period. 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 on 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."[1] 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."[2]

[1] Foote, Richard J., Klein, John W., and Clough, Malcolm. THE DEMAND AND PRICE STRUCTURE FOR CORN AND TOTAL FEED CONCENTRATES. U. S. Dept. Agr. Tech. Bull. No. 1061, 79 pp., illus., 1952. p. 14.

[2] Meinken, Kenneth W. THE DEMAND AND PRICE STRUCTURE FOR WHEAT. U. S. Dept. Agr. Tech. Bull. No. 1136, 93 pp., illus. 1955. p. 33. The last year included in Meinken's analysis is 1954.

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 add to the percentage obtained by expressing the average year-to-year change in production as a percentage of average production during the period. The basic reason, of course, is that elements of a multiplicative relationship were added, yielding a final result that is no longer precisely equated.

A similar limitation exists in the approach used by Meinken. In the method he used, the "direct effect of yield" is learned by multiplying the change in yield from one year to the next by the acreage of the earlier year. The "direct effect of acreage" is learned by multiplying the change in acreage from one year to the next by the yield of the earlier year. However, the sum of these direct effects does not exactly equal the actual change in production. The difference is referred to as an "interaction term"—the product of the two changes.

Though the approach used by Meinken also fails to equate directly changes in acreage and yield to changes in production, a useful feature is that the relative contribution of acreage and yield changes to production, year by year, may be evaluated. However, it does not provide summary measures of the relative influence of the production determinants during any specified period, unless the yearly "direct effects" are averaged.

Proposed Computational Method

Such summary measures may be obtained by applying the simple mathematical principle that a multiplicative relationship expressed in natural numbers becomes an additive relationship when expressed in logarithms. Hence, the relationship

$$P = A \times Y$$

where P=production, A=acreage harvested, and Y=average yield per acre becomes

$$\log P = \log A + \log Y \qquad (1)$$

When expressed as first differences of logarithms, to get changes from the preceding year, the equation becomes:

$$\Delta \log P = \Delta \log A + \Delta \log Y \qquad (2)$$

Unlike the two approaches already described, the equality of both sides of the equation is preserved in the sums.

A least-squares regression is computed, with $\Delta \log P$ as the dependent variable X_1, and $\Delta \log A$ and $\Delta \log Y$ as the independent variables X_2 and X_3, respectively. The only statistical coefficients required are—and this is important—b_{21} and b_{31}.[3] Their sum will exactly equal 1.00. The coefficients may be interpreted as follows: On the average, of each 1-percent change in production from the preceding year, — percent is ascribable to X_2 (acreage changes) and — percent is ascribable to X_3 (yield changes). This follows because the coefficient b_{21} measures the change in X_2 associated with a one-unit change in X_1, while the coefficient b_{31} measures the change in X_3 associated with a one-unit change in X_1. As the data are expressed in first differences of logarithms, the unit change involved here is a 1-percent change from the preceding year. This unit change is the exact sum of the changes in the two determining variables, hence the coefficients b_{21} and b_{31} represent the proportion that each comprises of the total.[4]

Comparison of Results Obtained by Alternative Methods

To learn whether results obtained from the three methods differ, each was used in an analysis of the relative influence of acreage and yield changes on

[3] Although equation (2) implies that we desire net regression coefficients on acreage and yield, for the purpose in hand we are interested only in the simple regression coefficients b_{21} and b_{31}. The net regression coefficients $b_{12.3}$ and $b_{13.2}$ will, of course, each be 1.00, as the unit change in production will exactly equal the unit change in either independent variable, with one independent variable held constant.

[4] This approach is basically a variation of that described by Foote and Fox to analyze the effects of changes in production on the alternative outlets—domestic consumption, net exports, and net changes in stocks. (FOOTE, RICHARD J., AND FOX, KARL A. ANALYTICAL TOOLS FOR MEASURING DEMAND. U. S. Dept. Agr. Agr. Handb. 64, 86 pp., illus., 1954. p. 8). Foote and Fox suggest a series of simple least-squares regressions with production the independent variable, and each outlet as dependent variables. Because this formulation places production on the right side of the equality sign, the coefficient b_{12} is the meaningful measure, and their sum will equal 1.00, as the authors point out. The method proposed here modifies this approach by (1) using a logarithmic formulation to convert a multiplicative relationship to an additive one, and (2) treating production as the dependent variable in a three-variable regression analysis, and considering the simple coefficients b_{21} and b_{31} (which are equivalent to the individual b_{12}'s derived in the Foote-Fox approach).

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TABLE 1.—*Relative effects of changes in acreage and yield on year-to-year changes in production of flue-cured and burley tobacco, 1944–56, as computed by alternative methods*

Method [1]	Percentage of year-to-year variation in production ascribable to—			
	Acreage changes		Yield changes	
	Flue-cured	Burley	Flue-cured	Burley
	Percent	*Percent*	*Percent*	*Percent*
1	60	49	40	51
2	59	48	41	52
3	80	56	20	44

[1] See text for explanation of methods.

year-to-year variation in the production of flue-cured and burley tobacco during the period 1944–56. Designating the method used by Foote, Klein, and Clough as Method 1, that used by Meinken as Method 2, and that proposed here as Method 3, the results were as shown in table 1.[5]

This comparison indicates that use of Methods 1 and 2 yield similar results, but they differ substantially from those obtained from Method 3. In this particular instance, Methods 1 and 2 fail to indicate the predominant influence of acreage changes on burley production during this period, and understate the influence of acreage changes on flue-cured production.

As a further test, an analysis was made of the relative influence of changes in acreage and yield on potato production during the period 1940–55. Use of Methods 1 and 2 gave similar results, but although they indicated the predominant influence of acreage changes, they attributed 58 to 61 percent of total year-to-year variation in production to that source, compared with 67 percent for Method 3.

[5] Meinken does not give summary measures for the entire period reviewed, but presents a chart showing the "direct effects" of acreage and yield changes year by year. In the illustration discussed here, the following computations were made to obtain summary measures which can be compared with those yielded by the other methods considered: (1) The "direct" effects of each were averaged for the period, disregarding direction of change. (2) The average "direct effect of acreage" and the average "direct effect of yield" were then each expressed as a percentage of their sum.

TABLE 2.—*Relative effects of year-to-year changes in acreage and yield on year-to-year changes in production of specified crops, 1921–56*

Crop	Period			
	1921–38		1939–56	
	Effect of acreage changes	Effect of yield changes	Effect of acreage changes	Effect of yield changes
	Percent	*Percent*	*Percent*	*Percent*
Wheat	42	58	64	36
Cotton	39	61	71	29
Soybeans [1]	[2] 73	[2] 27	61	39

[1] For beans.
[2] Period considered is 1925–38.

From this, the conclusion would appear to be as follows: Use of Methods 1 or 2 may give a quick approximation of the relative influence of acreage and yield changes on production, but there is a danger that they may erroneously indicate a factor as the more influential one. If the analyst wishes a more precise delineation of the relative contribution of each of the two determinants to production changes, the additional work entailed in Method 3 would appear to be justified.[6] But it should be remembered that this method gives the *average* relative contribution of acreage changes and yield changes to year-to-year variation in production. If extreme changes occur in a few years included in the period, the coefficients obtained are affected accordingly. For example, an analysis of the two determinants in burley tobacco production for the period 1944–54 showed that 53 percent of the year-to-year variation in output was attributable to yield changes and 47 percent to acreage changes. If the period 1944–56

[6] Much of the computational labor consists of obtaining the logarithms and computing the first differences. After the first differences of logarithms are determined and balanced, the coefficients may be obtained as follows:

$$b_{21}=\frac{\Sigma x_1x_2}{\Sigma x_1^2} \text{ where } \Sigma x_1x_2=\Sigma X_1X_2-\overline{X}_2\Sigma X_1 \text{ and}$$

$$\Sigma x_1^2=\Sigma X_1^2-\overline{X}_1\Sigma X_1$$

$$b_{31}=\frac{\Sigma x_1x_3}{\Sigma x_1^2} \text{ where } \Sigma x_1x_3=\Sigma X_1X_3-\overline{X}_3\Sigma X_1$$

It will be noted that $\Sigma x_1^2=\Sigma x_1x_2+\Sigma x_1x_3$.

is considered, however, the measures of relative contribution change to 56 percent for acreage changes and 44 percent for yield changes. The reason is that, owing to a sharp cut in allotments in 1955, harvested acreage dropped from 421,000 to 311,000 acres, a decline of 26 percent. Average yield per acre changed only 5 percent, declining from 1,586 pounds to 1,513 pounds.

Illustration of Use of Proposed Method

Method 3 was used to ascertain the relative effects of acreage and yield changes on year-to-year changes in production of cotton, wheat, and soybeans during the periods 1921–38 and 1939–56. The crops and the periods were selected to illustrate application of the proposed computational method; analysts who are working in these commodity areas may wish to examine other periods. Results of the analysis are shown in table 2.

Results for wheat confirm Meinken's finding that yield changes exerted the predominant influence on yearly changes in production in the period 1920–38. For the period following 1938, however, results show a greater influence of acreage changes than was found by Meinken, probably because of inclusion of 1955, when harvested acreage declined substantially from the previous year.

The analysis of cotton showed that in the period 1921–38 approximately 60 percent of the annual changes in production was attributable to changes in yield. In 1939–56, this contribution dropped to about 30 percent, whereas that of acreage changes rose to about 70 percent. During the more recent period, there were sharp fluctuations in harvested acreage of cotton, particularly in 1947, 1949, 1950, 1951, and 1954, when annual changes ranged from 20 to more than 50 percent. These sharp changes were chiefly the result of a postwar expansion in acreage and the operation of acreage controls in 4 of the 7 years 1950–56.

In the case of soybeans, the analysis showed that in both periods acreage changes were the predominant influence on changes in yearly production, but that the relative contribution of changes in yield was greater in the more recent period than in the earlier one.

Preliminary Report on Objective Procedures for Soybean Yield Forecasts

By Bruce W. Kelly

As part of its expanded research program, the Agricultural Estimates Division of AMS is exploring the possibilities of objective forecasts of yield for several crops. This paper summarizes results obtained from the first year's work on soybeans. Although these results must be regarded as tentative until more data become available, they nevertheless illustrate how the problem is being attacked.

TO DEVELOP TECHNIQUES for forecasting the yield of a crop, it is convenient to study individual components of yield separately. In our study of soybeans, the components considered were the number of plants per acre, the number of pods per plant, and the weight of beans per pod.

This preliminary report is restricted to forecasting the number of pods per plant that will reach maturity and be present on the plants at harvest time, based on 1956 data. As the number of plants per acre can be estimated from sample plots within fields, this is equivalent to forecasting the number of pods per acre.

As for cotton, a forecast made early in the season must allow for fruit not yet on the plants.[1] This is the situation with soybeans on August 1, which is the earliest forecast date considered here. The general approach used in this study was the same as for cotton—namely, to count the pods already present on August 1 and to seek an observable syndrome of plant characteristics that indicates what fraction of a 100-percent load is represented by that count. Again, as with cotton, all pods that will contribute to the final yield have

[1] See HENDRICKS, WALTER A., and HUDDLESTON, HAROLD F. OBJECTIVE ESTIMATES OF COTTON YIELD. Agricultural Economics Research. 9:20–25. 1957.