Effect of Weight-Period Selection on Measurement of Agricultural Production Inputs

By Ralph A. Loomis

Choice of weights is basic to construction of index numbers that are designed to measure change over time. The analysis in this article develops criteria for selection of weights and examines the results of using different periods as a basis for measuring change in the volume of selected inputs in farm production from 1910 to 1955. Laspeyres' weighted aggregative formula was considered the most appropriate formula for use in this analysis. Average cost rates were used as weighting units. The various indexes of combined inputs that are described here were developed for testing purposes. It is believed that the index of total farm inputs that will result when the aggregate production inputs of agriculture are measured and analyzed will differ substantially from any of the index-number series of selected agricultural inputs shown here. This paper is a report on the first phase of the project. It does not pretend to be an exhaustive study of the many problems that arise in the construction of an index of agricultural inputs. For instance, the problems associated with selection of weighting units and an index formula are not discussed. However, it is a reasonably thorough analysis of the problem of how to aggregate the different inputs in a meaningful way to show change over time when the composition, relative prices, and quantities of inputs change. The advice and leadership of Glen T. Barton in the preparation of this article is acknowledged by the author.

ONE of the main principles governing the choice of a weighting period is that the weights for that period reflect accurately the relative importance of the movements of the components of the index. This is particularly true in the construction of an index of inputs measuring changes in recent years. Wage rates of hired labor relative to prices of other inputs, for example, now average more than double that of the pre-World War II period. Use of prewar wage rates as weights would greatly understate labor input and its effect on changes in the aggregate of inputs. This analysis will develop a basis for choosing weighting periods that will minimize distortions caused by changes in the relative importance of inputs.

Weighting agricultural inputs by prices paid in a given period, that is, changing from current cost rates to the average cost rates of a given period, essentially revalues the inputs for each year. Weighting and combining inputs raises the problem of changes in relationships among cost rates of labor, machinery, land, and so on, over time. Use of different periods of time for obtaining average cost rates results in different relative weights among input factors. This, in turn, usually results in different magnitudes of change in the indexes of combined inputs over the same span of years.

Once the price weights are selected, the resulting index will represent the average overall change from the base period of quantities of individual and total inputs in terms of the price relationships that existed in the price-weight period. A given index number has only one base period. The base period is the year or period that is taken as 100 in calculating the index number. The weight period, on the other hand, is the year or period selected for calculating average cost rates to be used as weights in combining component inputs. More than one weight period may be used. The series of years for which indexes are to be calculated may be divided into two or more subperiods, with weight periods selected for use in each subperiod. When this is done, splicing is necessary in calculating final index numbers.

Quantity-Price Aggregates

Systematic observation and tests of data show the comparative effects of alternative price-weight periods on changes in the index of total inputs. It is difficult to specify any point in time as a demarcation between periods in which the com-
The position of inputs and the biases that result from relative price changes are sufficiently different to warrant separation.

In a critical examination of price and quantity data, the final test revolves around the effect of price weights on the composite index of inputs. This in turn is a function of changes in both quantity and price aggregates. Differences in indexes of combined inputs, resulting from use of different price-weight periods, may be seen in figure 1.

Selection of inputs for the evaluation of changes in indexes of combined inputs was based on the necessity of including a high percentage of the total inputs and using inputs for which data were readily available. Although the data used are tentative and subject to revision, the revisions are not likely to be of sufficient magnitude to invalidate the results of these tests. The selected inputs used for this analysis, which includes all the major inputs, are: All farm labor, farm machinery depreciation, motor vehicle depreciation, fertilizer nutrients, building depreciation, and net rent on farm real estate.

For selected price-weight periods, the general procedure in this analysis was to calculate quantity-price aggregates for each selected input, add them to obtain a total of selected inputs, and express this total as an index, with 1935–39 = 100. The price-weight periods tested were 1910–14, 1925–29, 1935–39, average of 1925–29 and 1935–39, 1937–41, and 1947–49.

The resulting indexes of total selected inputs for each price-weight period were plotted and analyzed for the entire 1910–54 period (fig. 1). It can be seen that regardless of the price weights used, after 1940 the indexes form a pattern that differs from the pattern before 1940.
The quantity-price aggregate data were analyzed in further detail to determine the effect of the different sets of price weights on the composite index. The results are given in table 1. The technique used is as follows: (1) The percentage that each input is of the total selected inputs was calculated for 1910-14, using weights provided by each of several weight periods (cols. 2 to 7); (2) the change in physical quantity of each input between 1910-14 and 1935-39 was calculated as a percentage (col. 8); and (3) the percentages resulting from steps 1 and 2 were multiplied, giving a percentage change for each input factor for each weight period (cols. 9 to 14). This latter percentage is a measure of the combined influence of changes in quantity of each input factor and each price-weight period on the final index of total inputs.

From the totals of columns 9 through 14 (table 1), it can be observed that using the weight periods of 1925-29, the average of 1925-29 and 1935-39, or 1937-41 would result in indexes of combined inputs within one point of each other, when indexes for the average of the years 1935-39 are calculated with 1910-14 as a base. Use of 1910-14 price weights would result in an index higher than, and 1947-49 price weights lower than, any of the indexes that would result from the use of the price-weight periods mentioned. These differences are largely the result of changes in the relative weight of motor vehicles, an input which increased substantially in physical quantity between 1910-14 and 1935-39 (see col. 8).²

² This report does not lend itself to a detailed discussion of weight-correlation bias, one of the limitations of weighted aggregate indexes. Nevertheless, it is important that the reader be aware of the effects on the composite index of changes in relative weights of inputs and changes in relative quantities of inputs. The accompanying table illustrates the effects of weight-correlation bias when the relative price weight of any given individual input is changed. For further information see the reference given in footnote 1.

<table>
<thead>
<tr>
<th>Relative price weight</th>
<th>Change in quantity of input</th>
<th>Contribution to &quot;bias&quot; of composite input index</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
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<tr>
<td>+</td>
<td>0</td>
<td>0, -, or +</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>-</td>
<td>0</td>
<td>0, +, or -</td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>


The same test was applied, using the same weight periods but using 1918-22 as a base period and measuring change in the index of total selected inputs from 1918-22 to 1935-39. Essentially the same patterns were evident.

The effects of different weighting periods on relative weights and on changes in the composite index of inputs were also evaluated with reference to the 1940-55 period. The weight periods tested were 1935-39, 1937-41, 1947-49, and 1952-54. In one test, 1935-39 was used as a base period, with measurement of changes in physical quantities of inputs between 1935-39 and 1950-54. A second test was made, using 1939-41 as a base period and changes in physical quantities between 1939-41 and 1952-54.

In the period 1940-55, all selected inputs except labor increased in physical quantity. The exception (labor) decreased. Use of either 1935-39 or 1937-41 price weights results in overweighting all the inputs, except net rent, relative to labor. Fertilizer is particularly overweighted relative to labor by the use of pre-World War II weights. Use of the 1952-54 price weights tends to overweight labor relative to the other inputs. Although 1947-49 price weights also overweight labor, they do so to a lesser degree than 1952-54 weights. The overweighting of labor, an input which is decreasing in physical quantity, results in a slight downward bias in the composite index of inputs.

Based on this evaluation, 1947-49 is the most suitable weight period for 1940-55.

Relative Price Movements

In evaluating price weights, another technique used was to compare the movement of various input prices relative to the movement of farm wage rates. Wage rates were used as the basis for comparison because labor is the largest single input, and also as a matter of convenience. The comparison was expressed as a ratio of indexes of input prices to the wage-rate index. If the comparative movements of wage rates and other inputs were exactly equal from year to year, the ratio of the indexes would be equal to 100, for by
Table 1.—Effects of different weighting periods on relative weights and on changes in the index of selected physical inputs (1910–14 base period)

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Percentage of value of total inputs in 1910–14 period using as weights</th>
<th>Change in inputs from 1910–14 to 1935–39 using as weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Labor</td>
<td>61.78</td>
<td>61.20</td>
</tr>
<tr>
<td>Farm machinery depreciation</td>
<td>3.16</td>
<td>2.89</td>
</tr>
<tr>
<td>Motor vehicle depreciation</td>
<td>5.90</td>
<td>2.25</td>
</tr>
<tr>
<td>Building depreciation</td>
<td>4.21</td>
<td>4.23</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>2.86</td>
<td>2.10</td>
</tr>
<tr>
<td>Net rent</td>
<td>27.40</td>
<td>24.33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

1 Estimates based on data in: Changes in Farm Production and Efficiency, USDA-ARS 43–15, June 1955; The Farm Income Situation, USDA-AMS, No. 155, Oct. 1955; Farm Labor, USDA-AMS, Jan. 1956; and unpublished manuscript by E. W. Grove, Farm Income Estimates Section, AMS, USDA.

2 Estimates based on data in: Worksheets of Farm Income Estimates Section, AMS, USDA.


4 Estimates based on data in: Worksheets of Land and Water Section, FERD, ARS.

Averages of Prices Paid Indexes

Prices-paid indexes (1935–39=100) were further evaluated by comparing the simple arithmetic averages of alternative weight periods with the average of the price indexes for the entire 1910–39 period (excluding two periods of unusual economic activity—1917–21 and 1931–34). The weight periods tested in this way were 1925–29; 1935–39; average of 1925–29 and 1935–39; and 1937–41.

The deviations of the weight-period averages from the 1910–39 averages were weighted on the basis of the relative importance of each input to total inputs. The weight period with the least deviation would be the most representative of the 1910–39 price index series. Based on this test, either the 1935–39, 1937–41, or the average of...
TABLE 2.—Ratio of indexes of input prices to wage rate index, 1910–40

<table>
<thead>
<tr>
<th>Selected inputs</th>
<th>1925–29=100</th>
<th>1935–39=100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average deviation from 100</td>
<td>Average deviation from 100</td>
</tr>
<tr>
<td>Feed</td>
<td>118 +18</td>
<td>99 —1</td>
</tr>
<tr>
<td>Livestock</td>
<td>107 +7</td>
<td>86 —14</td>
</tr>
<tr>
<td>Motor supplies 1</td>
<td>114 +14</td>
<td>95 —5</td>
</tr>
<tr>
<td>Motor vehicles 2</td>
<td>142 +42</td>
<td>84 —16</td>
</tr>
<tr>
<td>Farm machinery</td>
<td>122 +22</td>
<td>81 —19</td>
</tr>
<tr>
<td>Farm supplies</td>
<td>115 +15</td>
<td>93 —7</td>
</tr>
<tr>
<td>Building and fencing materials</td>
<td>118 +18</td>
<td>86 —14</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>122 +22</td>
<td>104 +4</td>
</tr>
<tr>
<td>Real estate value per acre</td>
<td>117 +17</td>
<td>134 +34</td>
</tr>
</tbody>
</table>

2 Price paid indexes available only for the years 1924–40.
3 Worksheets, Land and Water Section, Farm Economics Research Division, ARS.

1925–29 and 1935–39 would serve equally well as price-weight periods. The 1925–29 period would be the least representative of the periods tested. Most of the price-index evaluation thus far has been with reference to the 1910–39 period. Essentially the same techniques were applied to several weight periods with reference to the 1940–55 period. Prices for the periods 1935–39, 1946–50, 1947–49, and 1952–54 were tested to determine the representativeness of each to the 1940–55 span of years.

Observations of the movements of prices paid for inputs indicated 1947–49 to be the most representative price-weight period. Although it is slightly high relative to the 1940–55 period, it is not seriously so.

Slightly less emphasis was placed on testing the weight periods for the 1940–55 period because considerable analysis has been previously directed toward this problem. Nevertheless, alternatives were evaluated and price indexes scrutinized to determine the validity of 1947–49 as a price-weight period to be used in the construction of an input index.

Price Level of Inputs

Although price level, as such, would have no effect on the relative magnitude of index numbers, there is ample evidence of association between changes in price level and changes in the relative prices of component inputs. In periods of rapidly changing price levels, either up or down, there is likelihood of greater disequilibrium among component prices than during periods of relative price-level stability. One criterion, therefore, in selecting a price-weight period is to select a period most representative of the level of prices for a span of years or a relatively stable price period. During such a price-level period, the relative prices of inputs will approach the maximum degree of equilibrium attainable in a dynamic setting.

The indexes of prices paid that were used in this analysis includes those for farm labor, farm machinery, motor vehicles, motor supplies, farm supplies, building and fencing materials, fertilizer, feed, and land value per acre.3 Comparison was made of the movements over time of the prices-paid indexes of each individual input. Indexes with bases of both 1925–29=100 and 1935–39=100 were examined.

This simple comparison of indexes lends support to the division of the 1910–55 period into at least two distinct periods, for at approximately 1940 the level of prices swings materially upward as compared with most of the period before 1940. There is also some indication that pre-World War I prices are relatively low for some inputs.

**Evaluation of Weight-Period Testing**

The results of the tests are summarized first with reference to 1910–39 and 1940–55. Then some observations concerning two possible sub-periods, 1910–19 and 1920–39, are presented.

The general conclusions for the period 1910–39 are as follows:

1. Based on an examination of plotted indexes of prices paid for individual selected inputs, 1925–29 or 1935–39 appear to be equally suitable as weight periods.
2. Examination of the ratio of indexes of prices paid for individual inputs to the wage-rate index reveals that 1935–39 price weights are preferable to 1925–29 price weights.
3. The comparison of the average of price indexes of individual inputs for given weight periods to the average

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The conclusion is reached that there are several weight periods that could be used for the 1910–39 period without appreciably affecting the index of aggregate inputs. None of the weight periods is perfect. Indeed none of them could be perfect.

The 1935–39 period has advantages that fall outside the realm of statistical testing. This period was relatively free from major economic influences of war, deep depression, or high inflation. Thus, for the most part, it was free from relative price distortion associated with high and low price-level periods. Much of the basic data needed in constructing indexes are available in terms of 1935–39 dollars. These data materially reduce time and cost considerations. Also of major importance is the fact that the Farm Economics Research Division, Agricultural Research Service index of farm output uses 1935–39 weights for 1910–39. Thus
use of 1935–39 price weights for the input index will facilitate later analysis of changes in the relation of inputs to output.

The general conclusions for the 1940–55 period are as follows:

1. Based only on price indexes of individual inputs, 1947–49 price weights are more representative of the period than are 1935–39 or 1952–54 price weights.


3. Comparing the relative movements of the individual input indexes to the wage-rate index dictates the use of 1947–49 price weights in preference to others.

4. The evaluation of quantity-price aggregates and indexes based on them suggests that 1947–49 and 1952–54 price weights would serve equally well for the composite index for the 1940–55 period. Average 1935–39 weights would not be representative of this period. The 1947–49 weight period would result in the smallest bias in the composite index of inputs.

The conclusion can be reached that 1947–49 is the soundest weight period for 1940–55. It is not perfect, but the degree of its limitations is relatively insignificant for a macro-economic analysis of total agricultural production inputs for 1940–55. The use of 1947–49 price weights will facilitate also input-output analysis as the Farm Economics Research Division, Agricultural Research Service output series uses 1947–49 weights for the 1940–55 period.

It is clear from the preceding analysis that the 1910–55 period should be divided into at least two periods for the purpose of constructing an index of agricultural inputs. There is also some evidence that the 1910–19 period had characteristics that may warrant separating it from the 1920–39
Following are some observations and results of limited testing concerning 1910-14 price weights for the 1910-19 period:

1. The relative degree of mechanization heads the list of major changes between the 1910-19 decade and the years that follow. The introduction of automobiles, motortrucks, and tractors did not reach major proportions in the farming scene until after 1920.

2. The turning point of an era of expansion through adding of acreage, in favor of an era of intensification, was about 1920.

3. The price structure for agriculture in the pre-World War I period, was at a lower level than in the period that followed the war.

4. By testing the effect of different weight periods of the composite index of inputs over the period 1910-19, it was ascertained that a difference of one point would result as between using 1910-14 or 1935-39 price weights.

The evidence presented here is not sufficiently conclusive to warrant a decision as to whether to use 1910-14 price weights for the 1910-19 period or to use 1935-39 price weights for the entire 1910-39 period. The final decision on this period will await further analysis.

Measuring the Relative Influence of Acreage and Yield Changes on Crop Production

By S. M. Sackrin

Agricultural economists and others engaged in agricultural research frequently have occasion to analyze the effect of changes in acreage and yield on crop production. This article describes a method of deriving statistical measures that summarize the relative influence of acreage and yield changes, respectively, on year-to-year variation in production. This method is applied to an analysis of several major crops to illustrate how the effect on production of changes in acreage and yield may be evaluated.

It is axiomatic that the production of any crop is the direct consequence of number of acres harvested and average yield per acre. But frequently the question arises: Are changes in acreage or changes in yield more instrumental in causing variation in production normally experienced from year to year?

Answers to this question have been advanced for corn and wheat. Foote, Klein, and Clough say: "About 80 percent of the year-to-year variation in corn production in the United States during the period 1919-48 resulted from changes in yield per acre." In the case of wheat, Meinken writes: "From 1920 to 1938, changes in wheat acreage had much less effect on production than did changes in yield. Since 1938 the influence of acreage change has almost equaled that of yield."

Foote, Klein, and Clough do not give the full details of their computations, but the relative contribution of changes in corn yields apparently was ascertained as follows:

1. The average year-to-year change in yield (disregarding signs) was expressed as a percentage of the average yield for the period.

2. The average year-to-year change in acreage (disregarding signs) was expressed as a percentage of the average acreage for the period.

3. The two percentages were added. The result obtained in step 1 was then expressed as a percentage of this sum.

Retracing the computations in this way gave a percentage of 83.5, which is presumed to be the approximate 80 percent mentioned by the authors.

Limitations of Methods Previously Used

Although this approach may give a close approximation of the answer sought, its drawback is that it fails to equate strictly changes that take place in acreage and yield with changes in production. In other words, the sum of the results obtained in steps 1 and 2 described above fail to