AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

CHARLES O. MEIBURG AND KARL BRANDT

AGRICULTURAL PRODUCTIVITY IN THE UNITED STATES: 1870–1960*

Agriculture in the United States is internationally known as a prolific producer of food, feed, and fibers; in addition it is credited with a record of rapidly rising productivity of manpower. It is generally agreed that the productivity of labor has during the last ten years increased at a substantially higher rate in agriculture than outside of it (*14*, p. 9). *The Economic Report of the President,* January 1962 (*21*, p. 244) estimates that in recent years output per man-hour in agriculture has risen twice as fast as in non-agricultural industries. (See Table 1.)

It is of keen interest to all parties immediately or indirectly affected by the higher rate of productivity gains in agriculture in the United States to explore the causes of the rapid and differential rise in productivity. If the causational factors and their relative importance were known, such knowledge would provide a key to the improvement of low labor productivity in the agriculture of many countries. This becomes even more important if a substantial increase in agricultural productivity is a prerequisite for self-sustaining general economic growth as many have suggested (e.g., *7, 18, 19*).

Various assumptions and hypotheses about the causes of rising productivity in agriculture have been advanced. For example, Henry B. Parkes, in *The American Experience,* takes it for granted that it is primarily the result of an unusual abundance of land and natural resources (*6*, p. 8). R. A. Loomis and G. T. Barton suggest that the real causes of increases in productivity have been "new knowledge and technological change" and "such closely related forces as changing relative prices, increased specialization, increased size of farm operation, changes in institutional structures of education, credit, transportation, processing and marketing, and the economic activity, development, and progress of the general economy" (*5*, p. 1). Unfortunately these explanations and a multitude of similar ones are too vague to be helpful in finding convincing evidence of cause and effect relations that would contribute to a better understanding of the growth of agricultural productivity.

There is every reason to be suspicious of hypotheses which try to trace the cause of high productivity to a single circumstance, such as the favorable land-man ratio. In Europe the thesis has always been popular that the productivity

* This is the first report on a research project to explore the real causes of rising productivity in agriculture in the United States which has been made possible by a recent grant by the Relm Foundation.

TABLE 1.—INDEXES OF OUTPUT PER MAN-HOUR, 1947–1961*

(1947–49 = 100)

Year	Total	Agriculture	Non-agricultural industries
1947	97.4	90.6	98.4
1948	100.3	107.5	99.4
1949	102.2	101.6	102.4
1950	110.3	116.1	108.5
1951	115.2	114.1	112.8
1952	118.9	124.0	115.5
1953	123.9	138.0	119.0
1954	127.0	147.9	121.8
1955	133.1	152.9	127.5
1956	133.6	155.8	127.2
1957	138.0	167.0	130.3
1958	140.0	182.2	131.4
1959	145.9	181.4	136.9
1960	148.3	191.9	138.6
1961	152.3	206.7	141.3
Average annual rate of increase (per cent)	3.2	6.1	2.6

* *Economic Report of the President,* January 1962, p. 244 (Labor Force basis).

of agriculture in the United States is chiefly the result of a unique bounty of fertile farm land. In the United States it is widely believed that the rise in agricultural productivity is chiefly the result of the establishment of the Land Grant College system by the Morrill Acts and the research expenditures of the Government, and of the price support policies since 1934. These few examples, to which many more could be added, simply demonstrate that the state of our knowledge about this essential sphere of the economy in all countries is unsatisfactory, particularly our knowledge about the early stages of development when the division of labor is narrowly limited. This gap in economic knowledge seriously impedes the policies aimed at more rapid economic expansion in countries with predominantly agricultural employment of the population.

In an endeavor to identify the major causes of productivity increases by an economic study of the historical record of agriculture in the United States, it is at first necessary to find out what the record reveals about the change in productivity, its rate, and its variations over prolonged periods. In view of the substantial amount of pioneering work that various economists have done on measuring the outputs and inputs of agriculture, we shall rely primarily on the available results of such studies. The present article surveys earlier indexes of national agricultural output, output per worker, and output per man-hour, and finally several recent estimates of total productivity of American agriculture. The review will show significant similarities between the estimates of the different series. Since these estimates were developed somewhat independently by the various analysts, the similarity of their findings concerning the periods of greatest change

in productivity, as defined in these studies, increases the probability of their correctness. (N.B. The data reviewed in the present paper exclude from production most of the capital formation in agriculture which took the form of permanent improvements of land and on land.)

THE CHANGES IN NATIONAL AGRICULTURAL OUTPUT

To obtain a record of changes in the national agricultural output, we shall consider eight indexes of agricultural production which cover various phases of the period 1866–1960. These series are:

1. G. F. Warren's and F. A. Pearson's index of total crop production for the years 1866 to 1932 (*16*, pp. 5–7);
2. F. Strauss's and L. H. Bean's index of total marketed and farm-consumed agricultural production for the years 1869 to 1937 (*9*, p. 126, Table 60);
3. H. Barger's and H. H. Landsberg's index of agricultural output for the years 1897 to 1939 (*1*, pp. 42–43);
4. The Bureau of Labor Statistics' (BLS) index of gross agricultural production for the years 1909 to 1950 (*15*, p. 9);[1]
5. The United States Department of Agriculture's (USDA) index of farm output for the years 1870 to 1960 (*12*, p. 47);
6. The USDA's index of gross farm production, 1910 to 1960 (*13*, p. 37);
7. J. W. Kendrick's index of net farm output, 1869 to 1957; and
8. J. W. Kendrick's index of gross farm output, 1869 to 1957 (*4*, pp. 362–66).

With the exception of the USDA's index of gross farm production and Kendrick's index of net farm output, these series are designed to measure basically the same thing—gross farm output, or the output of farms which is available for human consumption and for the use of other industries.[2] These indexes, reduced to a common base, 1929 = 100, are presented graphically in Chart 1. Here it can be seen that, despite the variety of methods used to construct the series, the values obtained are remarkably similar and tend to change together. This uniformity is even more apparent when the range of high and low values for the individual series is considered, as it is at the bottom of Chart 1.

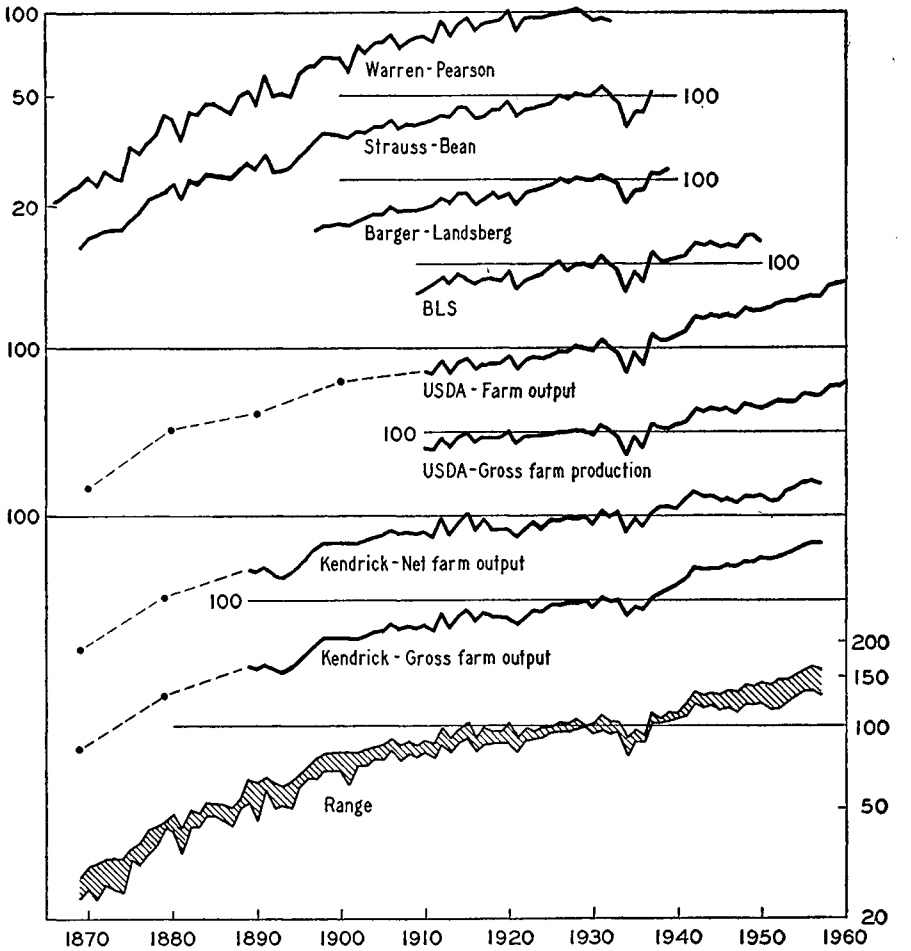
Discrepancies do exist after 1940 between the BLS index and the USDA series of farm output. These can probably be traced mainly to the fact that the two series use weights from different time periods. The USDA index is weighted by average 1935–39 prices before 1940, and average 1947–49 prices since 1940.[3] The BLS uses 1939 labor requirements as weights throughout. Because of the manner in which relative prices and labor requirements have moved since 1939, the two indexes diverge. Labor requirements for field crops, especially the grains, cotton, and sugar, have been reduced to a greater extent than have re-

[1] This index is based on earlier estimates and methods of the National Research Project of the Works Progress Administration (*2*).

[2] USDA gross farm production includes the output of farm-produced power of horses and mules and the production of grass and legume seeds. The former item accounted for one-fifth of gross farm production in the period 1914–19 (*13*, p. 36). Kendrick's net farm output is a measure of value-added in agriculture. Details of the definitions and methods underlying these series are presented in the Appendix.

[3] Kendrick uses changing weight periods similar to the USDA; hence, his series of gross farm output corresponds closely to USDA farm output.

CHART 1.—INDEXES OF FARM OUTPUT, 1866–1960*



* Data from the sources cited for Table 2, shifted to base 1929 = 100.

quirements for the production of livestock and fruits and vegetables. Yet average prices of the latter commodities have risen relative to that of the former. The USDA index, by using two sets of weights, reflects this shift in relative prices. On the other hand, the BLS figures are probably lower (for the years since 1939) than they would be if more recent labor requirement weights had been used. In other words, if both indexes were computed with weights from the same period, their results would probably be more nearly the same.

A further method of comparing the indexes is to consider their average annual rates of change. Such figures, shown in Table 2, indicate that over long periods the indexes always move in the same direction. There are also substantial similarities in the rates of changes for many periods. For example, between 1870 and 1900 each index rose about 3 per cent per year, and between 1870 and 1919 the annual increase ranged from 2 to 2.67 per cent.

TABLE 2.—FARM OUTPUT: AVERAGE ANNUAL PERCENTAGE RATE OF CHANGE, SELECTED PERIODS, 1870–1957*

Period	Warren-Pearson (1)	Strauss-Bean (2)	Barger-Landsberg (3)	BLS (4)	USDA Farm output (5a)	USDA Gross farm production (5b)	Kendrick Net farm output (6a)	Kendrick Gross farm output (6b)
1870–1957	...	...	...	...	1.86	...	1.58[a]	1.97[a]
1870–1900	3.36	2.93	2.93[b]	...	3.01	...	2.95[a]	3.05[a]
1900–1910	1.72	0.90	1.25	...	0.86	...	0.86	1.00
1910–1919	1.47	1.22	1.03	0.64	0.88	1.05	0.31	0.84
1919–1929	0.70	1.16	1.39	1.38	1.15	0.38	1.04	1.37
1929–1937	...	0.56	0.77	1.30	1.29	0.90	0.24	0.30
1937–1948	...	...	...	1.28	2.18	1.64	1.44	2.76
1948–1957	...	...	...	...	1.03	0.63	0.96	1.67
1870–1919	2.67	2.20	2.23[b]	...	2.17	...	2.05[a]	2.24[a]
1919–1937	...	0.89	1.11	1.34	1.21	0.61	0.68	0.89
1937–1957	...	...	...	...	1.66	1.18	1.22	2.27

* See Appendix Note for description of basic series. Annual average percentage rates of increase from the beginning year to the ending year in each period computed (compound interest formula) from data in the following sources: Warren-Pearson *16*, pp. 5–7; Strauss-Bean *9*, p. 126, Table 60 (i.e., adjusted for changes in livestock inventories), ideal index; Barger-Landsberg, *1*, pp. 42–43, 253; BLS, *15*, p. 19; USDA farm output, *12*, p. 47; USDA gross farm production *13*, p. 37, and revised data 1950–60 direct from USDA; Kendrick, *4*, pp. 362–66.

[a] Beginning year is 1869.

[b] Barger and Landsberg note that their figure for 1870 is an 1869–71 average based on the Strauss and Bean publication cited for column 2, but on the arithmetic index from its Table 58, rather than the one we selected for column 2.

Reliable estimates of farm output for years prior to 1870 are scarce. For this reason, one recently made by M. W. Towne and W. D. Rasmussen (*10*) deserves mention. Their estimates of gross farm product are as follows:[4]

Year	Value in 1910–14 dollars (millions)	Year	Value in 1910–14 dollars (millions)
1800	362	1860	2,156
1810	485	1870	2,597
1820	642	1880	3,906
1830	879	1890	4,638
1840	1,222	1900	5,837
1850	1,536	Average decennial rate of increase (*per cent*)	32

A single index of farm output from 1800 to 1960 may be formed by linking Towne and Rasmussen's estimates to those of the USDA.[5] Similarly, an index of

[4] This series was calculated by adding estimates of (1) sales and home consumption of crops and livestock, (2) net change in livestock inventories, (3) the gross rental value of farm dwellings, (4) the value of improvements made on farm, and (5) the value of home manufactures. From this total was subtracted the value of intermediate products consumed (*10*, pp. 265–66).

[5] To make the two more comparable only certain components of Towne and Rasmussen's figures were used. Specifically, their estimates of (1) sales and home consumption of crops and livestock and (2) net change in livestock inventories were added together for every decennial year, 1800 to 1900. The resulting sums (in 1910–14 dollars), roughly comparable in composition to USDA farm output, were expressed as percentages of the USDA estimates (1947–49 base) for the overlapping years 1870, 1880, 1890, and 1900. This yielded a relatively stable relationship of approximately 0.39. The Towne-Rasmussen data for 1800 to 1860 were then inflated by the constant (1/0.39), and the results were linked to the USDA index of farm output.

net farm output can be derived for the period since 1800 by linking the Towne and Rasmussen data to Kendrick's index of net farm output.[6] Both are shown in Table 3.

TABLE 3.—INDEXES OF FARM OUTPUT, 1800–1960*

(1929 = 100)

Year	Gross farm output	Net farm output	Year	Gross farm output	Net farm output
1800	4.0	4.6	1890	58.1	62.6
1810	5.4	6.2	1900	75.7	80.5
1820	7.2	8.3	1910	82.4	87.7
1830	10.0	11.4	1920	74.6	88.9
1840	14.2	16.1	1930	97.3	93.1
1850	17.8	20.1	1940	110.8	105.9
1860	25.6	28.6	1950	136.5	120.1
1870	31.1	34.5	1957	154.1	129.9
1880	50.0	52.4	1960	174.3	...

* Based on data from *10*, pp. 265–66; *12*, p. 47; *11*, p. 6; and *4*, pp. 347, 362–64. See footnotes 5 and 6 for manner of linking Towne-Rasmussen figures to later data.

These estimates of farm output for the nineteenth century are not as accurate or as reliable as estimates made for more recent periods, but they illustrate the significant increases in farm output which must have taken place during the nineteenth century. They are probably the most accurate measures available.

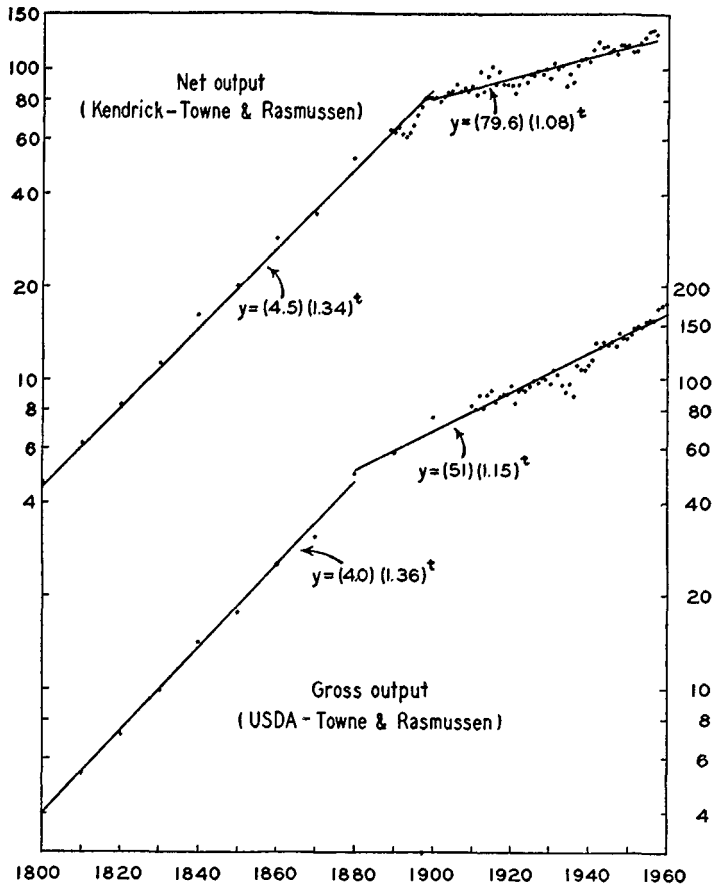
When plotted on semi-logarithmic scale and fitted with regression lines, as in Chart 2, these series give a clearer picture of how agricultural production has changed over time. Trend lines (fitted by least squares) show that throughout most of the nineteenth-century gross farm output was increasing at an average decennial rate of about 36 per cent, or at an average annual rate of 3.1 per cent.[7] At the same time net farm output (exclusive of intermediate goods) was increasing at roughly the same rate—34 per cent per decade, or 3 per cent per annum. This was of course a period marked by westward movement of the frontier, by the settling of most of the public domain, and by an increase in virtually every kind of agricultural input—land, labor, machinery, draft animal work, and productive livestock. Improved transportation methods, notably the long haul on the railroads, facilitated this expansion by making it profitable to bring under cultivation the higher yielding prairie lands of the Middle West.

Chart 2 also indicates that in the latter part of the nineteenth century, the rate of growth of the national agricultural output declined substantially. At some time between 1880 and 1900 the upward trend of gross farm output fell to about

[6] Towne and Rasmussen's estimates of intermediate goods purchased were subtracted from their estimates of total gross output. This provided a series of real net farm output (in 1910–14 dollars) similar in content to that of Kendrick's. The two series were linked together by comparing the two years, 1890 and 1900, for which common data were available, inflating the Towne-Rasmussen estimates by the factor (1/0.67), and incorporating the results into Kendrick's series which has a 1929 base.

[7] For USDA farm output, both trend lines were fitted using decennial data. For Kendrick's net farm output, the trend line 1800 to 1900 was fitted to decennial data; the trend for 1900 to 1957 was based on annual data, though the equation in Chart 2 has been adjusted so that it describes the decennial rate of change.

CHART 2.—TRENDS IN FARM OUTPUT, 1800–1960*



* Data from the sources cited for Table 3, shifted to base 1929 = 100.

15 per cent per decade, or about 1.4 per cent per year. The rate of increase in net farm output declined somewhat later—around 1900—to only 8 per cent per decade, or about 0.8 per cent per year.

This decline in the rate of growth of farm output coincides generally with the closing of the frontier and an expansion in industrial activity. Most of the suitable land had been taken into agricultural use and the supply of immigrant farm labor had begun to level off.[8] At about this same time, the natural rate of population increase began to decline gradually, because of a reduction in the birth rate (*20*, p. 23). From 1790 to 1880 the population had been increasing at the rate of about 33 per cent per decade or about 2.9 per cent per year, roughly the same order of magnitude as the increases in gross farm output. Between 1880 and 1930, however, the rate of population increase fell to 20 per cent per decade

[8] The number of immigrant farmers increased rapidly in the first half of the nineteenth century. In the latter decades their numbers fluctuated widely—from 13,000 to 60,000 per year with no trend clearly predominating. The number of persons immigrating as laborers, a classification that probably included many who eventually worked on farms, declined sharply in the final two decades of the century (*20*, p. 61).

or 1.8 per cent per year.[9] There seems to have been a close correlation between increases in agricultural output and population growth.

OUTPUT PER WORKER

The expansion of the nation's farm output has been great, but to get some idea of how efficiently the increased output was produced requires knowledge of the amount of resources that were used. It is not easy to obtain a composite measure of all agricultural inputs, and it is only recently that attempts to do so have been made. There are, however, several estimates of single inputs, such as labor and land, and hence, several indexes relating agricultural output to a single factor of production. Indexes of output per unit of labor have been the most generally used indicators of productivity in this country.

Such "partial" productivity indexes neither imply a change in over-all productive efficiency, nor do they show the unique contribution of labor to production. However, since labor represents such a crucial, though gradually diminishing proportion of total agricultural inputs, knowledge about changes in the productivity of farm workers should help us to understand when and why total productivity has changed. Moreover, sustained improvements in the real income of the farm population require an increase in the productivity of farm labor.

Labor productivity can be measured in terms of output per worker or output per man-hour. The simpler of the two measures, output per worker, will be considered first.

Chart 3 describes the movements of seven different indexes of farm output per worker. The first two are derived from Barger and Landsberg's National Bureau study. The third is published by the Bureau of Labor Statistics. The fourth and fifth are based on data from the Department of Agriculture. And the final two series are from Kendrick's work.

Each series was computed by dividing an index of agricultural output by an index of farm workers. Variations among the results are to be expected because of variations in both the output and the employment series.[10] And yet there are remarkable similarities, especially among Barger and Landsberg's series based on farmers and adult male laborers, the BLS index, USDA's farm output series, and Kendrick's gross farm output index.[11] This is demonstrated by the summary at the bottom of Chart 3 which describes the range of high and low values for all the indexes.

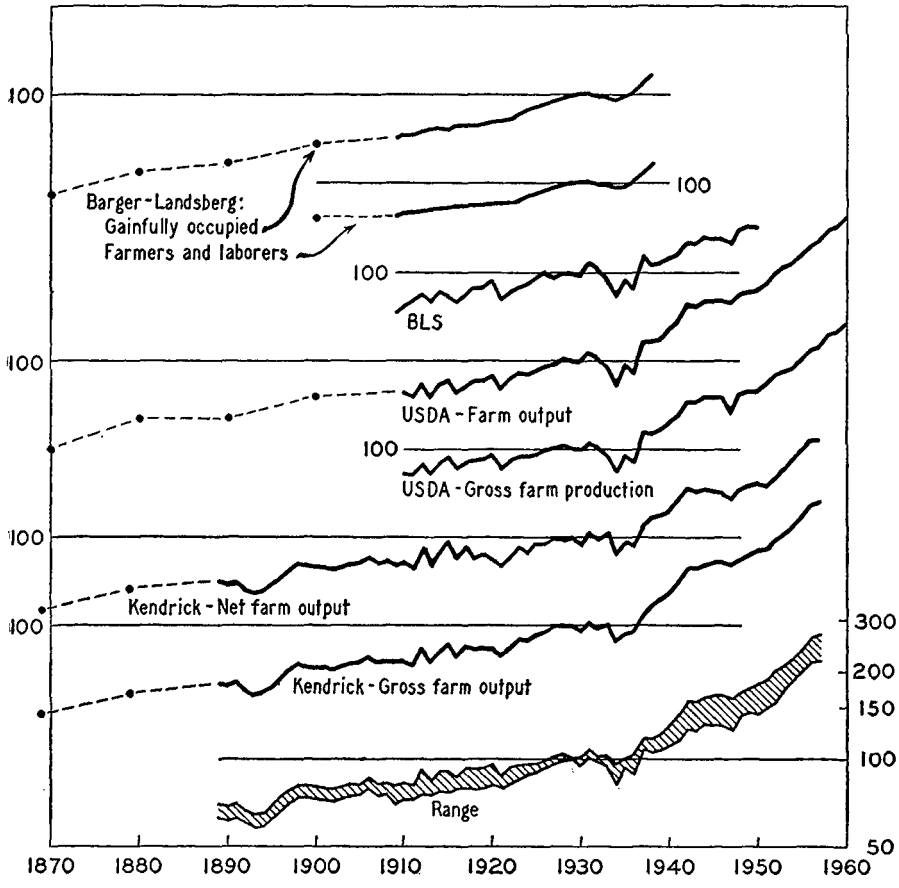
The average annual rates of change in output per worker, shown in Table 4, are also similar. The direction of change for each period is always positive for each index. The long terms (1870 to 1957) rate of increase has been about two per cent per year. When shorter periods are considered it appears that after a

[9] Between 1880 and 1950 the rate of population growth was even lower—17 per cent per decade or 1.6 per cent per year. These rates were calculated from data in *20*, p. 7.

[10] The differences in coverage of the various estimates of employment are described in the Appendix.

[11] The series based on USDA's gross farm production and Kendrick's net farm output differ primarily because of the previously explained differences in the definition of output. The divergence between the two estimates made by Barger and Landsberg can be attributed to the fact that the gainfully occupied series includes women and children while the alternate index does not.

CHART 3.—INDEXES OF FARM OUTPUT PER WORKER, 1869–1960*



* Data from the sources cited for Table 4, shifted to base 1929 = 100. (Note: Barger-Landsberg series based on five-year averages.)

temporary reduction in the early part of this century this growth rate has been increasing. In the most recent period from 1948 to 1957 the rise in output per worker has exceeded 4.5 per cent per year.

The indexes of output per worker based on USDA farm output and Kendrick's gross farm output diverge from the BLS index after 1940. As suggested earlier, the variations in output are mainly the result of using different weighting periods. In addition, since the late 1930's the BLS index of farm employment has been higher than the USDA index, adding to the discrepancies in the output per worker series.[12]

[12] The USDA estimate includes the following groups which BLS estimates exclude: (1) persons under 14 years of age and (2) farm workers with a non-farm job which occupies most of their time. Despite this difference in coverage, when the actual numbers of workers are indexed on a 1929 base, the two series are fairly similar up to the late 1930's at which time the BLS index becomes consistently higher than the USDA figures. This result obtains as the groups mentioned above become relatively less important, causing the USDA index of farm employment to fall more rapidly than the BLS series, which has excluded these persons all along.

TABLE 4.—FARM OUTPUT PER WORKER; AVERAGE ANNUAL PERCENTAGE RATE OF CHANGE, SELECTED PERIODS, 1870–1957*

Period	Barger-Landsberg I[a] (1a)	Barger-Landsberg II[b] (1b)	BLS (2)	USDA Farm output (3a)	USDA Gross farm production (3b)	Kendrick Net farm output (4a)	Kendrick Gross farm output (4b)
1870–1957	...	...	...	1.92	...	1.56[c]	1.94[c]
1870–1900	1.34[d]	...	...	1.41	...	1.16[c]	1.25[c]
1900–1910	0.78	0.30	...	0.29	...	0.28	0.43
1910–1919	1.09	0.74	1.64	1.13	1.32	0.57	1.09
1919–1929	2.27	1.76	1.22	1.52	0.75	1.41	1.75
1929–1937	1.21	1.11	1.76	2.11	1.71	1.04	1.11
1937–1948	...	...	1.94	3.55	2.98	2.78	4.11
1948–1957	...	...	...	4.60	4.18	4.53	5.26
1870–1919	1.18[d]	...	...	1.13	...	0.88[c]	1.06[c]
1919–1937	1.80	1.47	1.46	1.78	1.17	1.25	1.46
1937–1957	...	...	...	4.02	3.52	3.56	4.63

* See Appendix for differing definitions of "farm worker" used by the cited authors. Annual average percentage rates of increase from the beginning year to the ending year in each period, except columns 1a and 1b, computed (compound interest formula) from data in the sources shown below. For columns 1a and 1b rates are computed from five-year averages centering on the beginning and ending years. Basic sources: Barger-Landsberg, *1*, pp. 251, 253; BLS, *15*, p. 9; USDA computed from employment data *12*, p. 43, and *22*, p. 15, and for farm output *12*, p. 47, and for Gross farm production *13*, p. 37 with revised data 1950–60 direct from USDA; Kendrick, *4*, pp. 362–66.

[a] Workers defined as "gainfully occupied."

[b] Workers defined as "farmers and adult male laborers."

[c] Beginning year is 1869.

[d] Beginning figure is 1869–71 average.

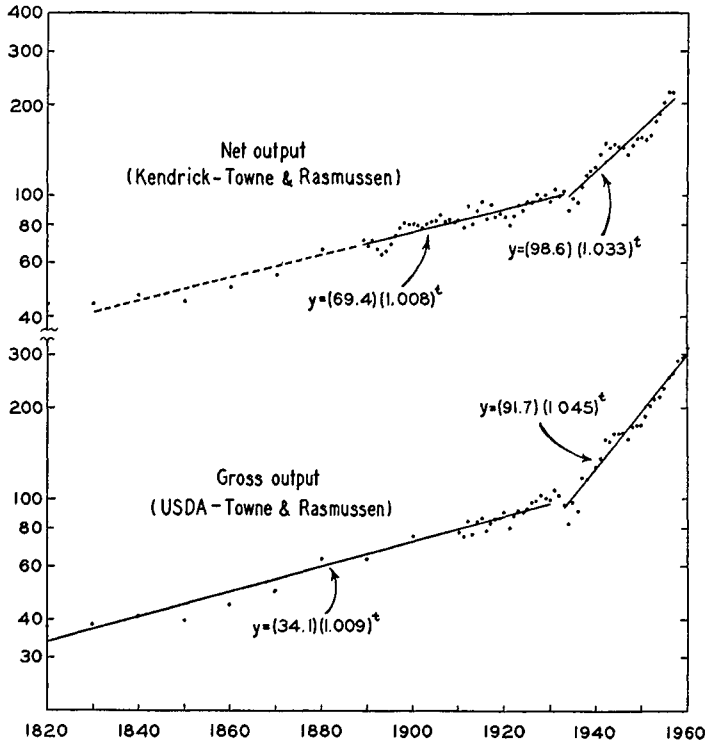
Chart 4 presents the indexes of USDA (gross) farm output per worker and Kendrick's net farm output per worker, both linked to Towne and Rasmussen's estimates of farm output in the nineteenth century.[13]

The trend lines here suggest that during much of the nineteenth century and the early part of the twentieth century, output per worker was increasing at a rate of about 10 per cent per decade, or slightly less than one per cent per year. They also indicate that a break in trend occurred, probably during or immediately after the depression of the 1930's. From the mid-1930's on, output per worker has been increasing at a much faster annual rate—between 3.3 per cent (for net output) and 4.5 per cent (for gross output).

Estimates of farm employment indicate how many persons follow agricultural pursuits, but they provide little or no information about the extent to which the people work. For example, the USDA series includes farm operators and hired farm workers who spend *one hour or more* for pay per week. Clearly, the amount of labor expended by the farm workers enumerated in this fashion is subject to wide variability; the number of hours worked per person per week

[13] For the series based on USDA farm output, the trend line for 1933 to 1960 was fitted to annual data; the trend for 1820 to 1930 was fitted to decennial data, and then the equation was adjusted to describe the annual rate of change. For the series based on Kendrick's net farm output, both trend lines (1889 to 1930 and 1934 to 1957) were calculated from annual data. The trend for the earlier period is virtually the same as one fitted to decennial data for the period 1830 to 1930; hence, we have extended this one back to 1830 in Chart 4.

CHART 4.—TRENDS IN OUTPUT PER WORKER, 1820–1960*



* Data from the sources cited for Tables 3 and 4, shifted to base 1929 = 100.

could vary from one to fifty or sixty or more. The large proportion of unpaid family labor which is typical for an agricultural system consisting chiefly of family farms introduces into the estimates a further, and perhaps even more important, source of variation.

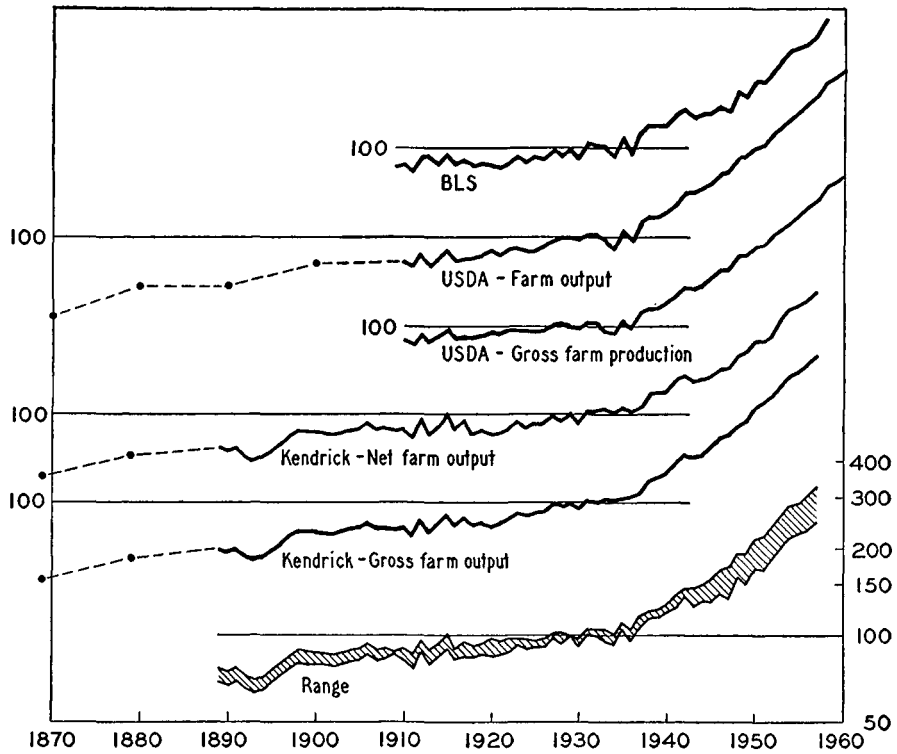
OUTPUT PER MAN-HOUR

In all likelihood, unpaid family labor represents a declining proportion of the actual labor effort involved in American agriculture. Similarly, part-time help and operator labor has become relatively more important. These circumstances suggest that the measure of "output per worker" may tend to underestimate the actual increase in labor productivity. Hence we turn to consider the more refined measure: output per man-hour. Such an estimate has an advantage over the simpler output per worker series to the extent that it defines labor input more accurately.[14]

[14] This is still only a partial productivity index and should not be thought of as describing the unique contribution of labor to the production process. Instead, measures of output per man-hour should properly be interpreted as reflecting the interaction of many factors. More specifically, they attempt to estimate how much more output an individual can produce in an hour as a result of new methods and techniques, improved varieties, additional machinery and equipment, as well as improved labor skill.

Chart 5 depicts five indexes of output per man-hour over various periods of time, together with the range of high and low values. The USDA and the Kendrick series are based on the previously discussed measures of output and on closely related estimates of man-hours. The USDA constructs a series of *equivalent man-hours* which Kendrick uses to develop his own estimates of *actual hours worked*.[15]

CHART 5.—INDEXES OF FARM OUTPUT PER MAN-HOUR, 1869–1960*



* Data from the sources cited for Table 5, shifted to base 1929 = 100.

The BLS index of output per man-hour is based on the value added or net output of the agricultural sphere of the economy, and as such corresponds closely to the concept underlying Kendrick's series of net farm output.[16] The

[15] The USDA series of equivalent man-hours is built up by calculating the average number of man-hours of labor required per acre of crops or per head of livestock for each region of the country. These figures are then applied to the regional estimates of acres of each crop and numbers of livestock produced. Time for general farm maintenance and other overhead labor is estimated separately and added to the direct labor for crops and livestock in order to arrive at total man-hours of all farm work.

Kendrick takes the USDA series and increases it by 10 per cent "in order to come closer to an actual hours-worked concept. This factor was based on an informal opinion by some of the [Agriculture] Department's technicians that actual hours would run 5 to 10 per cent above man-equivalent hours" (*4*, p. 352).

[16] The Office of Business Economics, United States Department of Commerce, estimates the total value of farm output to include (1) cash receipts (from marketings and Commodity Credit Corporation loans), (2) consumption on farms, (3) net change in inventories, and (4) gross rental value of farm homes. The value of intermediate inputs is calculated and covers such items as feed, fertilizers, seed, gasoline, insurance, machinery repairs, veterinary services, and gross rents paid

number of man-hours is expanded from the results of a monthly sampling of households by the Bureau of the Census. Only hours actually worked during the survey week are included. Persons with jobs but not at work are excluded from the computation.[17]

All of the indexes tend to move together, as Chart 5 indicates. In this case the increased spread between the high and low values of the indexes which occurs after about 1940 can be explained largely by differences in the output measures. Over time intermediate goods produced off the farm have become an increasingly larger proportion of gross farm output with the result that net farm output has tended to rise less rapidly than gross farm output. Hence, those series of output per man-hour based on a value-added concept of output (BLS and Kendrick's net farm output) increase less rapidly than those based on gross farm output.

Similarities between the indexes are apparent when average annual rates of change are considered in Table 5. With one exception the rates of change are positive and of the same order of magnitude, at least for those series based on comparable output data.

TABLE 5.—FARM OUTPUT PER MAN-HOUR: AVERAGE ANNUAL PERCENTAGE RATE OF CHANGE, SELECTED PERIODS, 1870–1957*

Period	BLS (Census) (1)	USDA		Kendrick	
		Farm output (2a)	Gross farm production (2b)	Net farm output (3a)	Gross farm output (3b)
1870–1957	...	2.05	...	1.69[a]	2.07[a]
1870–1900	...	1.43	...	1.19[a]	1.28[a]
1900–1910	...	0.20	...	0.24	0.39
1910–1919	0.26	0.48	0.56	-0.20	0.32
1919–1929	1.04	1.40	0.60	1.24	1.57
1929–1937	1.39	1.74	1.45	0.83	0.88
1937–1948	3.29	4.81	4.24	3.82	5.17
1948–1957	5.02	5.47	5.03	5.70	6.44
1870–1919	...	1.00	...	0.74[a]	0.93[a]
1919–1937	1.20	1.55	0.98	1.06	1.26
1937–1957	4.06	5.11	4.59	4.66	5.74

* See text for description of man-hour series used by authors cited. Annual average percentage rates of increase from the beginning year to the ending year in each period computed (compound interest formula) from data in the following sources: BLS, *14*, pp. 17–18, Census series; USDA farm output, *12*, pp. 40–41, and *5*, p. 57 for years prior to 1910; USDA gross farm production, *13*, p. 37, and revised data 1950–60 direct from USDA, man-hours, *12*, p. 34; Kendrick, *4*, pp. 362–66.

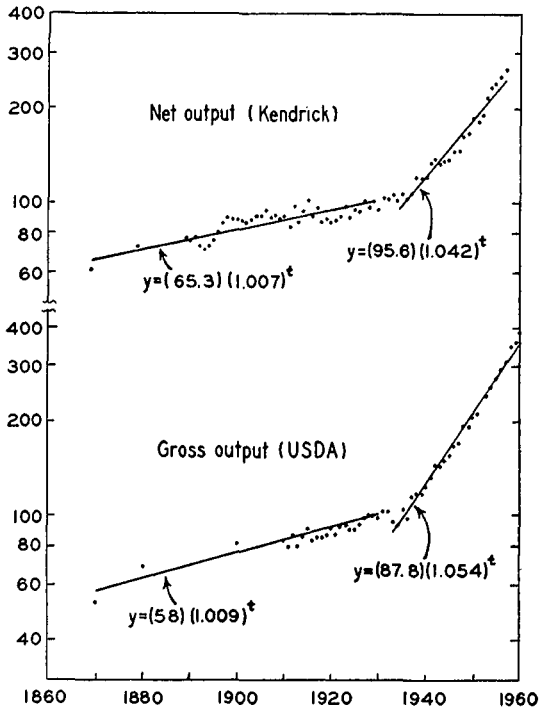
[a] Beginning year is 1869.

to non-farm landlords. These two estimates—total farm production and intermediate inputs—are then deflated by appropriate price indexes. The difference between the resulting figures represents the "real" product of, or value added by, agriculture. This differs from the BLS estimate of farm output discussed in the previous sections, which was more of a measure of gross output.

[17] The BLS study actually makes two estimates of output per man-hour, one based on Bureau of the Census labor force data which attempts to measure hours worked (excluding paid vacations and paid sick leaves), the other based on BLS data which measures hours *paid*. We have chosen to reproduce only the index based on Census data; both series show virtually the same changes over time.

The long-term pattern of changes in output per man-hour is shown graphically in Chart 6.[18] Up until about 1933 or 1934, net output per man-hour was increasing at the average annual rate of 0.7 per cent, while gross output (USDA farm output) per man-hour was increasing at about 0.9 per cent per year. Since that time both net and gross farm output per man-hour have been increasing much more rapidly—by about 4–5 per cent annually.

CHART 6.—TRENDS IN FARM OUTPUT PER MAN-HOUR, 1869-1960*



* Data from the sources cited for Table 5, shifted to base 1929 = 100.

OUTPUT PER UNIT OF TOTAL INPUT

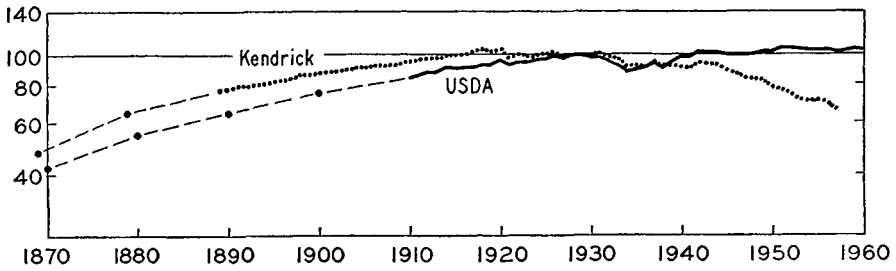
A partial productivity ratio can not measure changes in over-all productivity, because it cannot take into account factor substitution. For example, as machines are substituted for labor, the change in output per man-hour over time will be greater than the change in output per unit of total input. Recognizing this discrepancy, however, is easier than rectifying it. It is easy to say that what is needed is an index of total factor productivity (for a particular industry or the whole economy); to derive a meaningful measure of such a concept is extremely difficult. Only recently have substantial efforts been made to establish measures

[18] In this case, decennial data are used to fit the trend lines prior to 1930, annual data are used since 1930. The rates of change shown are annual rates.

of over-all productivity in agriculture. The two most notable attempts are those of the Department of Agriculture (*5, 12*) and of Professor John W. Kendrick (*4*).

These measures are based on the previously discussed indexes of output and independently derived indexes of farm inputs. Since the input series diverge substantially it would be well to discuss them briefly at this point. The two indexes are shown in Chart 7.

CHART 7.—INDEXES OF FARM INPUTS, 1869–1960*



* USDA data from *12*, p. 47, shifted to base 1929 = 100, Kendrick data from *4*, pp. 362–64.

The USDA has computed an index of agricultural inputs "in the aggregate." It apparently originated as a part of a study to determine simply agricultural productivity. In general, it measures changes in those inputs "which are subject to control by the decisions of farmers" (*5*, p. 4). Specifically, it includes (1) farm labor, (2) real estate, (3) mechanical power and machinery, (4) fertilizer and lime, (5) feed, seed, and livestock purchases (from non-farm sources), and (6) such miscellaneous items as irrigation supplies and maintenance, veterinary services, insurance, property taxes, and interest on inventories and operating capital.

Kendrick, on the other hand, derived his estimate of inputs as part of a larger study of productivity in the whole economy. Since he is concerned with the broader picture, of which agriculture is only a part, Kendrick concerns himself mainly with *net* concepts. For example, the output series that receives most attention is net farm output (i.e. gross farm output minus intermediate products purchased from non-farm sources). And the input series represents an aggregation of farm labor and durable capital (i.e. land, machinery, and inventories). Neglected as inputs are those materials supplied annually by businesses in the non-farm sector, such things as fertilizer, veterinary services, and feed and seed purchases (from non-farm sources).

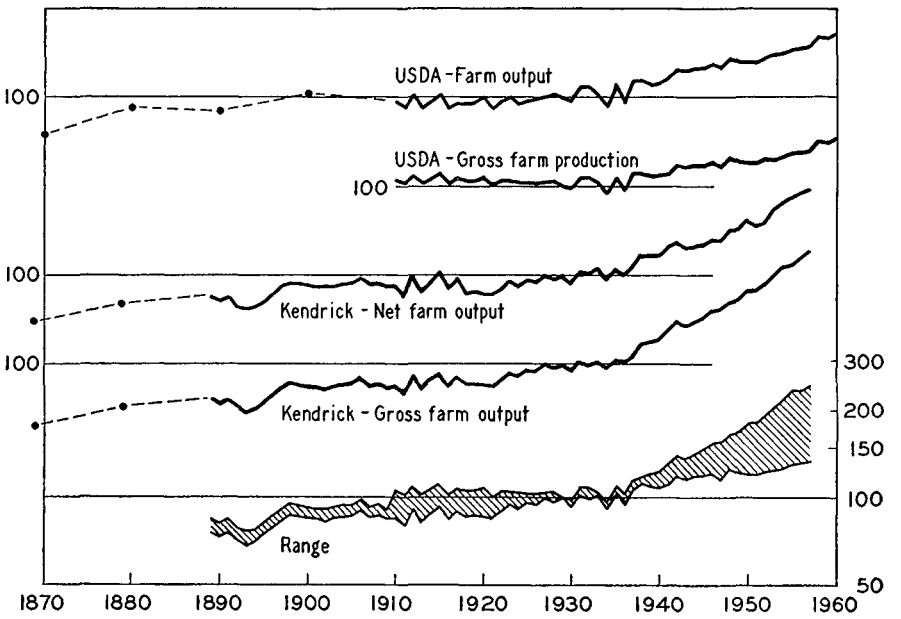
The main difference between the two input series lies in the fact that the USDA includes non-durable intermediate purchases whereas Kendrick excludes these. Since these items have been growing in importance relative to labor, land, and durable capital, Kendrick's index of inputs is much lower in recent years than that of the USDA. In fact, the former series shows a substantial decline since 1930—about 35 per cent—while the latter has increased slightly—about 4 per cent.

The indexes of farm output per unit of total input are displayed in Chart 8. The general pattern of movement is the same, but as the summary indicates, there have developed significant differences in the high and low values of the indexes in recent years.[19] Substantial discrepancies are also visible in the average annual rates of change, shown in Table 6. However, considering the differences in the series underlying these estimates of productivity, it is probably surprising that the general pattern of the indexes exhibit as much similarity as they do.

Of the series presented in Chart 8, the choice of the best estimate of over-all productivity is between the USDA index, based on (gross) farm output and gross input, and the Kendrick index, based on net farm output and net input. For the economy as a whole, changes in the ratio of net output to net input is the relevant one. This is not so certain when the field is limited to a single industry. For example, when it becomes profitable to substitute non-farm produced intermediate goods for farm inputs, the ratio of net output to net input tends to overstate the gains in productivity of agriculture inputs. This ratio is to be questioned as a measure of over-all changes in productivity for much the same reason that the ratio of output to labor, or any other single input, is questioned; it is affected by changes in the composition of inputs, i.e., factor substitution.

In recent years agriculture has witnessed a large-scale shift in the production of intermediate goods from the farm to the non-farm sector. For example, it has become more efficient to produce fertilizer and energy for locomotion with "non-

CHART 8.—INDEXES OF FARM OUTPUT PER UNIT OF INPUT, 1869–1960*



* Data from the sources cited for Table 6, shifted to base 1929 = 100.

[19] This is in part the result of choosing 1929, rather than a more recent year, as the base.

TABLE 6.—FARM OUTPUT PER UNIT OF INPUT: AVERAGE ANNUAL PERCENTAGE RATE OF CHANGE, SELECTED PERIODS, 1870–1957*

Period	USDA		Kendrick	
	Farm output (1a)	Gross farm production (1b)	Net farm output (2a)	Gross farm output (2b)
1870–1957	0.82	...	1.21[a]	1.59[a]
1870–1900	1.07	...	0.95[a]	1.07[a]
1900–1910	-0.39	...	0.02	0.11
1910–1919	-0.15	-0.11	-0.50	0.03
1919–1929	0.40	-0.37	1.24	1.57
1929–1937	1.71	1.43	0.80	0.86
1937–1948	1.63	1.07	2.69	4.03
1948–1957	1.03	0.62	3.70	4.43
1870–1919	0.54	...	0.50[a]	0.69[a]
1919–1937	0.98	0.42	1.05	1.25
1937–1957	1.36	0.87	3.14	4.21

* See text for discussion of measures of "inputs" used by USDA and Kendrick. Annual average percentage rates of increase from the beginning year to the ending year in each period computed (compound interest formula) from data in the following sources: USDA farm output, *12*, p. 47; USDA gross farm production computed from *13*, p. 37, and revised data 1950–60 direct from USDA inputs, *12*, p. 47; Kendrick, *4*, pp. 362–66.

[a] Beginning year is 1869.

farm" resources than with "farm" resources. Consequently, the "traditional" farm inputs of land, farm labor, and farm capital contribute relatively less while the non-farm inputs, produced by industrial labor and machines, contribute relatively more. Therefore, it may be the case that the ratio of net output to net input tends to overstate the increase in agricultural productivity.

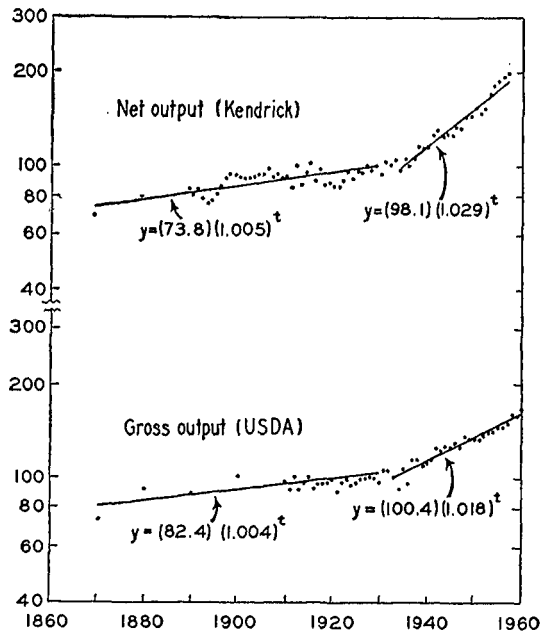
The USDA index of farm output per unit of (gross) input and Kendrick's net farm output per unit of (net) input are plotted in Chart 9, together with trend lines.[20] In general both series show similar movements over time, though in recent years, as intermediate goods have increased in relative importance, the Kendrick series has increased more rapidly. Again there is a break in the trend during the 1930's, though this shift may be somewhat less obvious than in previous cases. From 1870 to 1930 output per unit of total input rose at the rate of 0.4 to 0.5 per cent per year. Since 1930, this ratio has tended to increase between 1.8 per cent and 2.9 per cent annually.

SUMMARY

It is not appropriate at this stage of the research to formulate hypotheses that explain why American agricultural productivity has risen. However, certain generalizations can be made about the probable timing and magnitude of productivity increases, recognizing the limited concept of "production" used. (Cf. p. 65.) From the analysis of the data of the various authors reviewed, the following dynamics emerge:

[20] Decennial data were used to fit the trend lines prior to 1930; annual data were used since 1930. The indicated rates of change are annual rates.

CHART 9.—TRENDS IN FARM OUTPUT PER UNIT OF INPUT, 1869–1960*



* Data from the sources cited for Table 6, shifted to base 1929 = 100.

1. The output of agricultural products (measured gross or net of intermediate goods) increased at the rapid rate of about 35 per cent per decade through most of the nineteenth century. Toward the end of the century, when most of the available land had been occupied and more and more manufacturing industries were being developed, the rate of growth of agricultural output declined. Throughout the present century net farm output has risen at the rate of 8 per cent per decade; gross farm output has increased about 15 per cent per decade.

2. The decline in the rate of growth in farm output at the end of the nineteenth century does not appear to have had substantial impact on output per worker and output per man-hour. These indexes increased at a rate only slightly less than one per cent per year up until the mid-1930's, since which time they have been rising about 4–5 per cent annually. The failure of the change in the rate of output to influence the rate at which output per unit of labor was increasing may be explained by movements in farm employment. Toward the end of the nineteenth century, the rate at which farm workers had been increasing began to slow down. After World War I, farm employment began to decline absolutely. The number of persons actively engaged in agriculture reached its peak in 1916 at 13.6 million and from then on declined so that by 1960 only 7.1 million remained (*12*, p. 43; *22*, p. 15).

3. Over-all productivity, i.e., the output per unit of the aggregate of all inputs, has followed the same general pattern as the partial labor productivity indexes. That is, it has tended to rise steadily—at the rate of about 0.5 per cent per year prior to 1930 and at the much faster annual rate of 2–3 per cent since then. That

the ratio of output to total input has increased at a much lower rate than the partial productivity ratios reinforces the observation that over time capital has been freely substituted for farm labor.

4. A comparison of the USDA estimate of productivity changes, based on gross output and gross input, with the Kendrick estimate, based on net output and net input, indicates more clearly than before the contribution of purchased input to the increase in agricultural output. As non-farm produced intermediate goods have become an increasingly important share of gross farm output, Kendrick's index of productivity, which excludes these items, rises more rapidly than the USDA's index, which includes them. While this may be in part the result of the arbitrary definition of farm and non-farm sectors of the economy, it does suggest that net farm output may be more responsive to changes in these intermediate goods than has been thought (e.g., *4*, p. 29). This in turn raises the possibility that non-farm industries have contributed more to raising agricultural productivity than is generally assumed.

CITATIONS

1 Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939* (Nat. Bur. Ec. Res., New York, 1942).

2 Raymond G. Bressler, Jr., and John A. Hopkins, *Trends in Size and Production of the Aggregate Farm Enterprise,* Report No. A-6, National Research Project (Philadelphia, 1938).

3 B. F. Johnston and J. W. Mellor, "The Role of Agriculture in Economic Development," *American Economic Review,* September 1961, pp. 566–593.

4 John W. Kendrick, *Productivity Trends in the United States* (Nat. Bur. Ec. Res., Princeton, 1961).

5 Ralph A. Loomis and Glen T. Barton, *Productivity of Agriculture: United States, 1870–1958* (U.S. Dept. Agric. Tech. Bull. No. 1238, April 1961).

6 Henry Bamford Parkes, *The American Experience* (New York, 1947).

7 W. W. Rostow, *The Stages of Economic Growth* (Cambridge, 1960).

8 E. E. Shaw and J. A. Hopkins, *Trends in Employment in Agriculture, 1909–36,* Report No. A-8, National Research Project (Philadelphia, 1938).

9 Frederick Strauss and Louis H. Bean, *Gross Farm Income and Indices of Farm Production and Prices in the United States, 1869–1937* (U.S. Dept. Agric. Tech. Bull. No. 703, 1940).

10 Marvin W. Towne and Wayne D. Rasmussen, "Farm Gross Product and Gross Investment in the Nineteenth Century," *Trends in the American Economy in the Ninteenth Century* (Nat. Bur. Ec. Res., Princeton, 1960), pp. 255–312.

11 U.S. Dept. Agric., *Index Numbers of Agricultural Production* (Stat. Bull. No. 273, December 1960).

12 U.S. Dept. Agric., *Changes in Farm Production and Efficiency* (Stat. Bull. No. 233, July 1961).

13 U.S. Dept. Agric., *Major Statistical Series of the U.S. Department of Agriculture, Vol. 2, Agricultural Production and Efficiency* (Agr. Handbook No. 118, September 1957).

14 U.S. Dept. Labor, Bur. Labor Statistics, *Trends in Output per Man-Hour in the Private Economy, 1909–1958* (Bull. No. 1249, 1959).

15 U.S. Dept. Labor, Bur. Labor Stat., *Productivity Trends, 1909 to 1950: Agriculture* (March 1952).

16 G. F. Warren and F. A. Pearson, *The Physical Volume of Production in the United States,* Memoir 114, Cornell University Agricultural Experiment Station (Ithaca, New York, 1932).

17 Alvin S. Toslebe, *Capital in Agriculture: Its Formation and Financing since 1870* (Nat. Bur. Ec. Res., Princeton, 1957).

18 Alfred Saco, "Farm Productivity and Income as Related to Economic Growth," *Problems of Development,* Series of Lectures on Economic Growth, University of Madrid, January–February 1961 (Paris, 1961).

19 Alfred Saco, "Production and Agricultural Real Income in Relation to Economic Growth," working paper for the Sixth FAO Regional Conference for Latin America.

20 U.S. Bur. Census, *Historical Statistics of the United States, Colonial Times to 1957* (1960).

21 Economic Report of the President, January 1962.

22 U.S. Dept. Agric., *Farm Employment* (Stat. Bull. No. 236, September 1958).

APPENDIX

INDEXES OF AGRICULTURAL OUTPUT

Warren-Pearson Index of Crop Production (*16*). Published in 1932 by the Cornell University Agricultural Experiment Station, this was an attempt to derive an index of agricultural production, extending from 1866 to 1932, by measuring the output of 33 crops and combining these estimates in proportion to their relative importance in the period 1926 to 1930.

Livestock production was excluded since "all livestock is produced from crops, except the part that is produced from pasture" (*16,* p. 52). This means that the index is not strictly comparable with the others. However, partially offsetting this excluded item was the inclusion of that part of production used for feed for livestock and horses and mules.

The relative importance of each crop was calculated for the period 1926–30 by estimating the annual average value of its output for these years. In addition an index of the physical volume of production for each commodity was developed, using as a base 1926–30 = 100. For each crop the index of production was multiplied by its relative importance in the base period, and the resulting products were summed to form the annual index.

Strauss-Bean Index of Farm Production (*9*). This index, published by the USDA in 1948, measures agricultural production for crop-years from 1869 to 1937, after eliminating the output used for seeds and for livestock feed. It represents essentially that proportion of farm production available to the non-farm economy plus those products consumed on the farm.

The index was based on Fisher's "ideal formula" which uses price-weights of the given year in combination with those of the base year. What this amounted to was the calculation first of two indexes, each with a common base period (in this case 1909–13 crop-years). However, one of the indexes used as weights the prices of the given year; the other used as weights the average prices for the crop years 1909–13. Fisher's "ideal index" was obtained by taking the square root of the product of the two resulting figures.

Barger-Landsberg Index of Farm Output (*1*). The Barger-Landsberg index covering the period from 1897 to 1939, appeared in a 1942 publication of the National Bureau of Economic Research. Farm output was defined to include "products sold to non-farm purchasers, products used by farm families as con-

sumers . . ." and "additions to inventory." Excluded from the estimates was that proportion of each crop used up in the production process, for example, the milk fed to calves and the crops used for feed and seed.

The Edgeworth formula was used to prepare the index, which was derived by calculating the ratio of the values of output for successive pairs of years. The values in each comparison were computed by applying a constant price to the quantities in each year. The constant price was the average of prices for the two years. Because the results of such a chain of successive comparisons may vary significantly from that obtained by a direct comparison between two far-removed years, direct comparisons along the same lines were made for the years 1899 and 1909, 1909 and 1919, 1919 and 1929, and 1929 and 1937. The annual series was then fitted into this framework.

Bureau of Labor Statistics Index (*15*). This measure of agricultural production grew out of an index originally designed by the National Research Project under the Works Progress Administration (*2*). It extends from 1909 to 1950. Like the other indexes, it depends upon USDA estimates for most of the basic output data. Unlike the others, however, it combines estimates of gross production, regardless of the ultimate disposition.

Instead of utilizing prices to weight the quantity of each commodity, the BLS follows the procedure set up by Bressler and Hopkins. An estimate was made of the number of man-hours required to produce a unit of each commodity in the base period. This figure was then multiplied by the quantity of the particular product produced for each year. The results were added together, and these sums were expressed as percentages of the average annual sum for the base period.

The estimates for 1909 to 1935 were based on the National Research Project's series, using man-hour labor requirements for the period 1924–29 as weights. The figures since 1935, prepared by the Bureau of Labor Statistics, used 1939 labor requirements as weights. The two sets of figures were then linked together on the base 1939 = 100.

USDA Farm Output Index (*12*). The USDA index of farm output measures annual changes in the volume of farm production which is, or will be available for human use. From 1870 to 1900 it has been calculated for dicennial years; it is available annually for the years since 1910. "It includes crops produced during the crop-year minus hayseeds, pasture seeds, and cover-crop seeds and also hay and concentrates fed to horses and mules. The index includes also, on a calendar-year basis, 'net' livestock production other than that from horses and mules. Net livestock production is gross livestock production minus production of hay and concentrates fed and production of hatching eggs for broilers and chickens raised." (*12*, p. 9).

The index is calculated by the weighted aggregate method. The quantity of each commodity is multiplied by a fixed price-weight. The values thus determined are added for each year, and the aggregate is then expressed as a percentage of the base year or period. For 1939 and subsequent years, average 1947–49 prices are used as weights; for years prior to 1939, average 1935–39 prices are used as weights. The two series have been spliced at 1940 to form a single index.

USDA Gross Farm Production Index (*13*). This series, available annually since 1910, represents a measure of the year-to-year changes in the combined volume of (1) total crop production and (2) total livestock production (including horses and mules), minus the feed consumed by livestock. The latter calculation is made in order not to count twice that portion of crop production which is used for livestock feed.

Gross farm production, a byproduct of the USDA farm output series, is also calculated by the weighted aggregate method. The two series differ in that farm output excludes (and gross farm production includes) an allowance for two producer goods—farm-produced power in the form of horses and mules and certain grass and legume seeds. The former component accounted for one-fifth of gross farm production in the period 1914–19 and for one-tenth as late as 1935–39 (*13*, p. 36).

Kendrick's Indexes Net and Gross Farm Output (*4*). These series, for the years 1869, 1879, and 1889 to 1957, are closely related to each other. Of the two, the gross farm output index more closely resembles in concept the USDA index of farm output. It represents the sum of the deflated values of (1) cash receipts from farm marketings and CCC loans, (2) net change in farm inventories, (3) farm products consumed directly in farm households, and (4) the gross rental values of farm homes. Net farm output, one the other hand, is a value-added concept. It is derived by subtracting from the estimates of gross farm output the deflated value of farmers' purchases of intermediate products consumed in the production process. These include feed, seed, fertilizer, motor fuel, irrigation aids, insecticides, veterinary services, and other items charged to current expenses.

Both series use 1939 base deflators through 1940, 1947–49 base deflators from 1940 to 1953, and a 1954 base thereafter.

FARM EMPLOYMENT

The studies surveyed have used several sets of data to derive estimates of farm employment. Barger and Landsberg relied on the Census of Population. The Bureau of Labor Statistics looked to a revision of estimates originated by a National Research Project. The USDA prepared their own estimates. Kendrick uses an index of farm employment which corresponds closely to the USDA series.

Barger and Landsberg derived two estimates of farm employment from the Census of Population. The first—gainfully occupied—counts those persons who were engaged in farm work "regularly" or "most of the time." It, therefore, includes women and children, many of whom share but a small fraction of the work load. These estimates for the census years 1900, 1910, and 1930 have been revised because of changes in the instructions to enumerators and because of differences in the dates on which they were taken. The accuracy of this series is, however, questionable, even after substantial revision. And so Barger and Landsberg suggest as an alternative measure of agricultural employment a series of farmers (including managers and foremen) and adult male laborers. After deriving these two series for census years, Barger and Landsberg used USDA estimates for interpolation (*1*, p. 242).

For the years prior to 1939, the Bureau of Labor Statistics index of output per

worker used employment figures developed by the National Research Project (*8*, Table 7). In the earlier period the estimates included all persons engaged in farm work for two or more days per week, regardless of age: owners, family workers, and hired workers. For the period 1939–50 the series corresponds more closely with that used by the Bureau of the Census in its *Monthly Report on the Labor Force*. This means that the BLS figures exclude (1) all workers under 14 years of age, and (2) all farm workers who also have a non-farm job at which they spend most of their time. These are included in the USDA figures (see below). In addition, the BLS counts those persons who do work on more than one farm only once, whereas the USDA counts them on each farm. Because of these discrepancies in coverage and because these groups have become relatively less important, the USDA series has declined more rapidly and the BLS index of farm employment (1929 = 100) is consistently higher than the USDA index since the late 1930's.

The USDA estimates of farm employment are based on a survey of 20,000 to 25,000 farmers who report the number of persons working on their farms during the last complete calendar week in each month. The Census of Population and the Census of Agriculture provide bench-mark data. Included in the estimates are (1) all farm operators who spend one hour or more during the survey week at farm work or transacting farm business, (2) unpaid members of the operator's family who do unpaid farm work, so long as they put in 15 or more hours, and (3) persons (including family members) who do one or more hours of farm work for pay during the survey week. The first two groups are classified as "family workers," the latter group as "hired workers."