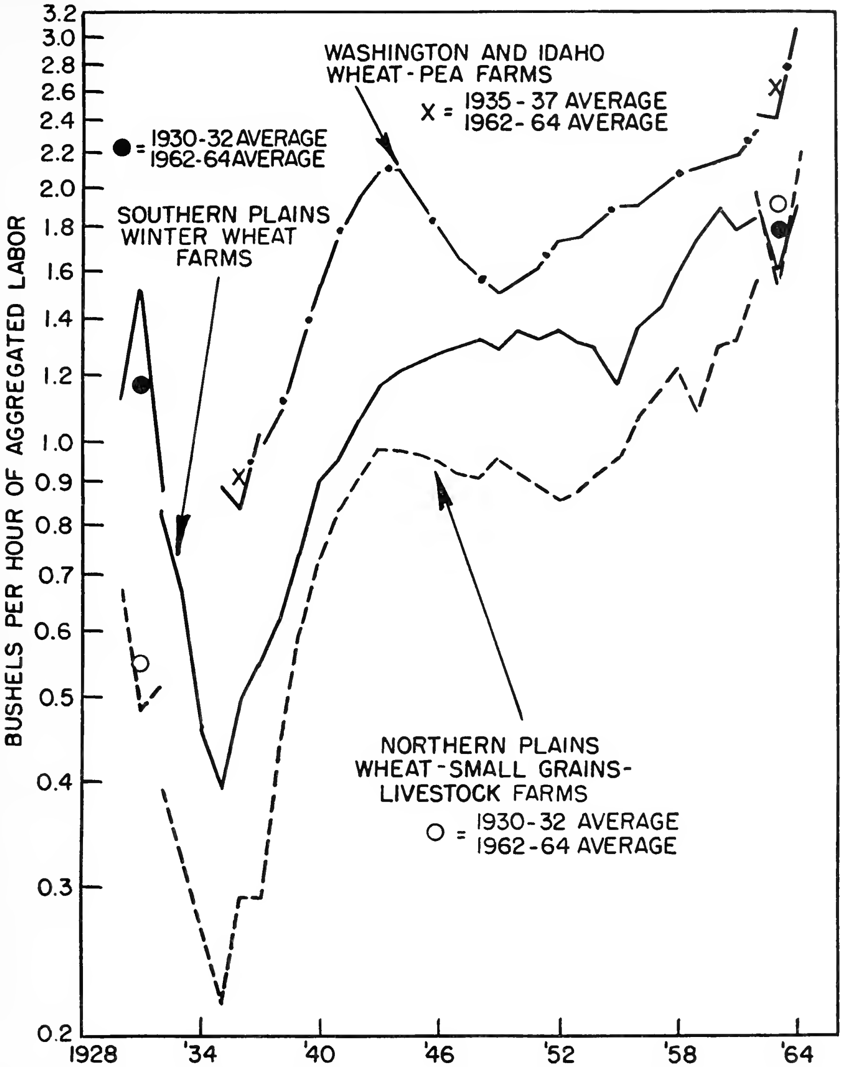
Productivity on the Great Plains roughly doubled during the period from 1930 to 1960. This clearly has been only a minor factor in the national picture since 1930. The Northwest has contributed more, by nearly quadrupling output per hour of aggregated labor. This is more rapid than the national trend, but the scope of the area is smaller. None of the wheat productivity curves can be fitted to any variant of the national accelerating function. This is not surprising because many of the technological gains in wheat productivity were made long ago.[2] What remained (and remains) to be gained in productivity in wheat production is mainly through biological inputs such as higher-yielding seed and chemical ferilizers that have contributed more in the Northwest than on the Great Plains.

Corn. Figure 5 shows productivity indicators for cash grain farms in the central Corn Belt. In the same way as on most wheat farms,

[2] Cf. W. N. Parker and Judith L. V. Klein, *op. cit.*

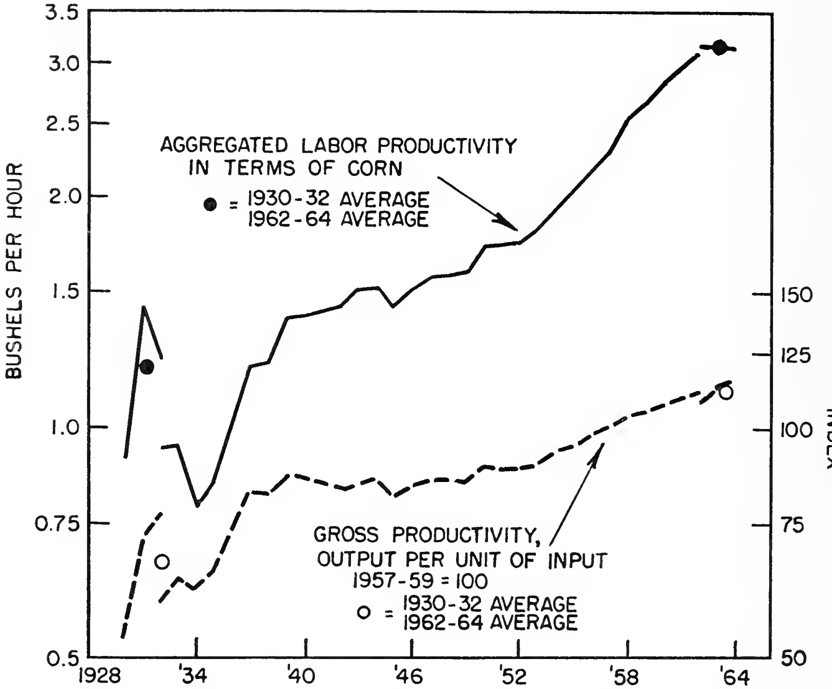


Productivity in wheat production on Washington and Oregon wheat-fallow farms, southern Plains wheat-grain sorghum farms, and northern Plains wheat-corn-livestock farms. (5-year averages.) (Fig. 4a)



Productivity in wheat production on Washington and Idaho wheat-pea farms, southern Plains winter wheat farms, and northern Plains wheat-small grains-livestock farms. (5-year averages.) (Fig. 4b)

the start of the curve for aggregated labor productivity is depressed because of crisis conditions. The precrisis level of the first three years reflects crop yields on a level with those that prevailed in the 1920's. Recovery to the precrisis level in the late 1930's was followed by only a rather slow rise in aggregated labor productivity until sometime in the early fifties when a quicker pace began. The total rise in productivity was higher than in the case of the Great Plains wheat farms, but



Productivity on cash grain farms in the Corn Belt. (5-year averages.) (Fig. 5)

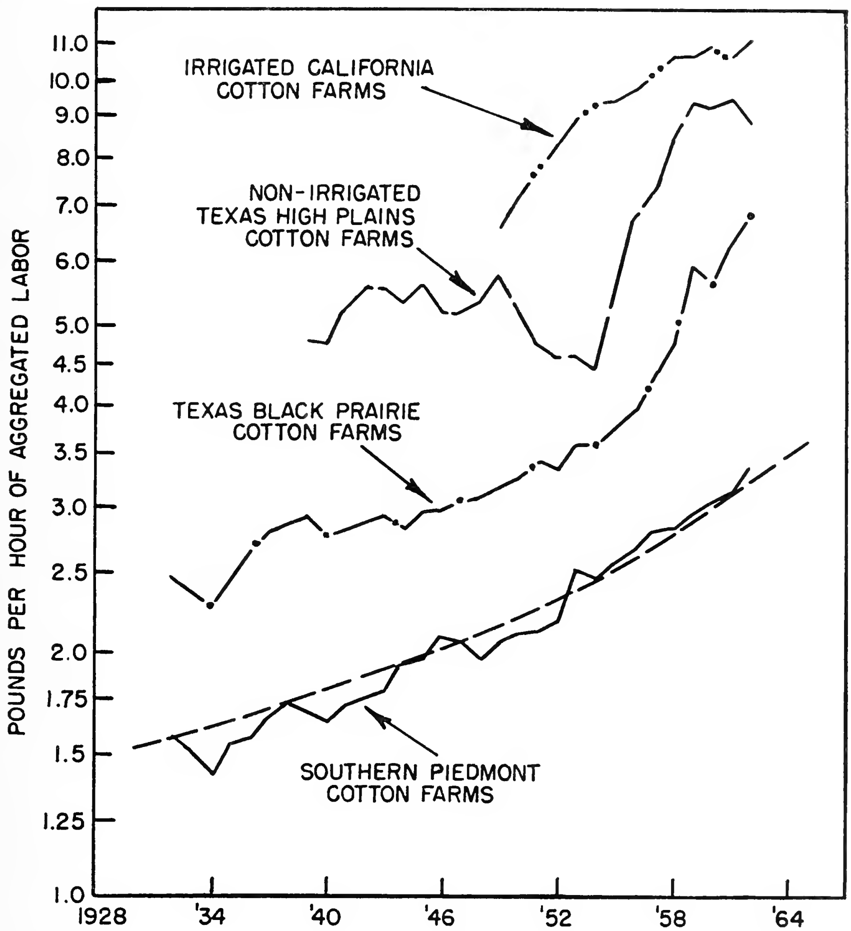
the time pattern is strikingly similar. The tempo is somewhat slower than that of the national trend. The curve for corn could be fitted to a variant of the national trend (accelerating at 3.5 percent per year) with about a 10-year lag behind the national trend.

The gross productivity curve shown on the same graph shows smaller gains on the whole than the aggregated labor productivity curve, but at least the trends are in the same direction for the most part, in contrast to the comparison made for eggs (Fig. 9, page 35). Gross productivity in corn production appears to have advanced somewhat more rapidly than is the case with the national trend for agriculture, which points to the lack of comparability between gross productivity trends.

Soybeans. When the same farm type is used to compute productivity indicators for soybeans, a diagram with a striking resemblance to that for corn emerges (not shown on the graph). The soybean component was small in the beginning and grew larger during most of the period covered, which makes this diagram less conclusive.

Cotton. Productivity indexes for cotton-producing farms are shown in Figures 6a and 6b. Ten farm types are represented, but only two of these for the whole period. These two show a slight drop during the crisis years, but their first five-year averages are likely to be representative of longer-term trends; averages for the first three years are slightly above the first five-year averages, but the cotton yields in Georgia and Texas in those years were also somewhat above the level to be expected from comparison with data of the 1920's.

The lowest productivity level (in terms of pounds per hour) is found in the Piedmont-area farm type, and this is also where the rate of productivity change has been lowest and most continuous. As shown in Figure 6a, this curve can be fitted to a function accelerating 3.5 percent per year, at a time lag of about 15 years behind the national trend. The other curves are too irregular, and most of them too short, to be fitted to any continuous trend line. The black prairie, the peanut-cotton,

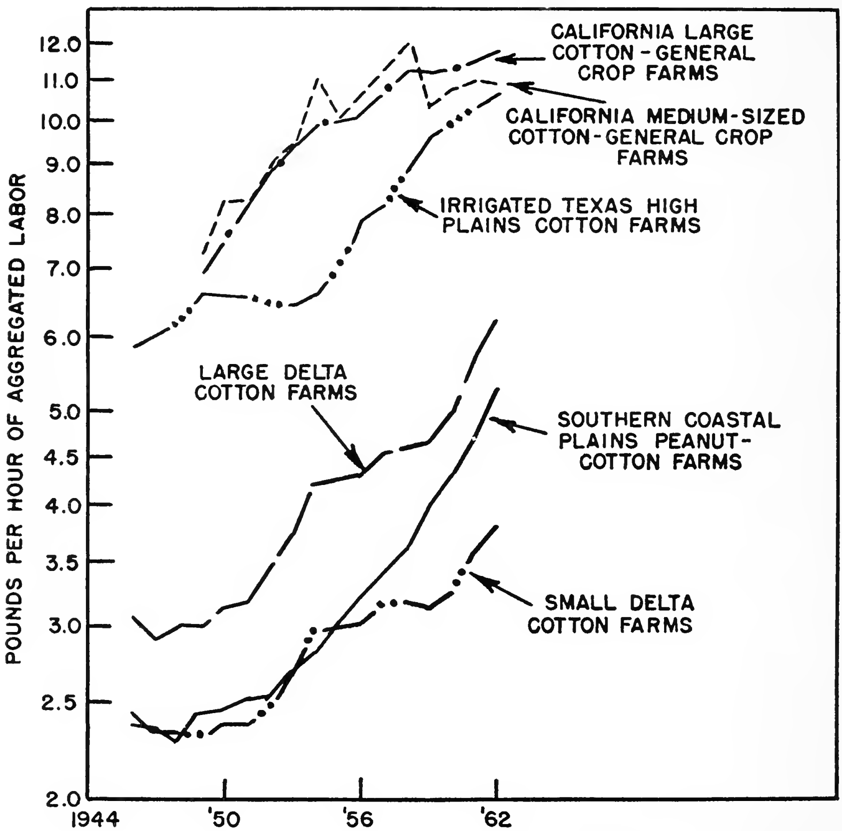


Productivity in cotton production on irrigated California cotton farms, non-irrigated Texas high plains cotton farms, Texas black prairie cotton farms, and southern piedmont cotton farms. (5-year averages.) (Fig. 6a)

the large and small delta, and the irrigated high plains farms are not far removed from the national trend of productivity rise, as far as the data go. The black prairie farm displays a markedly slower rate of improvement from the late thirties to the early fifties, and a more rapid rise thereafter. The lull of the forties is also in evidence in the Texas high plains non-irrigated farms and, to the extent possible to show, in the shorter coverage of the other series outside of California.

Viewed in this way, the productivity rise of most cotton farm types is mutually quite consistent and in line with the tendencies of the wheat and corn farms.

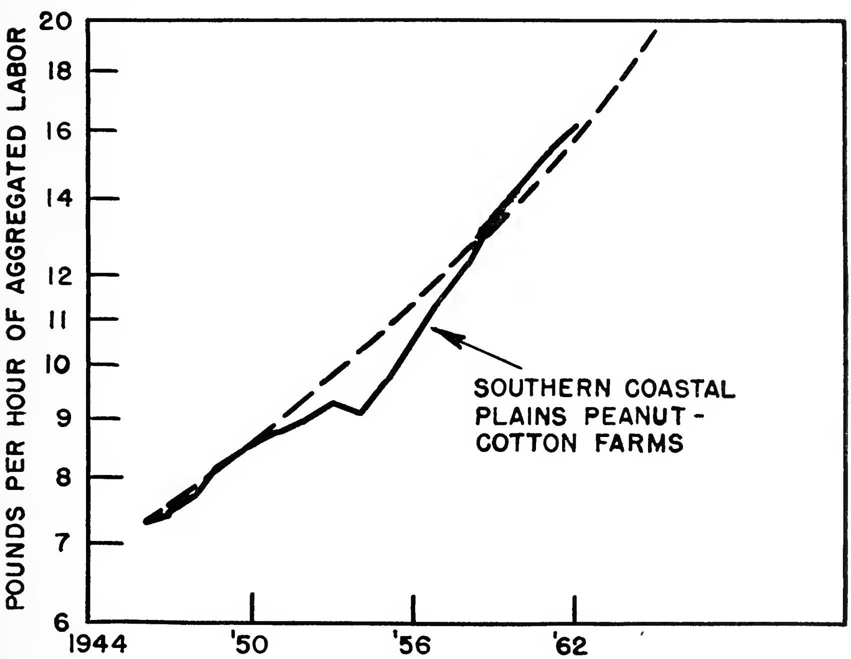
One may notice that the rate of productivity rise on the small-scale delta farm type is nearly as rapid as on the large-scale one; and the latter, although by far the largest among all the farm types shown, is



Productivity in cotton production on medium-sized California cotton-general crop farms, large California cotton-general crop farms, irrigated Texas high plains cotton farms, large delta cotton farms, southern coastal plains peanut-cotton farms, and small delta cotton farms. (5-year averages.) (Fig. 6b) only about average both in level of productivity and in its rate of increase.

The three California farm types appear to form a pattern apart from the rest. At the beginning of the series, in the late forties, all three were on a higher level of productivity than any of the other farm types, and all three were consistently rising at a time when the other farm types were lingering in a period of standstill or rather slow change. Later on, in the period when the other farm types began an acceleration of trend which in many cases exceeded the general rate of productivity increase in the same years, the California farm types leveled out, with only much smaller relative productivity gains around 1960 (in absolute terms — as pounds per hour — they are more impressive than in index terms). As a result, the difference in the absolute level of productivity has again diminished. The Texas high plains farms, which are now close to those of California in the absolute level of productivity, may also be entering a phase of slower increase; no such deceleration is as yet evident on the other farm types with their continuing lower absolute level.

Peanuts. One of the cotton farm types has peanuts as a second major crop. Separate productivity indicators for peanuts from this farm type are shown in Figure 7.

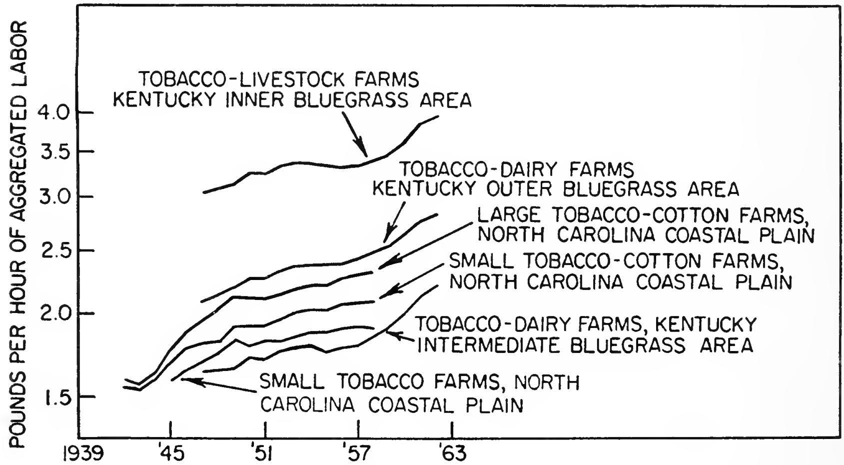


Productivity in peanut production on southern coastal plains peanut-cotton farms. (5-year averages.) (Fig. 7)

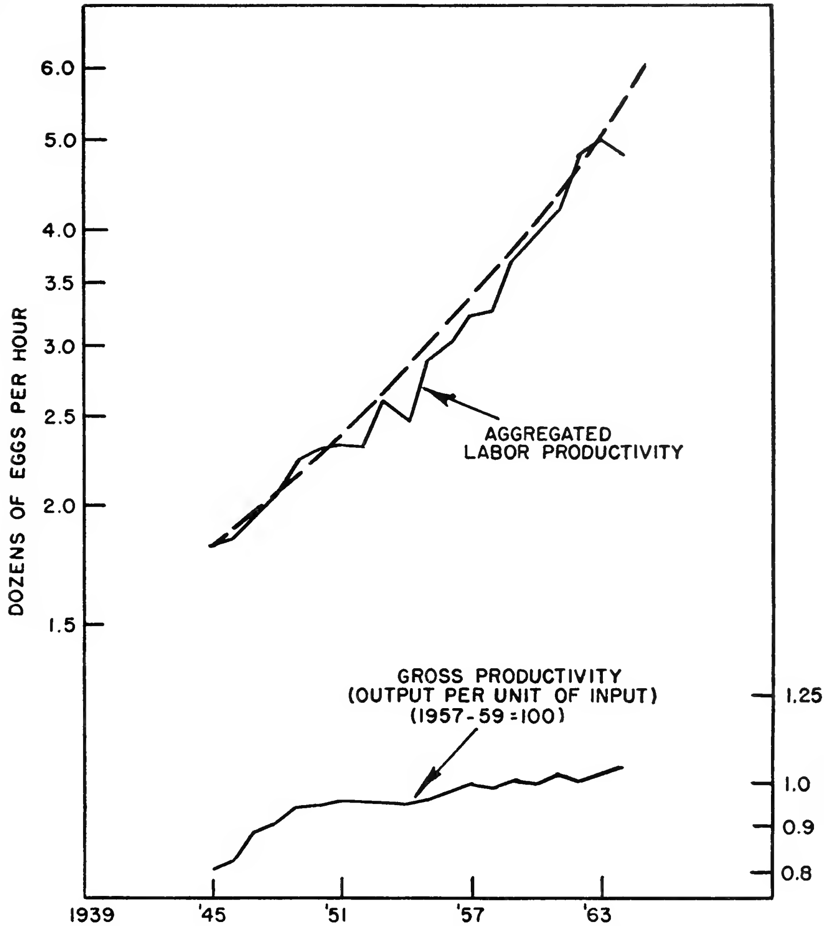
The trend from the mid-1940's to the early 1960's can be fitted to the national trend of productivity increase at 3.5 percent per year with no time lag. In addition, peanuts also display a lag around 1950 as was discussed in connection with both grain farms and cotton farms.

Tobacco. Productivity trends for six tobacco-producing farm types are shown in Figure 8. The time coverage is short and not quite the same for all the farm types. As far as the data go, the following generalizations may be made. They all show a nearly static productivity situation in the early and middle part of the 1950's. Those represented in the middle and late forties indicate some gain at that time (this is mainly on tobacco-cotton farms, at a time when cotton productivity generally was stagnant). Those represented in the early 1960's again indicate some productivity rise. These are all Kentucky farm types, combining tobacco production with dairy or beef production, but there is no clear connection with the productivity trends in those commodities on other farm types or even on the same ones.

There is hardly a case for curve-fitting in this material. If tobacco productivity were assumed to represent some variant of the national agricultural productivity trend at 3.5 percent annual acceleration, then the tobacco trend would be about 25 years behind the national one (i.e., the gains made in tobacco productivity from 1940 to 1965 could be compared to those in national agricultural productivity from 1915 to 1940, or some similar 25-year period).



Productivity in tobacco production on Kentucky inner bluegrass tobacco-livestock farms, Kentucky outer bluegrass tobacco-dairy farms, large North Carolina coastal plain tobacco-cotton farms, small North Carolina coastal plain tobacco-cotton farms, Kentucky intermediate bluegrass tobacco-dairy farms, and small North Carolina coastal plain tobacco farms. (5-year averages.) (Fig. 8)



Aggregated labor productivity in egg production on New Jersey poultry farms. The broken line represents acceleration at 3.5 percent per year lagged 5 years ahead of the national trend. (Yearly data.) (Fig. 9)

Eggs. Aggregated labor productivity data for egg-producing farms in New Jersey are shown in Figure 9, together with gross productivity data drawn from the Farm Costs and Returns publication.[3]

The aggregated labor productivity trend has been rapid — in fact, slightly higher than the national trend during the same years. The

[3] Broiler farms have been represented in the Farm Costs and Returns series for only a few years. The data published are too incomplete to allow computation of aggregated labor productivity (the contributions of the integrators are not shown). For the same reason, the gross productivity indexes shown in the publications are not conceptually comparable with those for other farm types (they are much more net).

broken line on the diagram shows acceleration at 3.5 percent, but five years ahead of the national trend (i.e., the egg productivity movement from 1945 to 1955 was the same as the national agricultural productivity movement from 1950 to 1960).

The gross productivity trend shows nothing of this. During most of the period it is almost horizontal, thus exemplifying the inability of gross productivity measurement to illustrate changes in a highly specialized line of production with a large volume of external inputs.

Milk. Data for six types of dairy farms are shown in Figures 10a and 10b. Three of these farm types are in the Great Lakes states, one in the Northeast, and two in Kentucky.

The pattern of productivity gain is similar on all six types as far as the data go. The timing of changes differs considerably from that of most crop farms. The impact of the depression was smaller than on most crop farms and the predepression level was soon regained. Subsequent productivity improvement was slow up until the mid-1940's. Since then improvement has been rapid on all six farm types, precisely in the period when crop farms were developing slowly and some of them not at all. On some of the dairy farms, at least, progress appears somewhat slower in recent years, again in contrast to most of the crop farms, many of which experienced very rapid productivity gains in the same years.

All of the dairy farm data could be fitted, with some reservation, to some variant of the national trend of 3.5-percent annual acceleration, most of them at approximately a 10-year time lag behind the national agricultural trend.

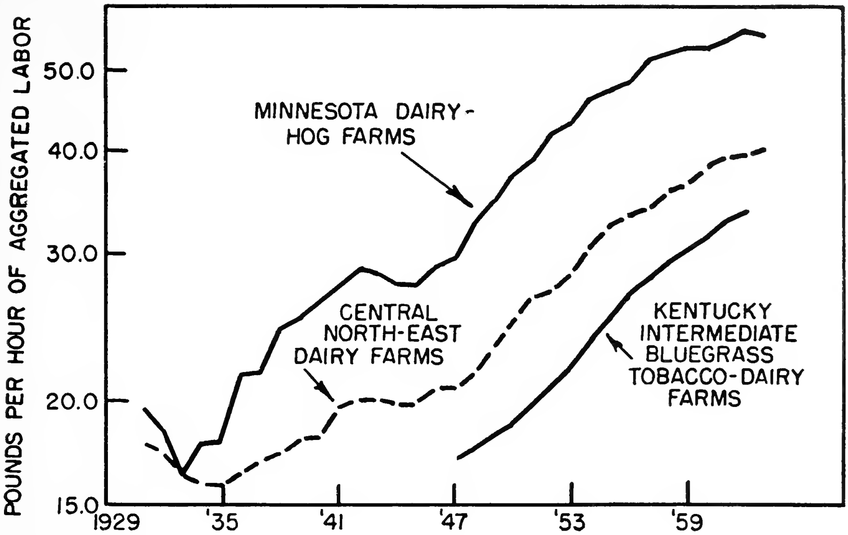
Hogs. Productivity data from three hog-producing farm types (all in the Corn Belt) are shown in Figure 11. They are all rather closely similar in trend and in trend variation, if at somewhat different absolute levels. The depression dip is somewhat more marked than on the dairy farms but less so than on most cash crop farms.

There was rather slow productivity development in the early 1940's, as on the dairy farms, and subsequent more rapid gains in the late part of the same decade when most crop farms were improving more slowly. This is noteworthy because these Corn Belt farms have a large crop-producing component integrated into their livestock production.

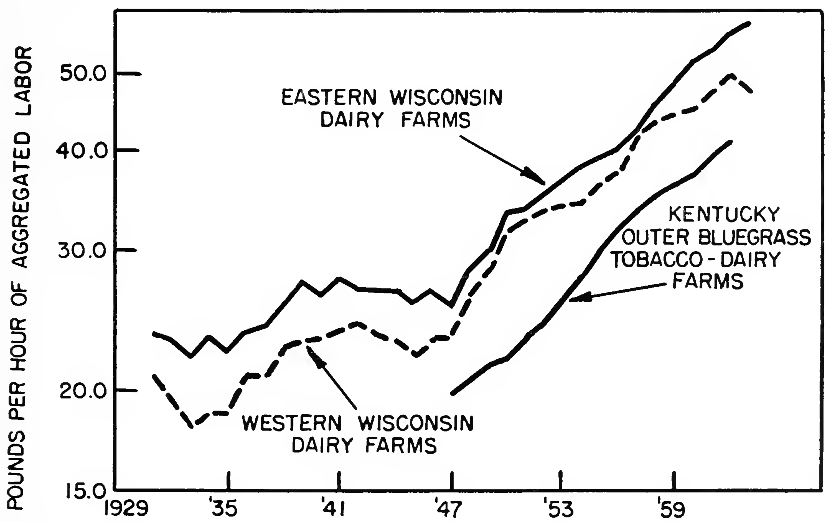
All three curves from hog-producing farms could also be fitted to variants of the function with 3.5-percent annual acceleration, with about a 10-year lag behind the national agricultural trend.

Beef. Data from three types of cattle ranches are shown in Figure 12a. Productivity indicators from four types of farms producing beef along with some other commodity are shown in Figure 12b.

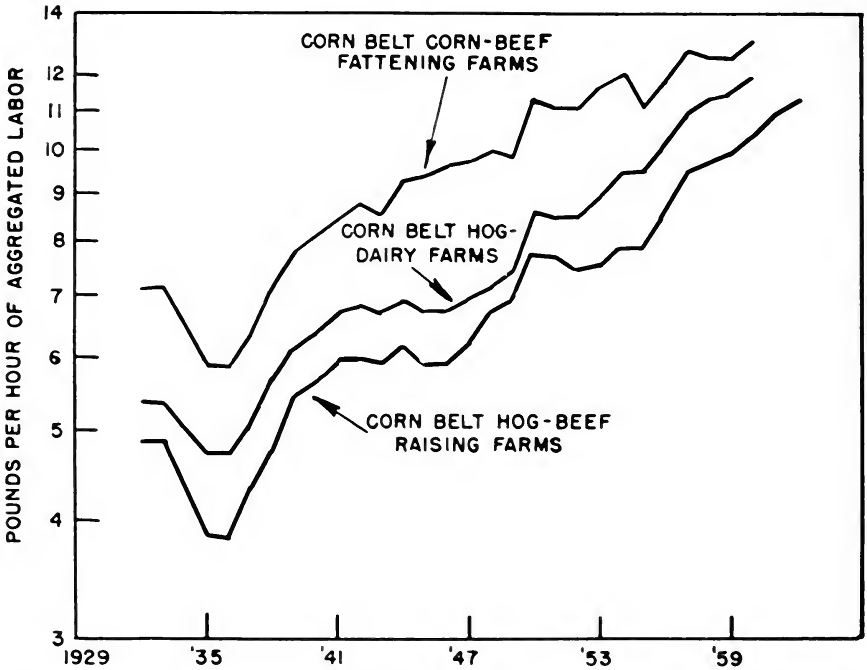
Both types of diagrams have two striking features in common: a rather slow long-term trend of change and wide fluctuations that can readily be identified as being associated with the "beef cycle." By con-



Productivity in milk production on Minnesota dairy-hog farms (3-year averages), central northeastern dairy farms (3-year averages), and Kentucky intermediate bluegrass tobacco-dairy farms. (5-year averages.) (Fig. 10a)



Productivity in milk production on eastern Wisconsin dairy farms (3-year averages), western Wisconsin dairy farms (3-year averages), and Kentucky outer bluegrass tobacco-dairy farms. (5-year averages.) (Fig. 10b)

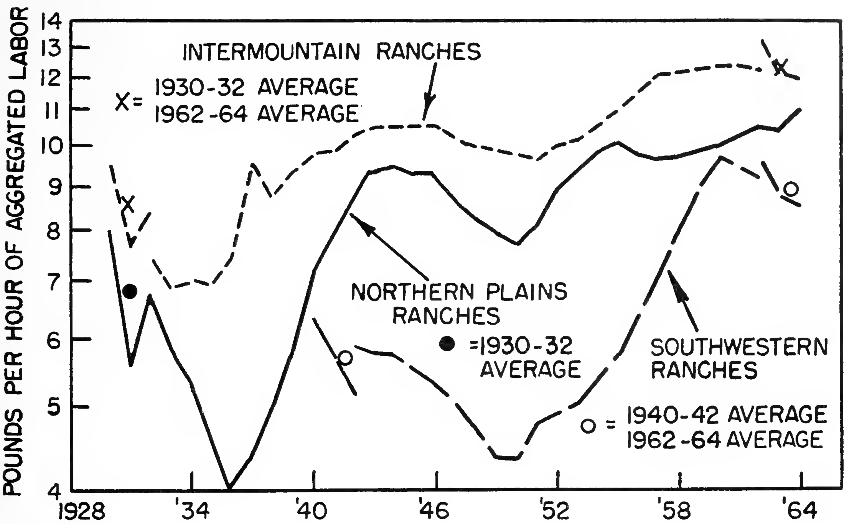


Productivity in hog production on Corn Belt hog-beef fattening farms, Corn Belt hog-dairy farms, and Corn Belt hog-beef raising farms. (5-year averages.) (Fig. 11)

trast, the diagrams shown in Figure 12b do not have very much in common with those for the same farm types on account of their second (or first) product (compare with Figures 4b, 8, and 11). The only connection that can be traced directly is in the depth of the depression dip on one of the wheat farms, but this almost coincides in time with the low point of a beef cycle.

The cycle tops (around 1944-45 and 1955-56) and troughs (around 1935, 1950, and 1959) are more marked on the mixed farm types (Fig. 12b) than on the ranches (Fig. 12a). The intermountain area ranches, which are a pure one-product farm type, show the smallest cyclical variations. The hog-beef-fattening farm type (Corn Belt) shows a variation that is quite close to that of the northern Great Plains ranches, with one-year's lag.

Due to the strong cyclical variation, the much weaker long-term trend is difficult to measure. The trend from one peak to the next, or from one trough to the next, would be the only possibility, but the cycles are so few and are distorted by so many incidentals, that the information becomes very imperfect. Most of the ranch and farm types



Productivity in beef production on intermountain beef ranches, northern Plains beef ranches, and southwestern beef ranches. (5-year averages.)
(Fig. 12a)

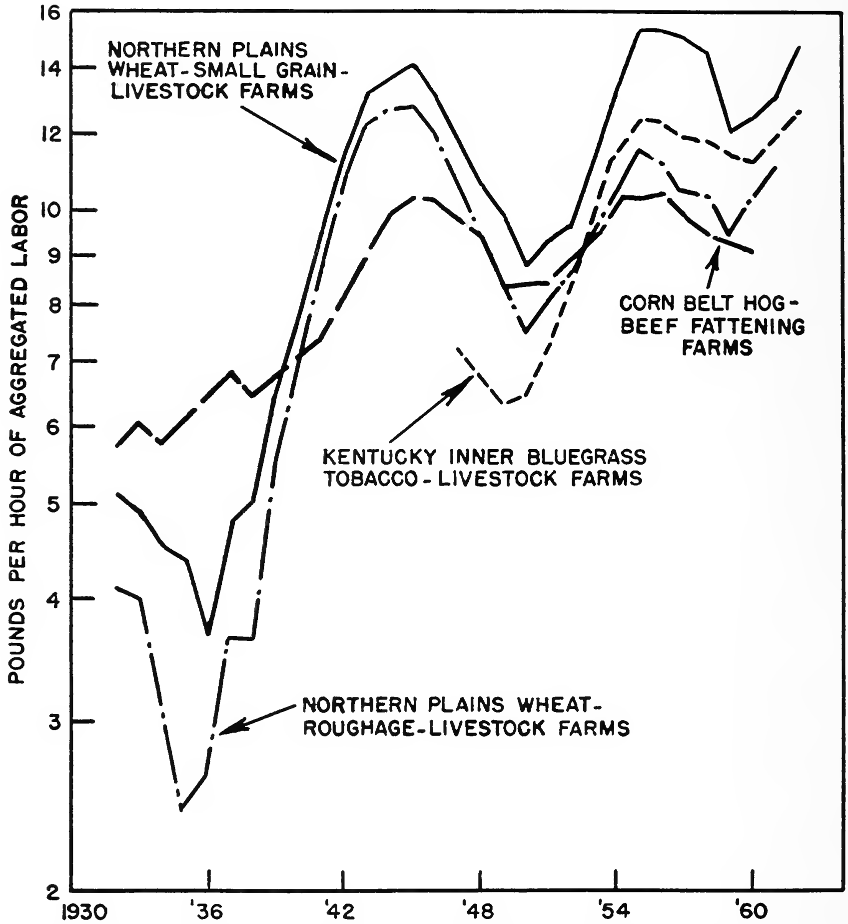
show some rise in productivity, however. Some of them could, with reservations, be fitted to the national trend of 3.5-percent annual acceleration, but with a time lag of about 50 years behind the national trend.

Sheep and Wool. Productivity trends for sheep ranches in the northern Great Plains and in the Southwest are shown in Figures 13a (for sheep) and 13b (for wool). Divergencies between the two sets of diagrams are due mainly to variation in the relative prices of the two closely associated commodities, and to a lesser extent to variation in the role of different races of sheep with different wool-producing capacity.

In terms of sheep (live weight), all changes up until around 1950 may be no more than a recapturing of the precrisis level of productivity. Over the last dozen years, productivity gains have been large and cannot in any way be explained as compensation for previous losses.

In terms of wool, the picture looks more complicated. The precrisis level on the northern Plains was high enough not to be regained until the mid-1950's, and there have been some gains since then. If there is a cyclical pattern similar to that of the beef cycle, the present material may be insufficient to determine the scope of any longer-range gain.

None of these curves can be fitted to any variant of the national 3.5-percent acceleration trend.

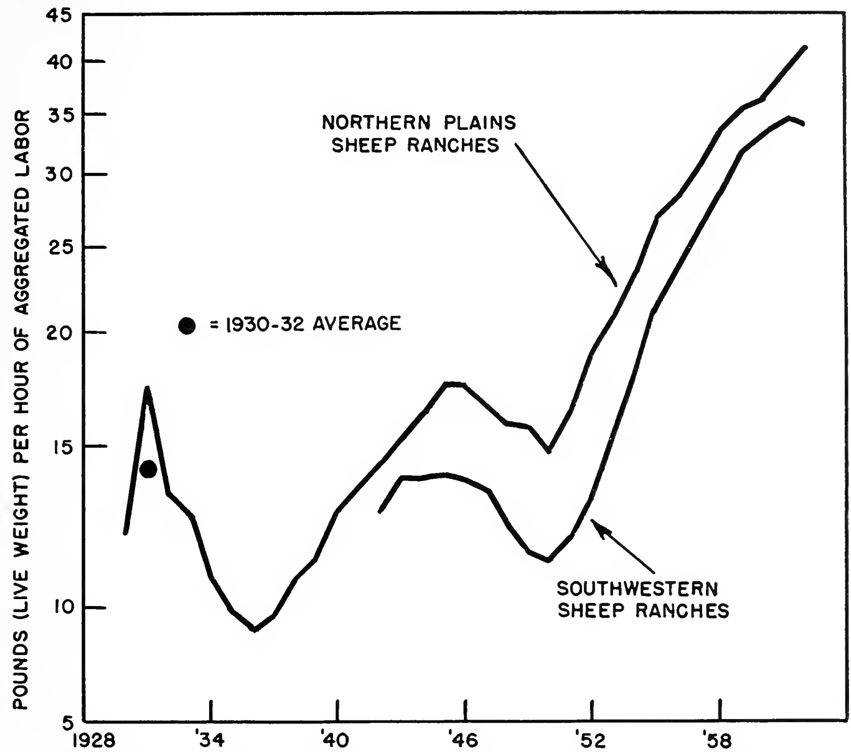


Productivity in beef production on northern Plains wheat-small grain-livestock farms, northern Plains wheat-roughage-livestock farms, Corn Belt hog-beef fattening farms, and Kentucky inner bluegrass tobacco-livestock farms. (5-year averages.) (Fig. 12b)

Summary of Commodity Analyses

Most of the trends are more uneven at the commodity level than at the aggregate level. This is only what would be expected: in a country as large and as varied as the United States, many localized trends are certain to be mutually offsetting.

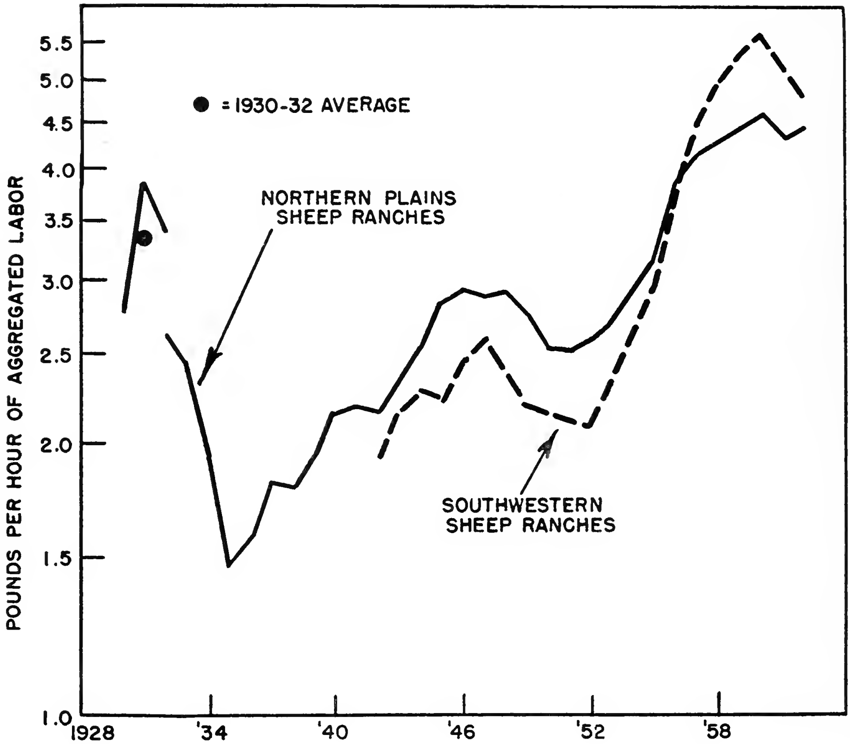
Nevertheless, several of the commodity trends contain elements that can also be recognized in the aggregate trend. The continued acceleration through the 1950's is especially clearly reflected in a very large part of the commodity-level curves.



Productivity in sheep production on northern Plains sheep ranches and southwestern sheep ranches. (5-year averages.) (Fig. 13a)

Moreover, several of the commodity diagrams can be fitted to variants of the continuously accelerating function found in the aggregate of United States agriculture. In these cases, productivity gains can be read as accelerating at a constant acceleration rate of 3.5 percent per year; in most such cases, the commodity trend is either lagging behind or advancing ahead of the national trend. The rate of 3.5 percent may possibly be interpreted as the rate at which pent-up technological gains are released into productive reality (the "storehouse of knowledge" problem). It may be reasonable to assume that such release cannot take place at an any too rapid a rate, especially not as long as the bulk of the commodity or the farm type is still characterized by previously rational, lower-productive technology.

Be this as it may, there are farm types on which productivity change is definitely not accelerating and where it may even be interpreted as decelerating. This is above all true of the Great Plains wheat farms and could also be true of the Northwest wheat farms after their yield gains have been cashed in. The same may be true of certain cotton farm types, namely the most highly productive ones (in California and



Productivity in wool production on northern Plains sheep ranches and southwestern sheep ranches. (5-year averages.) (Fig. 13b)

on the Texas high plains). All of these farm types had experienced a good deal of productivity improvement before the period under study (wheat) or else productivity was already high when production was started not too long ago (cotton both in California and on the Texas high plains).

The slow productivity change in beef production, especially on the ranches, is possibly indicative of specific obstacles to productivity improvement, as might be expected in an environment such as that of the Rocky Mountains, where feed production can hardly be expanded and feed conversion does not improve much either.

It appears from the data analyzed above that productivity in cash crops has moved along rather similar patterns in the wheat areas, the Corn Belt, and the cotton areas. Periods of slow and of rapid productivity increase roughly coincide in most cases. By contrast, productivity in animal husbandry appears rather independent and may have a pattern of its own. When these differences are aggregated, they partly offset each other in the national productivity indexes.

CHANGES IN CAPITAL INTENSITY

The causes of productivity change are many and complex, and any exhaustive causal analysis would necessitate further work both on conceptualization and measurement. It should be mentioned that the same event can have several sets of causes, each of which is indispensable in the sense that if that set of causes failed to materialize, the others would also be powerless to set off any effect. In the case of productivity increase, one may point to changes in the input mix as primary causes. Greater inputs of some of the most efficient factors of production replace parts of the less efficient ones which are then withdrawn and used elsewhere in the economy. Seen from one angle, it is quite feasible, in principle, to explain all of the productivity changes from changes in the characteristics and the quantities of production factors employed. At the same time it is of course true that none of this would happen unless financial conditions and other practical circumstances made it feasible for farmers to obtain the improvements in input mix that lead to higher productivity. Financial feasibility is thus another set of causal factors that must not be included in the equation together with the physical inputs, but must be analyzed separately to answer another facet of the same general complex of problems.

The financial factors are being examined in a separate inquiry. At present we are most directly concerned with the changes in physical inputs and how they may explain or at least illustrate the process of productivity change. Since the present inquiry is concerned with examining policy problems, the crucial productivity problem is seen as the relation between capital intensity and productivity. Rather than attempting any comprehensive causal analysis, this section examines those changes in capital intensity that can be characterized with the means at hand.

There is no arguing about the general tendency towards higher capital intensity in United States agriculture. When measured in constant prices, farmers' expenses for machinery and mechanical power, fertilizers and lime, and other inputs produced outside the farm sector have all increased more rapidly than farm output — both over the long run since 1910 or 1920 and in the shorter run since around 1950. The incremental capital-to-output ratio of these inputs, although still high in most cases, is thus declining in physical terms. Conversely, the stock of productive animals has increased less than the output of animal products. Land has hardly changed at all in aggregate terms.

Along with all this, the input of direct labor (in physical terms) has been declining at an accelerating rate until the late 1950's and possibly at a decelerating (but still high) rate since then. Rising ratios of land, livestock, and externally generated capital per unit of direct labor are mainly corollary of this change in the use of direct labor. In a statistical sense these changing ratios might explain much of the productivity change, the remainder being explicable by changes in area-unit crop yields, animal-unit yields of animal products, and changes in the output mix. But such a statistical explanation would amount to little more than a reiteration of the story already told. Decline in manpower and rise in yields *are* the productivity change; they do not explain it. What needs explaining are the forces that rendered possible both the rises in yields and the reduction in the use of direct labor.

When productivity is measured in terms of aggregated labor, changes in the input mix may be expressed as changes in the proportions between direct and indirect labor. A regression analysis was tried for three of the dairy-farm types, with only two variables — the ratio of direct to indirect labor, and a dummy variable for the years 1946-1953 to account for an abnormally high rate of capital goods acquisition in those years. On all three farm types, an R^2 value close to 0.8 was obtained.[1] Although this might go a long way in explaining the productivity change (the residual being attributable mainly to yield changes), it does in fact little more than restate the problem once again. The ratio of direct to indirect labor is an expression of a whole series of physical and economic causative factors, but of itself it does not really explain anything.

The ratio of direct to indirect labor expresses two things: the large decline in the use of direct labor and the very small increases in the application of indirect labor due to the rise in productivity in the factories and offices supplying factors to agriculture. These two things are, of course, interrelated but to further explore their mutual relations is not within the scope of this inquiry.

If capital intensity has risen in the sense that each acre and each worker is associated with more capital, then there is a remarkably stable relation between capital and output. Table 3 shows a few selected indicators.

It is easy to note that even the total of all assets has risen at approximately the same rate as net output. The bulk of the asset value being in real estate, it is necessary to stress that the area of land used in agriculture is nearly constant. Changes in real estate values are so closely tied in with productivity changes that the analysis of capital intensity should be done on capital other than real estate; this is why column 8 in Table 3 shows the ratio of output to the subtotal of column 6. This ratio falls in the early part of the period shown, then rises again and reaches a value above that of 1940. But total variation is slight, with some renewed decline shown by the 1965 figure.

It is also conspicuous that the value of machinery capital has risen more than capital in general and more than output. Livestock and other capital (which includes crop and feed inventories and working capital) have risen at about the same rate as output.

A further step is to ask whether capital intensity has raised the

[1] Leunis, *op. cit.,* Chapter 5.

Table 3.—Production Assets Used in Agriculture at Current Prices on January 1 of Specified Years From 1940 to 1965 and Relation to Gross Output During the Same Years

Year	1 Farm real estate	2 Live-stock	3 Ma-chinery	4 Other	5 Total	6 Total less real estate	7 Net output[a]	8 Ratio of 6 over 7	9 Ratio of 3 over 7
				billions of dollars					
1940	27.9	3.9	3.8	2.2	37.7	9.8	8.8	1.11	.43
1945	45.5	8.0	6.9	5.1	65.6	20.1	20.9	0.96	.33
1950	64.6	12.4	11.2	6.7	95.0	30.4	27.7	1.10	.40
1955	85.8	11.0	15.8	7.4	120.0	34.2	27.9	1.23	.57
1960	116.0	15.2	19.2	7.1	157.5	41.5	30.4	1.37	.63
1965	144.3	14.4	20.9	6.6	186.1	41.8	34.9	1.20	.60

[a] Gross output less interfarm transfers.
Sources: Asset data from "The Balance Sheet of Agriculture." USDA Agricultural Information Bulletin 290, p. 15. Revised 1965. Production data the same as used in previous sections of this publication.

"real capital ratio" in the sense proposed by Joan Robinson,[2] or in some related sense. Is the capital associated with one worker now a higher proportion to that worker's earnings than before? The data in Table 3 suggest the opposite, and this is confirmed by wage data. The index of composite farm wage rates (USDA), with the 1910-1914 period set at 100, rose from 131 in 1940 to 366 in 1945, 432 in 1950, 519 in 1955, and 629 in 1960; in a new index series, with the 1957-1959 period set at 100, 1963 has already advanced nine index points over 1960. In total, then, the wage level has increased about five times from 1940 to 1963, which is a greater increase than in the current value of either total farm production assets, or total assets less real estate, or total net farm output. Only machinery capital has increased in current value somewhat more rapidly (about 5½ times) than did farm wage rates. What all of this means is that the "real capital ratio" in agriculture has not really increased—if anything, it has gone down somewhat. But a number of accounting problems indicate that this conclusion should not be overemphasized. Only the ratio of machinery capital to the wage-cost of labor may have risen somewhat, but probably not very much.[3]

At the farm-type and commodity levels the above conclusions can be made more detailed and more explicit. The ratio of land (as acres) per worker is an inverted expression of the rate of rural exodus and the concomitant increase in farm size. Moreover, as noted above, farmland value is highly dependent on productivity. Therefore, the current asset value of farmland and buildings, being already at least in part a consequence of productivity change, should not be used as a means of illustrating the capital-intensity aspect of productivity change. In the

[2] Joan Robinson, *op. cit.*

[3] Analysis by subperiods would show a more complex pattern, the details of which cannot be accounted for here.

analysis of capital intensity by farm types land value was therefore disregarded. Other capital was further disaggregated into machinery and equipment, livestock, and crop inventory.[4]

This analysis showed that both livestock inventory and crop inventory have a distinct disadvantage as elements of a "real capital" ratio: their price, too, varies with productivity, although in the opposite direction as land. Especially in regard to livestock, which is a large part of all capital on some types of farms, it turned out that the capital ratio often fell with increasing productivity. This is in a sense logical, for with the rise in productivity, the unit price of the output — the animals — should fall. When the output is also a form of capital (in this case not just "inventory" but also a productive asset in the full sense of the expression), then evidently the relation easily becomes paradoxical. Analysis of capital ratios for livestock capital (in current value terms) as a ratio of the wage cost of a full-time yearly wage worker was therefore abandoned. Also abandoned was the corresponding analysis of crop inventory capital value for the same reason as in the case of livestock, and because crop inventories are usually a small part of all capital.

The analysis was carried through in regard to the capital group "machinery and equipment." Even when machinery capital was expressed as a ratio of its current value per man-year of farm work used to the wage cost of a full-time wage worker, most farm types showed rather inconclusive curves. The main direction of the curve is horizontal, indicating no change to speak of. Several of the diagrams have incidental movements up and down, but the net result over the period under study is that few farm types illustrate any persistent tendency for the machinery-capital ratio to change with productivity.

The principal exceptions to this rule are the cotton farms. All of them have a distinct rise in the machinery-capital ratio over the period under study, and on most of these farms the rise in this ratio follows a curve quite similar to that of the productivity movement. This even extends to the California farms with their initial rise around 1950 and their subsequent slower movement in more recent years.

These peculiarities of the cotton farms reflect two different things. For one thing, mechanization on cotton farms has been more rapid in recent years than on most other field-crop farms, and their productivity improvement has depended more on this rising technical efficiency than on rising yields. The second, and probably the more important circumstance, is the fact that cotton is a subsector where wages are not only lower than in United States agriculture in general, but also have risen less than farm wages and farm incomes in other parts of the country. Therefore the wage cost of a full-time wage worker has not risen equally with productivity and capital accumulation, and the increasing assemblage of machines on these farms comes to represent a rising

[4] Working capital is not shown in the Costs and Returns publications.

ratio over the wage cost of labor. The same may be true in regard to some farm types not covered by the inquiry such as truck farms and broiler farms.

This may well explain the tendency for machinery capital to have risen more than the wage index in the country as a whole. It may be the effect of the wage lag in certain subsectors where labor has had less alternatives for employment.

In the sense of the "real capital ratio" there has thus hardly been any change in the degree of capital intensity, except in some subsectors with peculiar circumstances to explain the deviations. That this is true while the ratio of indirect to direct labor is rising is another sign of the rising efficiency of the industries and services supplying agriculture. This rising efficiency is in fact a principal source of rising aggregated labor productivity in agriculture.

PRODUCTIVITY AND EARNING POWER

Rising productivity means increased prosperity in the community where it occurs. More is produced with the same input, the same is produced with less input, or a rising level of inputs produces output at a rising rate. Barring any concealed inefficiencies to offset these gains, these movements should benefit the community. The question is which of its members benefit the most, or whether the gains are evenly or unevenly distributed across the community.

In a market economy, without any great manipulation of wage scales by vested interests, when aggregated labor productivity in agriculture rises more than average for the economy, the direct result should be a reverse movement of the relative prices of the output. If all industries improved their productivity at the same rate, the relative prices of their products should remain unchanged. Those industries that are unable to raise their productivity will have to charge relatively more for their products, or else reduce their volume of activity, or both. Conversely, those activities where aggregated labor productivity rises more than average for the economy will have to lower the relative prices of their products; otherwise factors would flow in from other parts of the economy or would fail to leave the activity in question when they should. The successful industry would then be oversized, and this would sooner or later reduce the price level of its output.

These tendencies for prices to move in the opposite direction of productivity can be observed in several of the commodity-level analyses presented briefly above. The cases of two-product farms with very different trends for the two commodities are especially telling. The best examples are perhaps the tobacco-dairy farms in Kentucky.

Such consequences may be partly averted in monopoly or quasi-monopoly situations, including "closed-shop" wage and employment rules enforced by labor unions or by other associations representing some vested interest in a powerful segment of the economy.

American agriculture does not have many such constraints; in fact, as has been often repeated, it offers more instances of classic "perfect competition" than most other parts of the economy. The concurrent condition of very low demand elasticity for farm products (in the aggregate) places severe limitations on the room for maneuvering between prices and volume of activity.[1] Consequently, rising productivity can be used for market expansion only to a limited extent. Whenever productivity rises faster than effective demand, resources must leave agriculture just to maintain the relative earning power of those resources that remain. There is thus unusually little room for maintaining relative prices in excess of what productivity would warrant.

At the same time, price supports have been and are in effect on certain commodities. Any distorting effect of these supports on the development of agriculture should become apparent from an analysis of the interaction between productivity and relative prices.

The concept of relative price used in the following is "unit price of the commodity as percentage of a per capita national income." This might also be called the "real price" or the "real-term" or "labor-term" price. Such a formulation of relative price will express the degree to which consumers get the commodity cheaper in real terms, i.e., against less of a sacrifice of their labor earnings. The ratio of labor force to total population being rather stable in the United States in recent decades, per capita national income may serve as a proxy for per-worker product in the national economy.

This concept of relative price may be placed in relation to the change in productivity. If, for instance, aggregated labor productivity in dairy farming has doubled over a certain number of years, then a man-year of aggregated labor produces twice as much milk as before. If, at the same time, the relative price (in the definition given above) has fallen to half, then a per capita national income (or any given fraction thereof) can buy twice as much milk as before. Such a price development would mean that a man-year of aggregated labor used in dairy farming still earns the same share of a per capita national income as before; its relative income position is unchanged. In such a case the aggregated labor used in dairy farming has received its share of the national productivity increases at the same time as its own specific contribution to that productivity increase has been passed on to the public in general. A change in relative price that was less than inversely proportional to the rise in productivity of the product in question would mean that not all of the gain would be passed on to the public. Part of it would be retained by the aggregated labor used in the product

[1] This holds in the aggregate, which is what counts when we are discussing the affairs of American agriculture as a whole. Some commodities may have relatively high elasticity coefficients, but others are close to zero in regard to price and some are even negative in regard to income. As a consequence, the aggregate has low demand elasticity. The relative ease of transfer of resources between enterprises within farming makes the effect pervasive.

and by other factors associated with its production. The reverse would be true if the relative price were to fall more than in inverse proportion to the change in productivity.

The relative earning power of aggregated labor expressed in this way is not too directly related to farmers' incomes. The earning power relates to all of the aggregated labor and to all other factors, including land and capital, used for the production of the product in question. If, for instance, the earnings of agriculture are being capitalized into land value to a higher degree than previously, then labor, especially on-farm labor, used for agricultural production may earn less income increment than indicated by the relation between productivity improvement and change in relative price. Something similar may of course also happen in the nonfarm sectors. The indicators about "earning power" thus refer to the trend in income that would result if factor shares (distribution between land, labor, and capital, and between subgroups of each) were to remain essentially unchanged in the distribution of earnings from the commodity in question.

Nevertheless, the relative earning power of labor used for agricultural production is an important indication of the general consequences of productivity change in the agricultural subsystem — how far these consequences accrued to the subsystem and how far they filtered through to the community at large. When this analysis is carried through to the commodity level, it will also tell something about the relative success of the several lines of production within agriculture. Some indications as to the effects of the commodity price support programs are also likely to emerge.

Figures 14 through 23 illustrate this problem. They show the ratio of relative price (as defined above) over the inverted productivity index. Or, expressed more simply, they show the productivity index multiplied by the relative-price index.[2] The level of each curve indicates the number of hours of aggregated labor needed each year to generate products to the value of one per capita national income of the commodity or commodity group in question. The higher the curve, the lower the level of relative earning power.

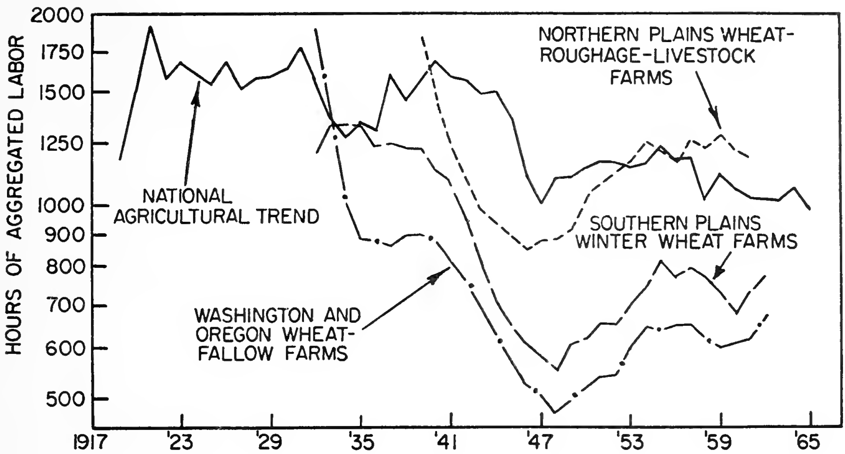
The meaning of the various levels of earning power within agriculture may be more easily seen if we first note the average for the national economy. Since the proportion between labor force and population in the United States has remained rather stable (close to 40 percent) over the period under investigation, and since the work year in factories and offices has been close to 2,000 hours over most of the period since 1930, it follows that the amount of labor needed, on the average in the national economy, to produce one per capita national income is about 800 hours.

[2] The price is the local price of the state where most of the farm type is located: i.e., Kansas wheat price for the southern Great Plains wheat farms, Washington wheat price for Northwest wheat farms, etc.

In addition to commodity curves, Figure 14 carries a curve for the whole national agricultural economy for the period since 1919. This curve shows a rather steady level of from 1,500 to 1,700 hours for most of the period from 1920 to 1944. The level was lower and the relative earning power was higher in 1919-20 and again from 1933 to 1936. During the great crisis, agriculture in some sense suffered less than other parts of the economy, principally because there was no unemployment. From 1944 to 1947 the level fell abruptly and the earning power of agriculture improved. Since then it has remained on what appears to be a new level of from 1,100 to 1,200 hours. The other figures (15-23) carry the part of the curve for the whole national agricultural economy that pertains to the years in question.

This improvement in the earning power of the agricultural subsystem in the late war years and the early postwar period could be explained, in the short run, by war shortages and by the rapid expansion of production that was carried out to meet the needs. Its continuation in the further postwar period can be explained in part by the same causes which tended to hold many farm commodity prices rather high, allowing many farmers to rapidly build up their equipment and hence their productivity. Continuation after 1950 may in part be the result of price supports, but it also reflects the changed proportions of direct and indirect labor in the input aggregate. Since indirect (off-farm) labor is now a larger share of the total, its higher wage expectations should have some effect in lowering the number of hours required to produce a per capita national income worth of farm products because the relative prices could not fall low enough to reduce the earnings of factories and offices supplying the farm sector with production requisites. However, the share of indirect labor in the aggregate from 1930 to 1960 rose only from about 16 percent to about 32 percent. This is not enough to explain all of the improvement in earning power, unless the wage differential between farm and nonfarm labor were to have widened in the same period, which is not the case. About half of the improvement in earning power can be assumed to have gone to on-farm (direct) labor and factors directly associated with it, such as land. To this extent, the improvement may very well be the result of price supports. To what extent this gain stayed with farmers (as workers) or was passed on to landowners is not clear.

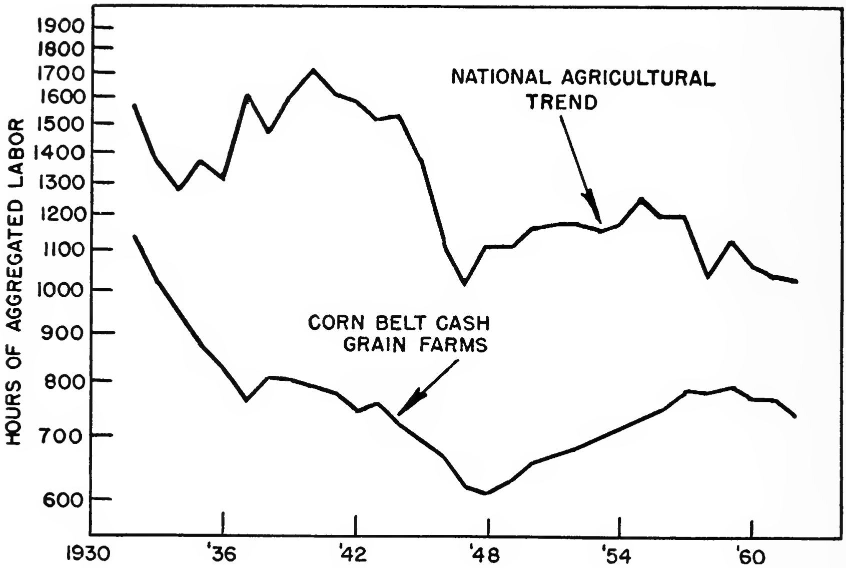
Wheat. Figure 14 shows the relative earning power of aggregated labor used on three types of wheat farms. The precrisis level for wheat farms may have been lower than for United States agriculture as a whole. In any event, the Great Plains farms had a level similar to that of agriculture in general in the late thirties, while the Northwest farms, because of their rapid productivity improvement based on rising yields, experienced substantial improvement in this period. Thereafter, all three wheat farm types improved spectacularly during the period of wartime and postwar shortages. This improve-



Rate of return in wheat production: Hours of aggregated labor needed to produce one per capita national income worth of wheat on northern Plains wheat-roughage-livestock farms, southern Plains winter wheat farms, and Washington and Oregon wheat-fallow farms. (Fig. 14)

ment was least striking on the northern Great Plains, where the whole picture broke down in 1934 and 1936, but these farms have reverted to the national level in recent years. The southern Great Plains farms and the Northwest farms have also lost some of the early gains. The Northwest farms have a considerably higher earning power as compared with the whole national economy. Substantially less than 800 hours are needed to produce a per capita national income worth of wheat in this area. They are also ahead of all other farm types represented in this material, except the California cotton farms (see Figure 16). Even the cash grain farms in the central Corn Belt (see Figure 15) do not reach this level. This, of course, is no reflection on relative productivity since the commodities are not the same; rather it indicates that the Northwest wheat farms are benefiting from the price support level, which is principally geared to areas with lower acre yields, combined with their own high acre-yield level. The southern Great Plains must similarly be benefiting substantially from the price support levels; their level of earning power is also close to that of the central Corn Belt with its high land productivity. The contrast against the northern Plains is striking and reminds one that most of the wheat surplus used to come from the southern Plains.

Corn and soybeans. Figure 15 shows earning power on cash grain farms in the central Corn Belt. The start of the curve was already below the contemporary level for agriculture as a whole, and it improved to the level of the national economy (about 800 hours) in the late thirties. Most of the subsequent improvement in the wartime and

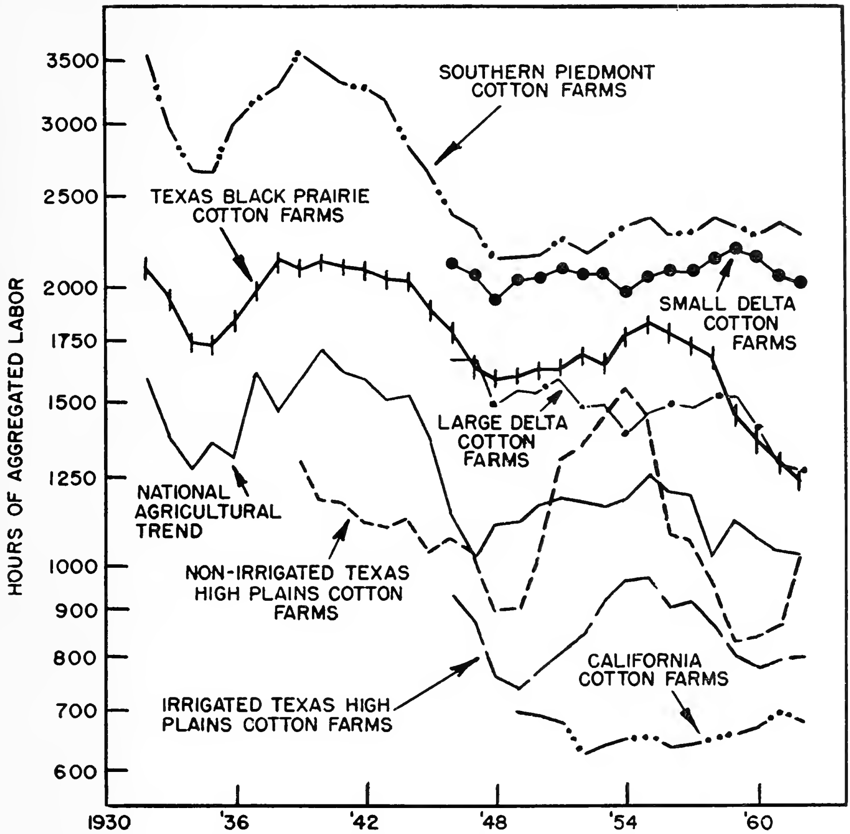


Rate of return in corn production: Hours of aggregated labor needed to produce one per capita national income worth of corn on Corn Belt cash grain farms. (Fig. 15)

postwar years has disappeared, even though the most recent years may indicate some renewed improvement of aggregated labor earnings in this area.

In both wheat and corn the improvement in earning power has in part antedated that of the national trend while in part coinciding with it and thus contributing to the rather sudden change in the period from 1944 to 1947.

Cotton. Data for seven cotton-producing farms are shown in Figure 16. The most striking feature of this figure is the wide variation in earning power between cotton-production areas. Those in California and the Texas high plains are better than the national agricultural average; those in California are even ahead of the national economy in general. The Southeast, the delta, and the Texas black prairie are behind the national agricultural average for all years for which data are available. The black prairie farms and the large delta farms (plantations, typified by a 1,000-acre unit) are found, in most of the postwar period, on the level of 1,500 hours, that characterized the national agricultural economy previously. But the black prairie farms required even higher inputs of labor for a per capita national income previously, as did the southeastern farms. Both of these types contributed visibly to the general improvement in earning power in the period from 1944 to 1947. The Texas black prairie farms have continued to improve in recent years as have also the large delta farms.

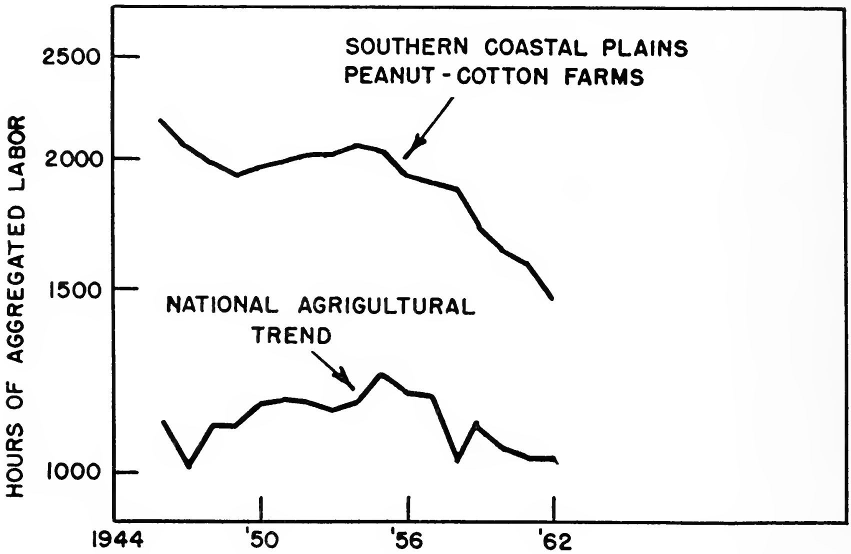


Rate of return in cotton production: Hours of aggregated labor needed to produce one per capita national income worth of cotton on southern piedmont cotton farms, small delta cotton farms, Texas black prairie cotton farms, large delta cotton farms, non-irrigated Texas high plains cotton farms, irrigated Texas high plains cotton farms, and California cotton farms.

(Fig. 16)

Peanuts. Figure 17 shows data on earning power for peanut-cotton farms in the southern coastal plains. Like most of the cotton farms in this area, this farm type has a level of earning power considerably behind that of agriculture in general. A sharp productivity increase in recent years is reflected in improvement in the earning-power level relative to agriculture in general. None of this improvement came in the period from 1944 to 1947.

Tobacco. Figure 18 shows rates of return in tobacco production for five tobacco-producing farm types. The rather short period shown indicates a steady level on each farm type, varying from something close to the national level on Kentucky tobacco-livestock farms to more than 2,000 hours on North Carolina costal plains farms. The combina-



Rate of return in peanut production: Hours of aggregated labor needed to produce one per capita national income worth of peanuts on southern coastal plains peanut-cotton farms. (Fig. 17)

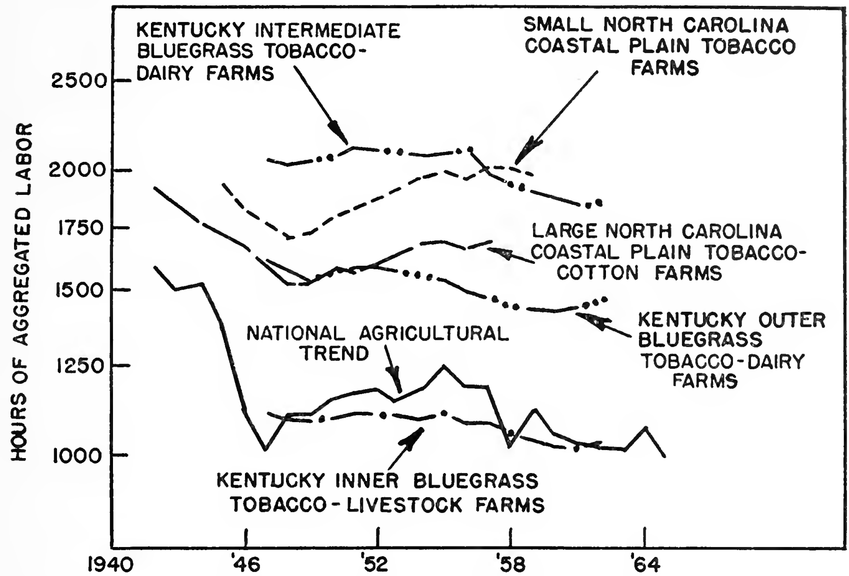
tion of slow-moving productivity and rather effective price supports can be assumed to be reflected in these results.

Eggs. The rate of earnings in New Jersey egg farms is shown in Figure 19. The nearly horizontal line indicates that the very dramatic gains in aggregated labor productivity have been accompanied by offsetting declines in the relative price of eggs, maintaining an earning power well below that of the national agricultural economy but close to the level that prevailed in United States agriculture prior to 1944. The low level of earnings in poultry farming is well known, and the data shown here indicate that most, if not all, of the gains in productivity have been passed on to consumers.

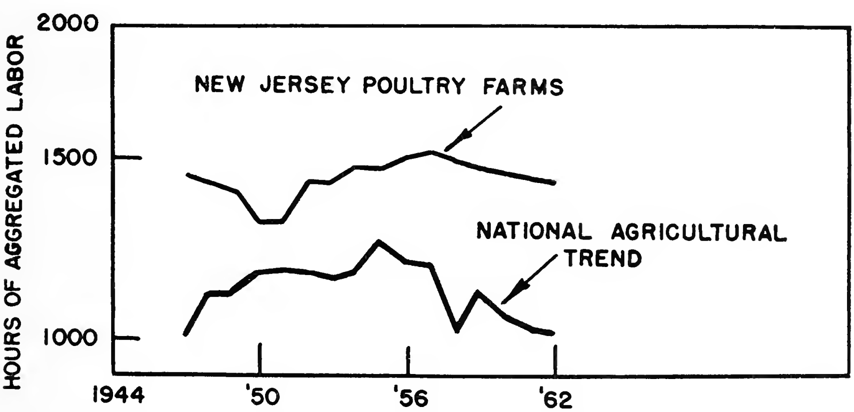
Milk. Data for four dairy-farm types are shown in Figure 20. The four farm types are rather close together and rather close to the national average. Only the Minnesota dairy-hog farms have attained a level not too far from the national average since the mid-1940's. All four farm types also followed the general improvement pattern from 1944 to 1947 rather closely.

The contribution of milk to the national aggregate is large, exceeded only by beef, and then only in recent years when the beef price went down less than the milk price. The close association of the milk curves to the national one is therefore not mere coincidence.

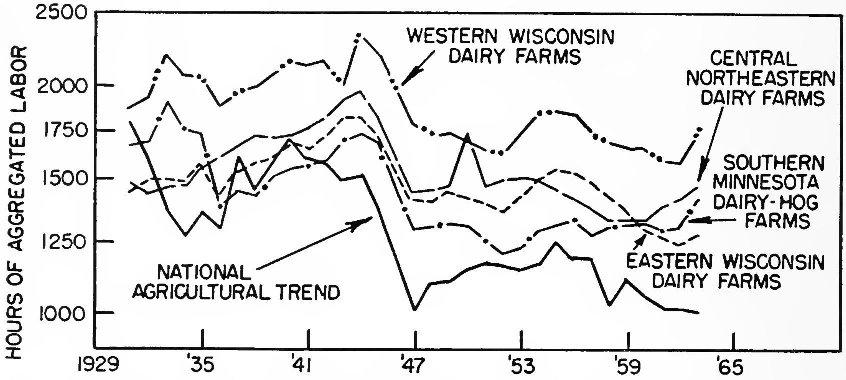
Hogs. Productivity curves for the three hog-producing farm types are shown in Figure 21. In general, these curves also resemble that of



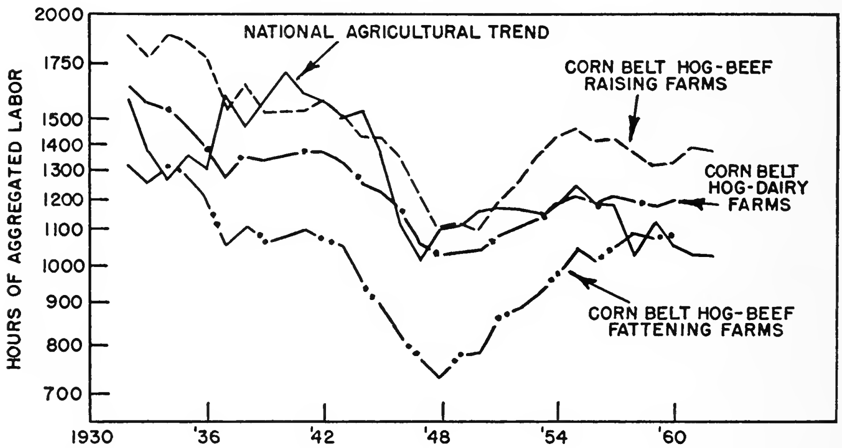
Rate of return in tobacco production: Hours of aggregated labor needed to produce one per capita national income worth of tobacco on small North Carolina coastal plain tobacco farms, Kentucky intermediate bluegrass tobacco-dairy farms, large North Carolina coastal plain tobacco-cotton farms, Kentucky outer bluegrass tobacco-dairy farms, and Kentucky inner bluegrass tobacco-livestock farms. (Fig. 18)



Rate of return in egg production: Hours of aggregated labor needed to produce one per capita national income worth of eggs on New Jersey poultry farms. (Fig. 19)



Rate of return in milk production: Hours of aggregated labor needed to produce one per capita national income worth of milk on western Wisconsin dairy farms, central northeastern dairy farms, eastern Wisconsin dairy farms, and southern Minnesota dairy-hog farms. (Fig. 20)



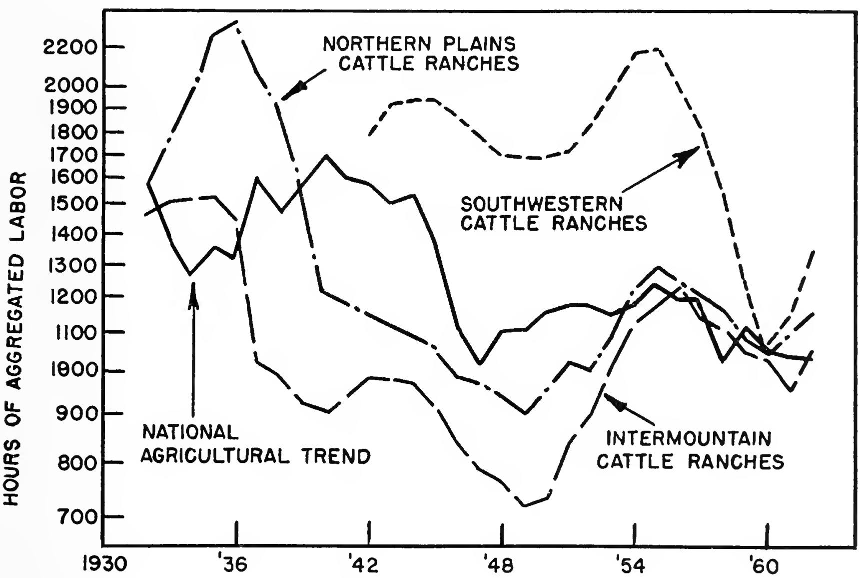
Rate of return in hog production: Hours of aggregated labor needed to produce one per capita national income worth of hogs on Corn Belt hog-beef raising farms, Corn Belt hog-dairy farms, and Corn Belt hog-beef fattening farms. (Fig. 21)

the national agricultural economy as well as those of the dairy farms. In both commodities, most of the productivity improvement has been absorbed by reverse movements of relative prices. The proportions between the levels of the three farm types have remained remarkably stable.

Beef. Figure 22 shows data from three types of cattle ranches. Two of these types show rates of earning equal to or better than the national average for agriculture. The third one (Southwest) is considerably behind, but then this is the ranch type that showed the lowest productivity in terms of beef. (See Figure 12a.)

The cattle ranches appear to have received their share in the general improvement of the earning power of agriculture. This is in contrast (in appearance only) to the fact that productivity in cattle ranching, and in beef production generally, has improved only slowly over the period under study. Again, this means that the relative price of beef has changed proportionately less than most other prices of agricultural commodities other than tobacco. The price advantage that has been passed on to consumers is thus a relatively small one.

There are still visible traces of the beef cycle, although with some complications. Upswings in productivity are marked by improvements (downward movements) in the curve for number of hours required to produce a per capita national income worth of beef. But these counterswings are smaller, indicating that part of the variation in productivity, both up and down, has been absorbed by a reverse movement of prices. There is some time lag, however, of one or two years between the variations in productivity and in rates of earning power. This apparently also works out differently on the different ranch types, and the



Rate of return in cattle ranching: Hours of aggregated labor needed to produce one per capita national income worth of beef on southwestern cattle ranches, intermountain cattle ranches, and northern Plains cattle ranches. (Fig. 22)

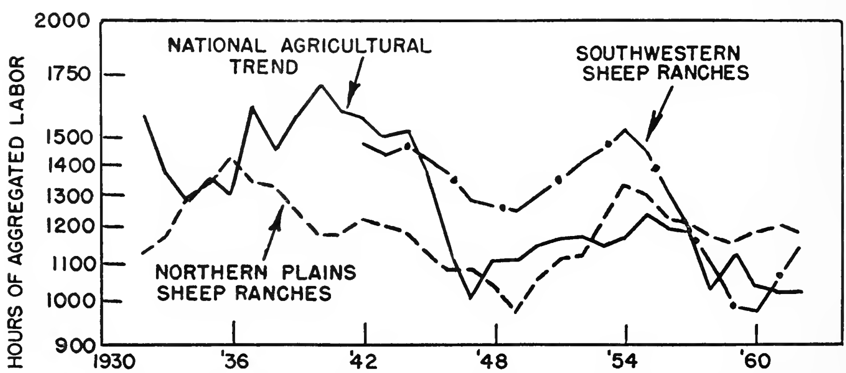
synchronization of movements is much less evident in these curves than in those on productivity. The intermountain area ranches, on which the cyclical swings in productivity were the smallest, show the least connection between these and the variations in rate of earnings.

For this same reason the improvement in rate of earnings in the 1940's is less concentrated in the years from 1944 to 1947 than is the case with some other commodities. This observation is important because beef is such a large part of all output. In addition, this reinforces the hypothesis that the suddenness of the change in the national level over those few years is in some way connected with the strong accumulation of machinery and other farm capital just after the war. This should have relatively little impact on the cattle ranches and a considerable impact on crop farms and also livestock farms raising large amounts of stockfeed as field crops.

Sheep and wool. Data from the two types of sheep ranches represented in the Farm Costs and Returns publications are shown in Figure 23. Both ranch types are relatively close to the general level of the rate of earnings and with about the same variation. Both also participate rather clearly in the general improvement occurring just after the war.

Summary of Earnings Rates

The most striking feature in the above analyses is the fact that relative prices have generally moved in the reverse direction of productivity, with a remarkable stability in relative earning power on each farm type as well as in the aggregate as a consequence. In addition, most farm types have experienced the same relatively rapid improvement in the 1940's as the total for all United States agriculture. Since part of this improvement goes to indirect labor because of its increased



Rate of return in sheep production: Hours of aggregated labor needed to produce one per capita national income worth of sheep and wool on southwestern sheep ranches and northern Plains sheep ranches. (Fig. 23)

share in the aggregate, the stability in the rates of earnings of direct farm labor and associated on-farm factors is all the more striking.

The main exception to this stability is seen in wheat production. Even the farms on the northern Great Plains have a much better rate of relative earning power than before the crisis because the precrisis level on those farms was rather far behind the general average. For the southern Plains and the Northwest, it is quite evident that the continuously high price supports on wheat are the main cause of this, for the agricultural sector rather favorable, level of earning power.

By inference, we may conclude that wheat is almost the only commodity on which price supports have really changed the pattern of relative earning power. The predominantly horizontal shape of the curve on most other farm types indicates that these lines of production have only about maintained the relative levels of earnings which they had at the start of the period regardless of price supports.

Another noteworthy feature that is a corollary of the preceding point is that most of the farm types can be rather clearly recognized as parts of the whole. The longer-term movements are in most cases parallel to those seen in the curve for agriculture as a whole. Apart from wheat, the main exception is beef where the beef cycle has had some influence, making the connection with total agriculture less clear.

This stability in the relative earning power of a man-year of labor used for agricultural production may at first glance seem rather puzzling. The rates of earning are sharply different, both between some commodities and between farm types producing the same commodity in different parts of the country and on different types and sizes of farms. Although farm size may have some influence, it is rather limited as illustrated by the cotton farms. The largest cotton farms are by no means the most productive; the most productive are the middle-sized ones. Location is a more plausible explanation. Despite all mobility of factors, including labor in recent decades, some other things may be less quick to change. In regard to many farming areas, the first thing that comes to mind is the concept of "reservation income." In a given area, farm people have some idea of a minimum income level below which they would leave farming and seek other employment. But this level of "reservation income" is clearly not the same in all areas. This is probably one of the principal reasons why the rate of earnings of labor in production of the same commodity can be so different in different areas.

Another part of the explanation for such diversity of levels is in the various rates at which farm earnings go to the land factor. The highest productivities are usually matched by the highest land-value levels, whether in the hands of owner-farmers or of landlords, or off farms or on farms. The areas with the highest levels of land values are also often those where rates of tenancy are highest. This is why, for instance, the relative rate of earnings of labor on the cash-grain farms of the Corn Belt are not in reality as far ahead of those of hog producers or dairy farmers in the same area because the latter categories are owners of their land and livestock to a somewhat higher degree than the cash grain area farmers. It is significant that differences in the level of earning power are much less striking among livestock farms than among cash crop farms.

This explanation regards mainly the level, and only to a small extent the direction, of the curve. The apparent stability may reflect still other, and in part hidden, factors than just "reservation income." The minor movements up and down may to a great extent reflect incidentals as well as the medium-term impact of policy; but there may be still other forces at work that have not yet been discovered or not yet discussed in proper perspective.

POLICY IMPLICATIONS

The material presented in this bulletin justifies some reflections on agricultural policy — past, present, and future. Specifically, the question about price and income supports as influencing or not influencing the pace of progress can in part be answered. The changing structure of agriculture, as expressed in the composition of the labor aggregate, will also have some interesting bearings on possible future courses of action.

On the whole, the analysis does not favor the contention that price supports and other federal policy measures intended to improve farm income have stifled progress in agriculture. Over the period under study productivity has risen more than ever before. This is especially true of the period since the mid-1930's. That is precisely the period during which CCC lending and other federal support measures have been in effect. On this point both the gross and the net productivity measures warrant the same conclusion. Specific to the aggregated labor productivity analysis is the finding that the period of price support measures has been a period in which productivity has grown more rapidly in agriculture than in the economy as a whole, at least as conventionally measured. If we believe that price supports have stifled progress, then the implied suggestion is that free markets would have generated even higher rates of productivity improvement. This is not very likely because the rates of improvement have been exceedingly high as it is, both for agriculture as a whole and for most commodities for which measures have been computed.

If anything, the opposite contention might be true. Perhaps support measures have actually stimulated productivity improvement. Thus phrased, the question cannot be answered on the basis of the present inquiry alone. The problem requires a thorough analysis of the flow of funds into and out of agriculture, specifically as this flow may have been affected by the support measures.[1]

[1] This is the subject of a parallel investigation in progress.

Whatever the answer to this type of question may be, it is not necessarily the same for all commodities. The case of wheat may have the appearance of associating high prices with stagnating productivity. Such a conclusion would not be well founded, however. On the Great Plains most of the productivity gains had already been made before the period under study, but in the Northwest the rapid gain in acre yields was in no way hampered by price supports. Acreage allotments may of course have had some of the effects of freezing the land-use pattern usually attributed to them, thus preventing some of the adjustments which would bring added productivity gains.

The same reasoning might be used in regard to tobacco, even though it may be less easy to argue that more productive technology would have played so much larger a part in the absence of price supports and acreage allotments.

Other supported commodities, such as corn, cotton, and milk, have contributed their share to the general productivity improvement in agriculture. By contrast, some unsupported ones, such as beef, have contributed less to the pace of progress. All of this points to the possibility that any slowdown in productivity development in wheat and tobacco that may be laid to the price and income supports may very well have been offset — perhaps even more than offset — by accelerated productivity improvement in other supported commodities. Whether the support measures have even promoted this accelerated progress can not at present be either denied or confirmed.

All of this does not suggest, let alone prove, that the support measures actually applied were the best that could have been chosen. It is still possible to argue that some system of more flexible supports conceived over the longer term but applied in response to the year-to-year situations as they unfolded could have done an even better job of piloting American agriculture through the phase of unprecedented productivity growth and structural change that lies behind us.

Looking forward, it is clear that agricultural policies of the future do not have to be a mere continuation of those of the past. Whether the effects of support measures on progress have been favorable, unfavorable, neutral, or a mixture of all these, a future in which productivity increase can be expected at a decelerating rate rather than the accelerating rate of the recent past will give reasons to take under renewed scrutiny the question of whether agriculture needs price and income supports and, if so, if it needs them more or less than before.

The analysis in this bulletin supports the conclusion that one can draw directly from the USDA balance sheets: that as the net income of the farming population becomes a smaller and smaller fraction of total gross turnover of agriculture, farmers will become increasingly dependent on stable prices as well as on reduced fluctuations in output. The scope for maneuvering is being narrowed. The aggregated labor productivity analysis emphasizes this conclusion by pointing to the fact that as indirect labor becomes a larger and larger fraction of the total labor aggregate, its rather inflexible income expectation puts more rigid limits to the variations in gross income that farmers can tolerate. If farmers take a loss on their prices, the factories and offices supplying agriculture are not willing to take their share of it.

This may point to one of the most significant shifts in agricultural policy of the future. Gradually, as indirect labor becomes a larger and larger share of the total, and perhaps one day exceeds direct labor in absolute quantity, the stress for future productivity improvement will be on a continued rise in the productivity of those factories and offices rather than on a continued decline in the direct farm labor force. Productivity improvement has really come from them all the time. But it has been dramatized, and to a large extent made possible, by the exodus of farm workers. As the farm work force shrinks to the point where it ceases to be the overwhelming majority of all the aggregated labor used in agriculture, continued exodus of farm workers will become of minor importance for continued productivity improvement. Maintaining and raising the productivity of the factories and offices without raising, and preferably while lowering, the relative prices at which they offer their output to the farmers will then become the most important policy problem for agriculture apart from the price and income supports themselves.

On the other hand, a point will be reached sometime in the not-too-distant future when farmers are so small a fraction of the total labor force, and their income expectation represents so small a fraction of national income, that continued productivity increase in agriculture will no longer represent such a major contribution to national welfare as it has up to now. In such a situation income supports and the question of what level of income farmers are allowed to enjoy will not be much of a problem for the general public. When farmers are a small corps of skilled professionals they will have to be granted such incomes as will attract men and women of the right caliber to the job and keep them there. The problem about the cost, and thus the productivity level, of external inputs produced and serviced by factories and offices can not in the same way be regarded as unimportant beyond a certain point. These costs will be increasingly critical for the cost at which agriculture is able to serve the community.

TECHNICAL APPENDIX

The Productivity Measures

Gross productivity is the ratio of all final outputs over all the conventional inputs. Inputs include labor, current production expenses, depreciation of capital, interest on the stock value of capital, and rent on real estate. The aggregation of several dissimilar elements renders the productivity measure to a high degree dependent upon the price weights (constant prices) used for expressing the diverse inputs on a common scale over time, and the classical index-number problem comes into play to a high degree. This problem is not too important in regard to agricultural output because the composition of farm output in the United States has been rather stable for a long time and because the relative prices of the more important farm products have varied only moderately in relation to each other. The index of farm output (net of interfarm transfers of feed, seed, and live animals) can be trusted, on the whole, both for the gross and for other productivity measures. The major types of output can be treated separately and in such cases there is no index-number problem in regard to output.

The input index presents more difficult problems. The "input mix" (i.e., the array of inputs used and the proportions between them) has varied considerably over time as new means of production were invented and gained wider application.[1] Along with such changes, and because of productivity changes within the industries that produce farm inputs, the relative prices of inputs have also varied far more than is the case with farm products. The choice of a base period for constant price weights can thus have a considerable influence on the productivity index. Since constant prices are used, the measure can not in any way give expression to rising productivity in the sectors producing external inputs. The most disturbing part of the problem is the pricing of labor. As productivity rises, less and less labor (in physical terms) is used together with given quantities of other inputs. Labor therefore becomes a smaller and smaller part of the total constant-price weighted aggregate of inputs. At the same time and as a direct consequence of the rise in productivity in agriculture and other industries the price of labor goes up in current terms. Whenever, by reason of changing price relations in general, the base period of the index has to be moved forward, the labor quantity used directly in agriculture at the point in time where the two indexes based on different sets of price weights are linked together will become a larger portion of total inputs in the new index than in the old one. The larger this portion is, the more productivity and labor earnings have risen. In each period between linkages, successive reductions in direct farm labor may be smaller in absolute terms, but these reductions will assume an equally prominent role as a source of apparent productivity gains in each period between linkages because the share of direct labor in the total cost bill does not go down as fast as does labor in physical terms.

In this way, the gross productivity index fails to give expression to the relation between physical quantities of inputs and outputs. The

[1] On these difficulties see V. W. Ruttan, "Agricultural and Nonagricultural Growth in Output per Unit of Input." Jour. Farm Econ. 39:1566-1576. 1957. Also see Z. Griliches, "Measuring Inputs in Agriculture: A Critical Survey." Jour. Farm Econ. 42:1411-1427. 1960.

fact that price weights have to be varied from time to time makes the gross measure an economic measure in disguise. In the case of measuring agricultural productivity, the most serious thing about this is not that this source of bias is an extreme case of the difficulties inherent in the index-number problem. Worse still, the difficulty is here a direct consequence of the change in productivity, that is, of the very phenomenon that the index should measure and help to explain.

But this is not all. The gross productivity index has another disability that is at least as serious. The index (the rate of the productivity change) is often strongly affected by the degree of aggregation chosen. It so happens that we treat agriculture as one industry. We might as well treat it as two or more industries; or we might merge it with forestry and fishing, as is sometimes done. Other industries can also be treated at a higher or a lower level of aggregation, and the effects on the index are sometimes profound.

The problem can be illustrated by a fictitious example of an industry ("industry 1") that may alternatively be treated as two subindustries, coded 1a and 1b. The following expressions may be written for year 0 (the present) and year n (at some unspecified future date)[2]:

Industry	*Year 0*	*Year n*
1	$\frac{100}{100} = 100$	$\frac{110}{100} = 110$
1a	$\frac{50(a)}{50(a)} = 100$	$\frac{55(a)}{50(a)} = 110$
1b	$\frac{50(a) + 50(b)}{50(a) + 50(b)} = 100$	$\frac{55(a) + 55(b)}{55(a) + 50(b)} = 104.8$

In the specification on two industries, industry 1b represents a later stage in the production of the same goods as 1a; together they represent the same turnover as industry 1. The reason why 1b shows a lower productivity rating than 1 and 1a is found in the fact that when 1b absorbs the entire output of 1a, this output is now also part of the input of 1b. On the higher level of aggregation, the value added in the earlier stage of production was treated as internal turnover. The index shown with industry 1b is therefore not comparable with the index shown with industry 1. The level of aggregation decides which goods and services will be treated as inputs and outputs and which ones will be netted out as internal transfers.[3]

There are similar examples within agriculture. The input index for United States agriculture, as computed by the USDA and used by most of those who discuss productivity in American agriculture, is net of

[2] The letters within parentheses indicate the inputs and outputs that are "internal" to subindustries a and b, respectively.

[3] In the same sense, see V. W. Ruttan, "Technological Progress in the Meatpacking Industry 1919-47." USDA Marketing Research Report 59. January, 1954.

interfarm transfers (feed, seed, live animals — or rather the "farm-produced component" of these). Whenever feed crops, seed, and animal husbandry were treated as separate industries, the interfarm transfers would become interindustry transfers in the way illustrated above. Feed crops would be the output of one industry and the input of another one. Likewise, ranching and feedlot operation could also be treated as separate industries, with further effects on the productivity index. Generally, the lower the level of aggregation, the lower the productivity index, as illustrated by the example above. The USDA Farm Costs and Returns publications, which are used as sources of commodity-level data in this publication, can give instructive examples of this principle. For instance, the egg farms in New Jersey are shown to have a very low index of gross productivity despite the fact that it is common knowledge that the poultry industries have absorbed large amounts of new technology in a short time.[4] The reason for the low index for egg farms is that the egg industry is a very specialized operation in which the ratio of external to internal inputs is very high and thus the consequences of disaggregation are unusually large. These gross farm-level and commodity-level indexes are therefore, in a very elementary sense, not comparable between themselves.

This property of the gross productivity index — that indexes on different levels of aggregation and for subindustries on different levels of functional specialization can not be compared between themselves — also has consequences for the use of the gross index at the national level. When the index for agriculture is not comparable with the indexes for its subindustries, then it is also not comparable with any index for the whole national economy. National income or product, however defined, is always "net" in the sense that interindustry transfers have been netted out. On the level of the whole national economy, there is no longer any choice between levels of aggregation; there is only one level — the comprehensive one. And this level is as little comparable with an industry-level aggregation (e.g., agriculture) as the latter is with its subindustries. This is the reason behind the often-repeated and fallacious statements about productivity increase in agriculture being slower than in the national economy as a whole.[5]

The same problem of level of aggregation also disturbs the validity of gross productivity as a measure over time. In the case of agriculture, it is easy to show that the degree of comprehensiveness has changed over time (e.g., when feed mixing became an external input, or draft power, for that matter). The gross index thus can not be taken to express the same things over the long run.

[4] See Figure 9 on page 35 and Figure 5 on page 30.

[5] Thus, for instance, see R. A. Loomis and G. T. Barton, "Productivity in Agriculture, United States, 1870-1958." USDA Technical Bulletin No. 1238. April, 1961. On page 1 of this publication it is said that productivity increased slower in agriculture than in the economy as a whole, even over the period from 1940 to 1957.

The origin of gross productivity measurement is in the needs of short-run forecasting, a situation where constant prices are often postulated for want of anything more informative. Gross productivity measurement has some usefulness in situations of this type, and generally for short-run and especially firm-level analyses where input mix and relative prices of both inputs and outputs have changed but little. For long-run analyses, and for comparison between essentially different production aggregates, gross productivity analysis is likely to produce more illusions than illumination.

Net productivity measurement shares some of the disabilities of gross measurement, but not all of them. The difficulties associated with the index-number problem are essentially the same as described above. The splitting up of production factors into "internal" and "external" adds some complications to the index-number problem, and the concept of "value added" is even more difficult to accept as a "physical" measure than in the case of the aggregates of total price-weighted output. On the other hand, there is no problem here about the level of aggregation. All interindustry transfers are treated as "external" inputs. In the fictitious example above, industry 1b would have the following equation:

Year 0	*Year n*
$\frac{50(b)}{50(b)} = 100$	$\frac{55(b)}{50(b)} = 110$

Hence the indexes for subindustries a and b can be freely aggregated to industry 1 and all the various industries can be treated as components of the national economy. The index of net productivity for agriculture or for any of its parts is therefore in principle directly comparable with that for the national economy.

At the same time, net productivity accounts for only part of what goes on within agriculture. It is a partial index, not a comprehensive one, and the output that it treats is value added, a quantity considerably smaller than total agricultural output. To find the rationale for the whole process of agricultural change, and its meaning for the national economy, one should also investigate the industries that supply agriculture with the goods and services commonly referred to as agriculture's external inputs.

This logically leads to a search for a productivity measure that is related to the entire output of agriculture and yet lacks some of the disabilities of the gross productivity measurement. The aggregated labor productivity measure meets most of the specifications. At the same time it leaves unsolved certain problems which are at least clearly stated rather than ignored. In this analysis, agriculture, together with those parts of other industries that produce and service farm production requisites, is treated as a subsystem of the national economic system.

Computation of the Aggregated Labor Productivity Index

Aggregated labor is the sum of labor used directly on farms and labor used indirectly, that is, used to produce and service farm production requisites. These requisites include both durable goods such as buildings, machines, implements, as well as repair and upkeep on these, and current inputs such as chemicals, seeds, live animals, feed mixing, and custom work. Durable goods can be treated either on the basis of their annual depreciation (as in the USDA data) or on the basis of annual acquisitions regarded as depreciated to zero in the same year because the conventional depreciation schedules are controversial.[6] This choice of statistical treatment makes some difference in the short-run variations of the index, but almost none in the long run. For the present study, depreciation was used in the year-to-year series for the total of United States agriculture, while annual acquisitions were used in the analysis of input-output tables and also in the commodity-level analyses.

Both current production expenses, including upkeep and repair, and costs of capital goods, whether by depreciation or acquisition value, are represented by their current value year by year. The costs of acquiring feed, seed, and live animals were divided into a farm and a nonfarm portion according to coefficients used by the USDA. The nonfarm (mainly service) component was 45 percent for feed bought, 47 percent for seed bought, and 10 percent for live animals bought. The farm portion was netted out in the calculations for total United States agriculture. In the commodity-level calculations, by contrast, estimates of its farm and nonfarm labor components were added to the data for direct farm labor on the farm type concerned.

The annual total of external costs was converted into estimates of nonfarm labor use by two parallel procedures. One way was to reduce this dollar amount to the current year's characteristic "labor share" in the nonagricultural part of the national product and then divide by the year's average industrial hourly wage. The other way was to compute the sum of external costs as a percentage of the year's nonagricultural national product, and then apply the same percentage to the nonagricultural part of the labor force. The former procedure yielded data in man-hours, the latter in man-years. They can be compared by means of available information about the average length of the work week in factories separately for each year. On the whole, the two data series generated in these ways are in good agreement. This provides a check on the accuracy of the computation.[7]

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[6] On the difficulty of depreciation scales, see Z. Griliches, *op. cit.*

[7] The shortcut procedures were first proposed in F. Dovring, "Labor Used for Agricultural Production." University of Illinois Department of Agricultural Economics AERR-62. 1963. Applications to three European countries are discussed in *Output, Expenses and Income of Agriculture in European Countries*, Series 5. Notes on method, pp. 173-175. United Nations, Geneva. 1965.

The shortcut procedures described above imply an assumption as to the character of the goods and services that agriculture buys from other sectors of the economy. These goods and services are assumed to represent a true cross-section of the nonagricultural economy as regards the distributive shares (part of the product going to labor) and also as regards the wage scales (the mix of higher- and lower-paid labor).

This assumption was tested through analysis of input-output tables, as described in detail elsewhere.[8] The productivity indicators coming out of this analysis are slightly more comprehensive than those from the shortcut method, inasmuch as they also include the effect of certain "final" agricultural products coming back to agriculture as parts of production requisites. This includes certain cotton and wool fabrics. This difference is slight in practice, however. Agreement with the results of the shortcut methods is close and leaves no doubt that the amounts of indirect labor have been computed with as much accuracy as the present purpose will require.

The input of direct (on-farm) labor has been borrowed from annual USDA data on labor input in agriculture. These data are expressed in man-hours. Where necessary, they were converted into man-years of direct labor on the basis of 2,400 hours of labor to a year of agricultural work; no indications were available to allow any precise observations on the actual variation in time or space in the length of the work year in farming.

The USDA estimates of labor use are based on labor efficiency norms that reflect average actual performance rather than peak-level efficiency. When converted into man-years, they yield figures that are not far removed from the decennial census data on numbers of workers employed principally in agriculture. This should approximate the number of labor years actually used because part-time employment should balance approximately between those who are mainly agricultural workers and those who are mainly nonagricultural workers. Some amount of disguised underemployment is thus included in the data, and productivity is in no way exaggerated.

The sum of direct and indirect labor, as described above, or its index-number representation, is the denominator in the productivity expression; the numerator is the sum of output for final use, including the portion reserved for direct human consumption on the farm where produced, or its index-number representation.

The estimate of aggregated labor is based on year-to-year data and price relations without any use of constant prices. It is not a

[8] Detailed analyses in W. F. Gossling, "A New Economic Model of Structural Change in U.S. Agriculture and Supporting Industries." Unpublished Ph.D. thesis, University of Illinois. 1964. Summary of findings, including mathematical comparison between the shortcut method and the matrix solutions, in W. Gossling and F. Dovring, "Labor Productivity Measurement: The Use of Subsystems in the Interindustry Approach, and Some Approximating Alternatives." Jour. Farm Econ. 48:369-377. 1966.

conversion in the sense of constant-price calculations; it is an estimate of actually existing quantities.[9] The index-number problem is confined to the output index and it is, as already mentioned, of moderate proportions. The index of aggregated labor productivity reflects, as accurately as can be done at present, the share of the nation's labor force that is used for agricultural production either directly on farms or indirectly in factories, offices, and other nonfarm places of work to produce the country's agricultural output for final use. In this way the index is comparable with the relatively simple concept of national product per worker in the whole economy. Here the index-number problem is also confined to the output side. It is also, with some further reserve, comparable with the still somewhat simpler concept of per capita national income. The new index is comprehensive in regard to the use of the nation's resources of human labor. There are errors, and there are some omissions, but neither are of great magnitude.

The Data Used

Farm output, as used for the aggregate-level index, is the same as used by the USDA for gross productivity measurement. For years after 1957, the output quantities were computed by the same treatment of annual data from the annual USDA *Agricultural Statistics.* Gross production of crop and animal products was reduced by the amounts of interfarm transfers of seed, feed, and live animals. The amounts of farmers' purchases of these items, reduced by certain coefficients applied by the USDA to separate the farm-produced from the service-and-processing components, were subtracted from the total of crop and livestock production. The farm-produced fractions were assumed to be 53 percent for seed, 55 percent for feed, and 90 percent for live animals, the balance being processing and transportation costs, handling charges, etc. These off-farm produced amounts were added to the total of off-farm produced production inputs. For the graphic representation, the output quantities at constant prices, rather than the index, were used.

For inputs, farm labor data from the annual USDA series on labor required on farms were used. The indirect labor was computed from the sum of expenses for fertilizer and lime, repairs and operation of capital items, depreciation and other consumption of farm capital, and miscellaneous expenses, plus the off-farm produced components of seed, feed, and livestock purchased. A specimen of the computation is shown in Appendix Table 1. This variant of the computation was modified for use in Figures 1, 2, and 3 by assuming a standard work year of 2,400 hours in agriculture for the whole period.

[9] A particular problem which is sometimes discussed in this connection is that of "dated labor" or expenditures made in the past. This is not a real problem, however, since the same products could always be obtained out of current production. See J. Horring, *op. cit.,* pp. 23 sq.

Note that in the Gossling index based on input-output tables capital goods are represented by annual purchases rather than by depreciation. The same is the case in the commodity-level analyses, based on the Farm Costs and Returns publications.

Commodity-Level Analyses

The costs-and-returns data up to 1957 were taken from the consolidated publication with revised data for the whole period,[10] while those for subsequent years were added, to the extent that the farm types continued to be identical. There are a few exceptions in recent years.

The costs-and-returns data are to a great extent estimates by interpolation between bench mark years, using various statistical sources in support. The data are therefore not as accurate as if a sample of farms had been covered by continuous observation year after year. Nevertheless the information appears sufficiently precise to be used for the kind of generalizations offered in this bulletin.

In computing these indexes, a special treatment was needed in regard to purchased feed, seed, and livestock.[11] The nonfarm component of these inputs was computed in the same way as the national index, but the farm-produced component could not be netted out unless the aggregated labor productivity concept were to lose its comprehensiveness with regard to specific products, above all those of animal husbandry.

In principle, the farm-produced components of these farm inputs are the products of the specific farm types where they were produced, and the aggregated labor used to produce them should have been computed on the basis of the input mix on those farm types. In practice it was not possible to trace these products down to the farm types from which they came, and their farm-gate value (in dollars) was therefore divided in equal parts between direct (on-farm) and indirect (off-farm) labor. The margin of error that this procedure sometimes introduces becomes part of a small component of the entire amount of aggregated labor and is therefore, in practice, negligible.

The amounts of farm and nonfarm labor computed for the farm-produced components of feed, seed, and live animals were added to those directly pertaining to the farm types on which these farm-produced inputs were used. Thus, for instance, the aggregated labor used to produce eggs on a New Jersey poultry farm, or the beef on a beef-fattening operation in the Corn Belt, includes the quantities of both farm and nonfarm labor used on other farms to produce feed crops and animal stock as well as the nonfarm inputs needed to bring

[10] W. D. Goodsell and I. Jenkins, "Costs and Returns on Commercial Farms, Long-Term Study 1930-57." USDA Statistical Bulletin 297.

[11] For details, see Leunis, *op. cit.*, Chapter 3. An example is shown in Appendix Table 1.

these farm-produced inputs from the producing farm to the farm on which they are used as inputs. A specimen of this computation is shown in Appendix Table 2.

As a test upon the accuracy and reasonableness of the productivity indexes thus calculated for each of several major commodities, these indexes were aggregated back to the total of the United States agriculture.[12] Summarized results are shown in Figure 3. The commodities covered by the commodity-level indexes represent a large part — about 75 percent — of all farm commodities produced in the country, and a somewhat smaller proportion of all farms in the country. Treating them as a sample of such percentage as they represent in each year (for example, 75 percent) may not sound too bold at first, but it does entail certain problems. Horticultural crops, which are totally absent from coverage in these indexes, are known to have a rather untypical productivity history (their main contribution to the national index is in recent years). Noncommercial farms may also have disappeared more rapidly during the 1950's than before. Another difficulty lies in the treatment of capital goods. In the farm-type data as well as in the matrix data for certain years acquisition of durable goods for investment has been treated as current expenditure, as if depreciation equaled acquisition in each year, while the year-to-year aggregate data use the conventional depreciation schedules applied by the USDA. This feature should exaggerate the use of nonfarm labor in years when accumulation exceeds depreciation, as happened especially in the late 1940's, and vice versa, e.g., in part of the 1950's.

[12] For details of procedure, see J. V. Leunis, *op. cit.,* pp. 28-38. Subsequently, the procedure has been applied to the entire time series from 1930 to 1964, using alternatively only the commodities represented by the farm-type series beginning in 1930 and all the commodities represented also by later farm-type series.

Appendix Table 1. — Specimen Computations of Dovring Indexes (In the Aggregate)

Item No.	Description	Year 1960
1-11	*Unweighted and weighted producer's expenditures in millions of dollars*	
1	Fertilizer and lime	1,463
2	Repairs and operation of capital items	3,986
3	Depreciation and other farm capital consumption	4,144
4	Feed purchased	4,848
5	Livestock purchased	2,508
6	Seed purchased	538
7	(4) × 0.45	2,182
8	(5) × 0.10	251
9	(6) × 0.47	253
10	Miscellaneous	2,728
11	Sum of items 1, 2, 3, 7, 8, 9, and 10	15,007
11a	Nonagricultural national income, billions of dollars	400.5
11b	Labor's share of item 11a, billions of dollars	290.8
11c	(11b) divided by (11a)	.72609
12	(11) × (11c), millions of dollars	10,896
13	Average hourly wage in manufacturing, production workers, dollars	2.26
14	(12) divided by (13), millions of man-hours	4,821
15	Millions of man-hours worked in agriculture	9,825
16	(14) + (15), millions of man-hours	14,646
17	USDA index of total agricultural output (1957–1959 = 100)	106
18	(16) to base (1957–1959 = 100)	94.95
19	(17) divided by (18), Dovring Index I	111.64
20	(11) divided by (11a)	.037471
21	Nonagricultural employment, thousands	54,347
22	(21) × (20)	2,036
23	(22) × 52	105,872
24	Average weekly hours in manufacturing, production workers	39.7
25	(23) × (24), millions of man-hours	4,203
26	(15) + (25), millions of man-hours	14,028
27	(26) to base (1957–1959 = 100)	94.38
28	(17) divided by (27), Dovring Index II (man-hour variant)	112.31
29	Persons engaged in agriculture, full-time equivalents	5,434
30	(29) + (22)	7,470
31	(30) to base (1957–1959 = 100)	95.71
32	(17) divided by (31), Dovring Index II (man-year variant)	110.75

Source: Gossling, *op. cit.*, p. 247.

Appendix Table 2. — Specimen Computations of Aggregated Labor Productivity at the Farm-Type Level on Dairy Farms in Western Wisconsin

Item No.	Description	1930	1931	1932	1933	1934
1	Total cash receipts, dollars	1,583	1,149	801	831	1,005
2	Value of perquisites, dollars	455	348	290	296	303
3	Change in inventory of crops and livestock, dollars	35	−135	25	−51	−217
4	Gross production (1) + (2) + (3), dollars	2,073	1,362	1,116	1,076	1,091
5	Government payments, dollars	0	0	0	3	49
6	Output (4) − (5), dollars	2,073	1,362	1,116	1,073	1,042
7	55 percent of total feed purchased, dollars	103	83	78	95	154
8	Farm labor (half of (7) converted by assumed farm labor wage), hours	206	218	300	432	542
9	Nonfarm labor (half of (7) converted by assumed nonfarm labor wage), hours	103	109	150	216	271
10	45 percent of total feed purchased, dollars	84	67	63	78	126
11	Nonfarm labor ((10) converted by assumed nonfarm labor wage), hours	153	131	143	177	238
12	90 percent of total livestock purchased, dollars	13	9	7	7	8
13	Farm labor (half of (12) converted by assumed farm labor wage), hours	26	23	27	32	31
14	Nonfarm labor (half of (12) converted by assumed nonfarm labor wage), hours	13	11	13	16	15
15	10 percent of total livestock purchased, dollars	1	1	1	1	1
16	Nonfarm labor ((15) converted by assumed nonfarm labor wage), hours	2	2	2	2	2
17	Nonfarm expenses, dollars	551	478	361	332	389
18	Nonfarm labor ((17) converted by assumed nonfarm labor wage), hours	1,001	937	820	755	734
19	Total nonfarm labor (9)+(11)+(14)+(16)+(18), hours	1,272	1,190	1,128	1,166	1,260
20	Labor share as a percentage of nonagricultural national income	65.7	70.8	77.6	79.4	75.2
21	Total nonfarm labor (19) × (20), hours	836	843	875	926	948
22	Total farm labor (8) + (13) + labor used on each farm type, hours	5,012	5,121	5,127	5,234	5,193
23	Total labor (21) + (22), hours	5,848	5,964	6,002	6,160	6,141
24	Physical output ((6) divided by price received by farmers for leading commodity (100 pounds of milk)), dollars	1,280	1,184	1,254	1,095	956
25	Accumulated labor production (24) divided by (23)	.219	.199	.209	.178	.156

Source: Adapted from J. V. Leunis, *op. cit.*, p. 21.

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