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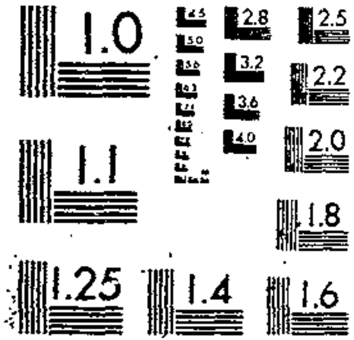

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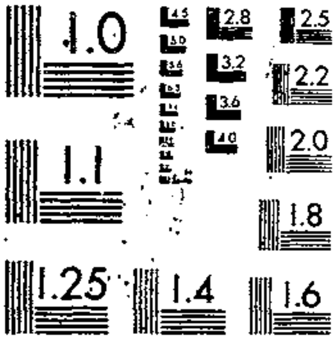

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MEASUREMENT OF U.S. AGRICULTURAL PRODUCTIVITY:

A Review of Current Statistics and Proposals for Change

U.S. Department of Agriculture
Economics, Statistics, and Cooperatives Service

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ABSTRACT

This report reviews the concept and measurement of agricultural productivity with special references to USDA multifactor productivity statistics. An American Agricultural Economics Association task force has examined the sources and procedures used in constructing the existing statistics and recommends that USDA: (1) place greater emphasis on improving methodology; (2) move further toward a complete factor productivity measure; (3) replace the requirements approach by direct sampling in constructing the labor input; (4) use the product approach in defining the agricultural sector; (5) improve accounting for quality change in inputs; and (6) adopt a series of specific improvements for constructing specific inputs and aggregating procedures.

Keywords: Agricultural productivity, Index numbers, Efficiency, Inputs, Outputs.

PREFACE

This report was prepared by the American Agricultural Economics Association (AAEA) Task Force on Measuring Agricultural Productivity in 1978, under the joint auspices of the AAEA economic statistics committee and the Economics, Statistics, and Cooperatives Service (ESCS), U.S. Department of Agriculture. Members of the task force were: Bruce Gardner (chairman), Donald Durost, William Lin, Yao-Chi Lu, Glenn Nelson, and Norman Whittlesey. The task force included faculty members of land-grant universities and ESCS staff economists. The task force would like to acknowledge the comments and advice of Sharon De Sha, Folke Dovring, Lyle Fettig, Ian Furniss, Zvi Griliches, Wallace Huffman, David Kincannon, John Lee, Willis Peterson, Vernon Ruttan, Earl Swanson, and Luther Tweeten.

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SUMMARY

Productivity statistics have been construed to mean several things and have been measured in a variety of ways. The two major methods of measuring productivity are partial and multifactor productivity indexes. Partial productivity relates output to a single input. Partial productivity measures are widely cited but have serious limitations and can be misleading in some uses. The most important uses of productivity statistics are: (1) identifying the sources of economic growth, (2) justifying the appropriation of agricultural research funds, (3) estimating production relationships, (4) serving as an indicator of technical changes, (5) comparing intersectoral economic performance, and (6) justifying price changes. In some of these uses, the available USDA statistics will not bear the weight sometimes put upon them.

The AAEA task force recommends changes in both conceptual and practical measurement areas. The most important are to move further toward a total factor productivity measure; to handle hired, operator, and family labor separately; to use the product approach in defining the agricultural sector; and to account for quality change in inputs. The task force has made the following recommendations on specific techniques in measuring productivity:

- Use a Divisia index to aggregate inputs.
- Use direct sampling instead of the "requirements" approach to construct the labor inputs.
- Adjust the procedures for converting land stock to a service flow.
- Improve statistical data on stocks of machinery and equipment.
- Adopt better procedures to depreciate structures and machinery.
- Use Bureau of Labor Statistics price indexes for machinery to construct farm machinery input indexes.
- Adopt a series of further detailed recommendations on specific items.

MEASUREMENT OF U.S. AGRICULTURAL PRODUCTIVITY:

A Review of Current Statistics and Proposals for Change

INTRODUCTION

U.S. agricultural productivity has increased in recent decades. But what is meant by productivity, and how is it measured? To some users, it is output per man-hour; to others, it is crop production per acre; and still to others, it is output per unit of total inputs used in production. Because of this diversity of definitions, economists, politicians, journalists, and others are solicited for broad and differing generalizations on American agriculture. In such statements, the factual basis for judging productivity tends to be taken for granted or passed over lightly. The purpose of this investigation, under the auspices of the Economic Statistics Committee of the American Agricultural Economics Association (AAEA), is to assess the U.S. Department of Agriculture's (USDA) current capability to measure the productivity of U.S. agriculture and to recommend such conceptual and statistical improvements as seem warranted.

DEFINING TERMS

The AAEA task force has undertaken to examine the sources and procedures used in constructing the existing statistics on agricultural productivity to determine what could and could not be inferred from the existing statistics; to decide how we would like to see agricultural productivity measured ideally; and to recommend practicable changes to improve its measurement. Because the major effort in measuring U.S. agricultural productivity is conducted by USDA's Economics, Statistics, and Cooperatives Services (ESCS), we also considered more narrowly the strengths and weaknesses of existing ESCS approaches.

The task force limited its efforts to productivity measurement in the agricultural production sector, because of the difficulties which immediately became apparent in treating these issues adequately. The area covered centers roughly on the economic activity described by USDA's statistics published annually in *Changes in Farm Production and Efficiency (12)*.[1]

This report goes into considerable detail on the theory and practice of productivity measurement. Readers familiar with the basic issues may wish to turn directly to the sections that focus on the problem areas in the existing USDA productivity statistics and the task force's recommendations for improvement. Earlier sections are intended to provide supporting material for our assessment. The task force thought it worthwhile to spend substantial space on the meaning and proper use of productivity statistics because, as it seems to us, inappropriate use of productivity statistics is currently an even greater problem than deficiencies in the reliability of the available measures.

Productivity is one of those terms that we tend to feel free to use without explicit definition, as if its meaning were intuitively obvious. Most people know that productivity has to do with the ratios of outputs to inputs. Numbers available on outputs relative to inputs generally show increasing trends and compare favorably with similar statistics for other countries, and so we refer to U.S. agriculture as being productive in these terms. Problems arise, however, as one goes further in drawing implications from productivity statistics. Recently, many have observed a decline in the

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[1] Italicized numbers in parentheses cite references listed at the end of the report.

rate of increase of measured productivity, challenging one to look at the statistics more carefully. Then it is found that there are many ways to construct ratios of outputs to inputs, not all of which tell the same story. There are problems both at the conceptual level—how productivity ought ideally to be measured—and at the practical level of obtaining data—how to measure reliably the conceptually appropriate variables. Some of these problems have concerned agricultural economists since USDA began publishing productivity measures in the fifties.

Many of the main problems were addressed in Loomis and Barton, Griliches, and Barton and Durost (*33, 17, 2*) in the early sixties. Since that time, the issues have been reviewed, clarified, and augmented in Griliches; Lambert; Fettig; the National Academy of Sciences—NAS; Christensen; Lu; Penson, Hughes, and Nelson; and Johnson (*20, 30, 14, 37, 5, 39, 34, 24*). Generally speaking, the points raised concern: (1) obtaining appropriate measures of inputs used, thought to be an especially serious problem for labor and capital services; (2) capturing changes in quality of inputs; and (3) obtaining appropriate weights on input and output categories and keeping weights updated. More recent interest has been triggered by a decline in the rate of growth of some productivity measures beginning in the sixties. This apparent decline gave new importance to the questions of whether productivity was accurately measured and what the statistics meant.

The testimony given by the official statistics is not unambiguous. The USDA multifactor productivity indexes published in 1979 are: 1978, 118; 1970, 102; and 1950, 71. This implies an instantaneously compounded growth rate of 1.8 percent between 1950 and 1970 and 2.1 percent between 1970 and 1978. However, to show the importance of choice of period for comparison the growth rate was 2.3 percent between 1950 and 1965, and 1.4 percent between 1965 and 1977. Thus, a judicious choice of periods can show either an increase or a decrease in productivity growth rates. Swanson provides further evidence that the USDA statistics do not imply a slowdown in productivity growth as clearly as some have supposed (*52*). The USDA statistics are shown in figure 1.

Were the discussion of interest only in academic circles, the best course might be to let each economist decide how productivity ought to be measured and what the existing productivity statistics reveal. A consensus of some sort becomes important, however, when public choices (and associated funds from the U.S. Treasury) depend importantly on the issue. The citation of trends in measured productivity in support of policy proposals is a major reason for investigating carefully the meaning of these statistics.

MEANING AND PURPOSE OF PRODUCTIVITY MEASURES

The agricultural sector in any given year makes use of certain quantities of service flows from scarce resources. There results a corresponding flow of agricultural output. The question, which leads to the measurement of productivity, is how much output is obtained from the resources committed? The primary purpose of a productivity measure is to answer this question by means of a number, a score by which different times, places, and sectors may be compared. Productivity statistics naturally have the characteristics of a performance measure. Among the many conceptual issues that arise with respect to productivity statistics, perhaps the most difficult from the point of view of the general public's understanding is the distinction between a technical and an economic performance measure.

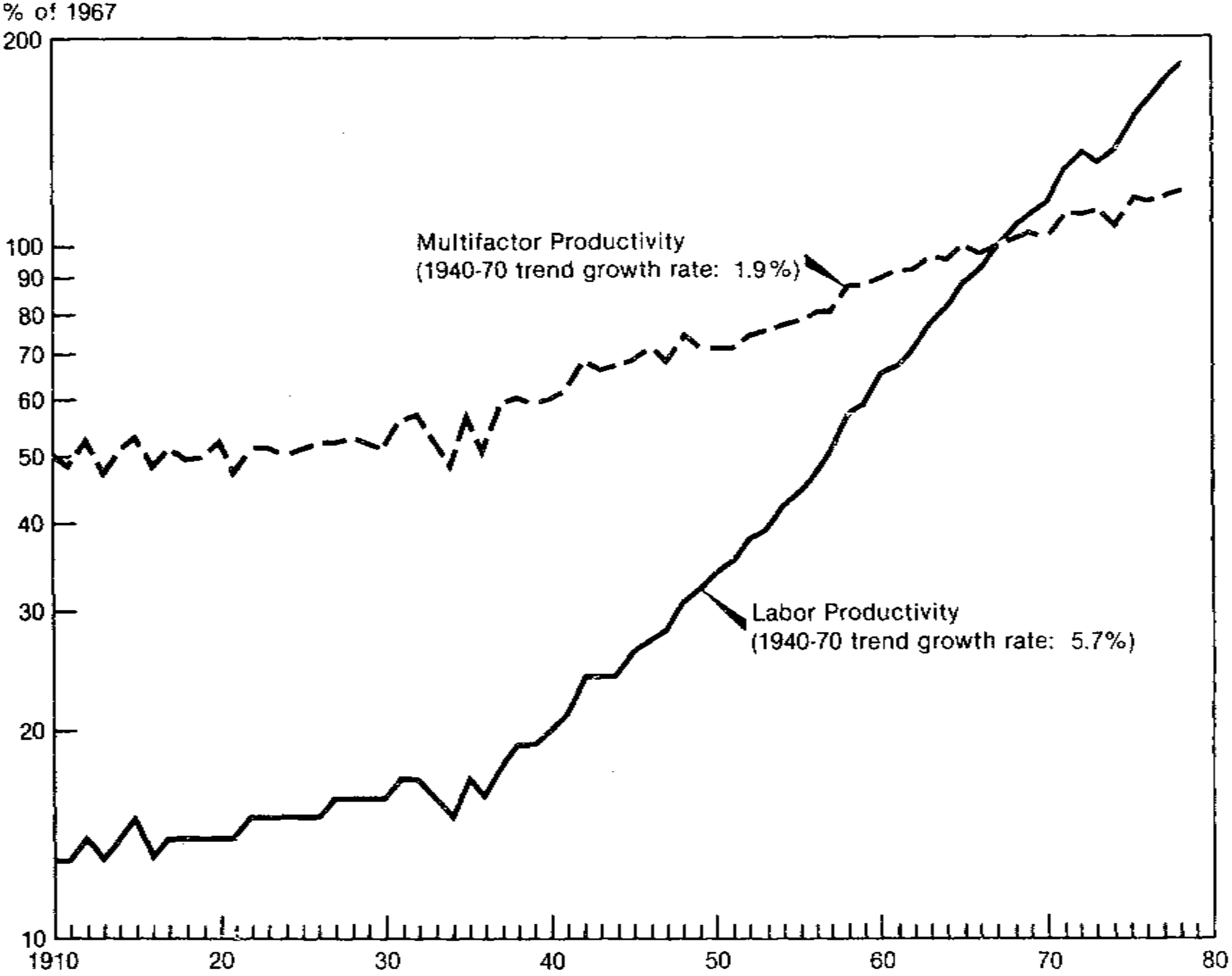
Concurrently, with the work of the AAEA task force, a substantially larger effort on productivity in the U.S. economy as a whole was carried out under the auspices of the National Academy of Sciences (NAS). The reader is referred to the NAS report for discussion of many general issues in productivity measurement. Unfortunately, however, some of the most vexing conceptual issues in agricultural productivity measurement are not resolved, at least not sufficiently for our purposes, in the NAS study. Before moving to specific problems, two general issues in the meaning of productivity statistics which tend to cause confusion will be discussed—first, the relationship between productivity and the theory of production, and second, the relationship between productivity and efficiency.

Productivity Measurement and the Theory of Production

Productivity is measured by an index of output quantities divided by input quantities. Many

Figure 1

USDA Productivity Indexes



Source: *Changes in Farm Production and Efficiency*, 1977, tables 44 and 67.

alternative indexes are possible because there are several different ways to measure outputs and inputs and to aggregate output and input categories. Supposing for the moment that measurement and aggregation on the output side are satisfactorily accomplished, there are two main types of commonly used productivity measures, distinguished by their handling of inputs—partial productivity and multifactor productivity. The ratio of output to quantity of a single input is called the partial productivity of that input and the ratio of output to all inputs combined is called total factor or multifactor productivity. Although the term "total" is more often used than "multifactor", the latter term is perferred, especially when considering empirical work, because any feasible productivity statistic will exclude some nonconventional inputs and hence be less than total.

Since partial productivity relates output to a single input, many partial productivity measures can be constructed, such as labor productivity, capital productivity, or land productivity. The most important and commonly used partial productivity measure in the nonfarm economy is labor productivity. In agriculture, this conception lies behind such statistics as "how many people a farmer can support"; for example, in the comparison that 35 years ago an American farmer produced enough food for 11 people, while today one farmer produces enough food for 65 people—47 at home and 18 abroad.

Labor productivity is the average product of labor in the terminology of production economics. It is a popular measure of productivity because labor is an important factor of production, estimates of man-hours are regularly calculated, and this partial productivity index is easy to compute and comprehend. Indeed, labor productivity is the standard measure of productivity in U.S. manufacturing and has been used for such purposes as deciding which product price increases are justifiable under formal anti-inflation programs.

While labor productivity may be a useful index, its uses are severely limited. It can be a meaningful performance measure if labor is the dominant fraction of total inputs or if the amount of other resources used remains unchanged. These conditions may not be a bad approximation for short-run changes in manufacturing. In agriculture, however, while labor constitutes a substantial fraction of total inputs in production, other inputs are considerably more important. Also, the amounts of nonlabor resources used have changed substantially over time, and their changes are not taken into account in computing the labor productivity index. Therefore, labor productivity does not measure output obtained from given resources, nor does it measure the attributes of labor as a productive resource, because higher output per man-hour can be achieved by increasing use of machinery, fertilizer, and other capital equipment.

These limitations are recognized by sophisticated users of labor productivity statistics in the nonfarm economy; for example, Clark and McCarthy explained the decline in measured U.S. aggregate labor productivity between the mid-1960's and the mid-1970's by means of changes in the ratio of capital to labor (*7, 35*). Because of these shortcomings a multifactor approach is generally preferable when measuring productivity. Figure 1 shows the indexes of labor and multifactor productivity in U.S. agriculture as estimated by USDA.

Other partial productivity measures such as yield per acre, pigs per litter, or pounds of gain per pound of feed are sometimes computed and cited for one purpose or another. While useful in some contexts, they are subject to the same limitations as noted for labor productivity. An attempt to use any one of them would actually be counterproductive, and indeed, may lead to contradiction; for example, milk produced per pound of feed is incompatible with milk produced per cow. Particularly widely cited in recent years, and particularly liable to misuse, are partial productivity measures based on energy; for example: "It appears that there is something seriously wrong with the American agricultural system. Since 1910, United States agricultural efficiency, as measured in energy, has decreased 10-fold."[2]

The economic theory of production is helpful in conveying a more exact understanding of the deficiencies of partial productivity measures. It leads us immediately to suspect, for example, that an important reason why labor productivity increases so much more rapidly than multifactor productivity (figure 1) is the historical increase in nonlabor inputs per man-hour in agriculture. If the production function is known, we can even calcu-

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[2] C. Lerza, "Emptying the Cornucopia," in *Food for People, Not for Profit*, New York: Ballantine Books, 1975, p. 48.

late how much measured labor productivity would change with a given change in the input mix without any change in the production function.

In general, the theory of production is an aid in looking for two types of error—a "type 1" error in which productivity changes but our index fails to measure the change properly, and a "type 2" error in which productivity does not change but our index does. Common instances of the second type of error can be avoided by using a multifactor rather than a partial productivity index. However, multifactor productivity measurement also involves problems on which the theory of production can aid our understanding, as discussed in the following paragraphs.

Index Number Problems

A major difficulty in computing multifactor productivity is constructing an aggregate input index. Disparate quantities such as hours of work, acres of land, pounds of fertilizer, and numbers of tractors are combined to produce a single aggregate input measure. Monetary value is a natural common unit of input measure for purposes of aggregation. Unfortunately, the use of money as a measuring rod cannot remedy problems in computing multifactor productivity. The inputs must be weighted to combine them for an aggregate, and no weighting scheme is faultless.

Consider an example in the production of poultry products. Let the quantities of output and inputs be as follows:

	Output	*Labor*	*Nonlabor services input*
	Index	*Million hours*	*Index*
1950	57	1,161	60
1975	98	249	110

The output and labor input are from the USDA publication, *Changes in Farm Production and Efficiency, 1977,* tables 1 and 32 (*12*). The nonlabor input quantity is a rough guess. The first step in the construction of a multifactor productivity index is to obtain an index of total input. A natural procedure is to use price weights to convert both inputs to dollars, add them up, and normalize on a base year (=100) to obtain an index. The 1950 wage rate is $0.60 per hour, and the price per index unit of nonlabor is $60. Then the input index value for 1950 is:

$$1161 \times \$0.60 + 60 \times \$60 = \$4{,}296.60 \longrightarrow \mathit{100.}$$

Using the same price weights to obtain a total input quantity index for 1975:

$$246 \times \$0.60 + 110 \times \$60 = \$6{,}749.40 \longrightarrow \mathit{157.}$$

Thus, we would say that input quantities in poultry production have increased roughly 57 percent between 1950 and 1975. We divide output by inputs in each year to estimate multifactor productivity:

1950 $57/100 = 0.57 \longrightarrow \mathit{100.}$
1975 $98/157 = 0.62 \longrightarrow \mathit{109.}$

Productivity has increased roughly 9 percent.

However, between 1950 and 1975, the relative prices of labor and nonlabor inputs changed dramatically. Suppose the price of labor was $2.50 per hour in 1975 and the price index of nonlabor inputs $120 per unit. Why not use the 1975 price weights for both periods? Use of this base period yields the following indexes of total input:

1950 $1161 \times \$2.50 + 60 \times \$120 = \$10{,}102 \rightarrow \mathit{100}$
1975 $249 \times \$2.50 + 110 \times \$120 = \$13{,}822 \rightarrow \mathit{137}$

This total input index yields multifactor productivity indexes as follows:

1950 $57/100 = 0.57 \longrightarrow \mathit{100}$
1975 $98/137 = 0.72 \longrightarrow \mathit{126}$

Productivity has increased roughly 26 percent.

Simply by changing the weights used in aggregation of inputs in this hypothetical but not implausible example, we change the rate of measured productivity growth by a factor of 2½. The disturbing aspect of this result is that of the two productivity indexes, the first using a Laspeyres index of inputs and the second a Paasche index, there are no objective grounds for choosing between them. The question of how best to proceed in this kind of situation is taken up in the following section.

The Production Function Approach

Some have attempted to evade index number problems by basing a productivity measure directly on the production function. In this context, changes in multifactor productivity are defined as shifts in the production function. Thus, if the form of the production function is fully specified and this function can be observed at different times, productivity changes may be measured as the change in a shift parameter in the production function over time (*3, 26*).

Unfortunately, not every plausible shift of a production function permits representation by means of a single statistic. The popular Cobb-Douglas, or constant elasticity of substitution (CES) production functions, contains shift terms which can be used to represent productivity change, but they may not accurately depict the production technology. Attempts have been made to specify more generalized production functions such as the variable elasticity of substitution (VES) production function (*34*); generalized power production function (*64, 57*); homothetic production function (*36, 44, 65*) and transcendental logarithmic production function (*6*). Each functional form has contributed to the study of production, but they all possess limitations in the study of productivity change. Some, like the VES, can be readily estimated for only two inputs. Production functions that can be estimated with more than two input variables often involve interaction terms which cause the number of terms in the function to multiply exponentially as the number of input variables increases. Consequently, estimation becomes difficult.

There remain problems even if the production function form can be correctly specified. The coefficients of inputs in the production function represent a given state of technology. As technological changes take place, these coefficients will also change, unless technical change happens to be factor-neutral. Thus, it is difficult to capture all relevant shifts of the production function by means of a single parameter. Finally, we frequently compare productivities in different time periods in which equilibrium (value of the marginal products of inputs is equal to input prices) does not exist. Thus, more output may be obtained from given inputs even without a shift in the production function.

Therefore, for practical purposes, the production function is not a suitable device for directly measuring U.S. agricultural productivity. This conclusion should not deter analysts from continued study of this topic, however, because their results are a useful check on other measures and may ultimately lead to improved empirically applicable productivity measures.

Index Numbers and Production Theory

While production functions may not be usable directly, production theory is helpful in the choice of index numbers. It helps in determining the appropriate method of aggregating inputs by increasing the understanding of the sources of error in alternative approaches.

Let the production function be:

$$(1) \qquad Q = f(L,K),$$

where Q, L, K are the quantities of output, labor, and capital per unit time. Capital means everything other than labor. This approach may be readily extended to more inputs but uses only two inputs for simplicity. The per-unit-time qualification is important to keep in mind because it implies that we want service flows of capital inputs, not stocks. If the production function has constant returns to scale, then:

$$(2) \qquad Q = f_L L + f_K K,$$

where f_L and f_K are the marginal products of labor and capital. Multiplying both sides by the price of output P yields $PQ = Pf_L L + Pf_K K$, or:

$$(3) \qquad V = VMP_L L + VMP_K K,$$

where V is the value of output and VMP is the value of marginal product. If the industry is operating competitively and is in equilibrium, the factors of production are paid the values of their marginal products; that is:

$$(4) \qquad VMP_K = r,$$
$$(5) \qquad VMP_L = w,$$

where r is the rental price of capital and w is the wage rate. Equation (3) then can be rewritten as:

$$(6) \qquad V = rK + wL.$$

Equation (6) is the formula used to aggregate inputs in computing the arithmetic multifactor input index. Therefore, arithmetic aggregation with factor prices as weights exhibits an inherent congruence with production theory.

However, difficulties arise when two periods must be compared between which relative factor prices have changed. Then the problem arises as to which of the two price-weights is best. As in the poultry example, the choice makes a difference in measured productivity; two answers are obtained to the same question, neither of which can be said better than the other.

Can production theory help out in this situation? Yes, at least partially, by indicating limiting cases in which productivity can be measured unambiguously, even when relative prices change; for example, if the production function has zero elasticity of substitution, that is, fixed coefficients relating each input to output, then arithmetic aggregation is appropriate, even if factor prices change. A second example arises from the Cobb-Douglas production function. Equilibrium conditions (4) and (5) imply that the coefficients on the input quantities are factor shares. Therefore, a geometric index of aggregate inputs, which combines inputs L and K as:

$$Q_I = L^{S_L} \cdot K^{S_K},$$

is a natural and unambiguous means of aggregation when production is Cobb-Douglas.

Solow used the geometric approach in a study of technical change in the United States for the 1909-49 period (*49*). Ruttan, Chandler, Lave, and Nevel have used the geometric approach in studies of technical change in U.S. agriculture (*42, 4, 31, 38*). Nonetheless, whether arithmetic or geometric indexes are preferable in practice has not been definitively resolved. Kendrick and Kleiman, Halevi, and Levhari conclude that the arithmetic index is preferable to the geometric index (*28, 29*). In addition to some technical advantages, the arithmetic index is simple to calculate and easy to understand. Moreover, it is used to measure productivity in nonagricultural industries. Use of the same measure makes agricultural productivity more easily comparable with statistics for other industries. The official USDA agricultural productivity index has also been computed with a Laspeyres arithmetic formula since the Loomis and Barton study on the productivity of U.S. agriculture (*33*). Other studies of U.S. agriculture using the arithmetic index include Barton and Cooper, Ruttan, Schultz, and Kendrick (*1, 42, 43, 46, 27, 28*).

Neither fixed coefficient nor Cobb-Douglas production functions are likely to be the correct specification, so the bias due to changing relative prices remains a serious concern with either an arithmetic or a geometric index. Three practical proposals have been made to minimize bias in a practical setting, the first two of which go back at least to Fisher (*15*). First, change weights frequently. Second, use an average of the weights for any two-period comparison. Third, use a Divisia index.

Frequent change of weights can avoid comparisons of two periods with wide price changes and thus reduce the bias. Barzel found that by changing weights every year instead of using one set of weights for the whole period, the spread between the Paasche and the Laspeyres indexes (which is used to measure the bias) was reduced from 19 percent to 13 percent in the data (*3*). Changes in weights are awkward because they require a chain-link construction of the time series of input and output indexes. One constructs a series of changes and from these reconstructs index-number levels, instead of initially constructing a time series of index-number levels. Nonetheless, because the biases can become large in instances like the preceding poultry example, the chain-link approach seems clearly the preferable approach. Currently, the USDA productivity series uses four sets of weights in its Laspeyres arithmetic index, linked at 1939, 1955, and 1965 (table 1).

Crossed-weight formulae were suggested by Irving Fisher as an ideal resolution of the problem of bias in fixed weights, although he was well aware that the results are not necessarily unbiased (*15*, p. 360). The Fisher index is the geometric mean of the Laspeyres and Paasche indexes. Rather than using the base period weights (Laspeyres) or the comparison period weights (Paasche), the Fisher index uses an average of weights in the base period and the comparison period. Diewert put forth several technical arguments in favor of Fisher Ideal index numbers (*8*). However, the fact that the Fisher index averages two opposite biases from the Laspeyres and Paasche indexes does not guarantee that it provides accurate answers.

An approach that recently has received considerable attention is the Divisia index. The Divisia index is a weighted sum of growth rates, where the weights are the input component's shares in the total value of inputs used. The Divisia index is consistent with a wider variety of production functions than either the arithmetic or geometric indexes. It is an exact specification for the homogeneous translog production function (*5*). This means basically that a Divisia index does not imply restrictions on the substitution possibilities as is done, for example, in the CES production function.

The Divisia index approach has been recommended by Jorgenson and Griliches and its properties spelled out by Hulten (*26, 23*). Unfortunately, some of the desirable properties depend on its being specified in continuous-time form. In a discrete-time approximation, the factor-share

Table 1—Percentage distribution of farm inputs

Year	Labor	Farm real estate	Machinery	Agricultural chemicals	Feed, seed, and livestock purchases	Taxes and interest	Miscellaneous
				Percentage of total			
				1935-39 weights			
1910	53.4	20.2	8.5	1.7	3.2	8.3	4.7
1915	51.6	19.8	9.8	1.6	3.0	9.3	4.9
1920	50.0	18.5	11.8	2.1	3.9	8.8	4.9
1925	48.9	17.8	12.0	2.3	4.6	9.7	4.7
1930	46.2	17.7	14.1	2.8	4.4	10.4	4.4
1935	47.0	19.2	12.9	2.7	4.1	9.7	4.4
1939	42.8	18.4	14.7	3.4	6.2	10.3	4.2
				1947-49 weights			
1939	54.4	17.0	10.1	1.9	6.5	7.0	3.1
1945	48.0	15.8	14.3	3.2	8.2	7.4	3.1
1950	38.1	16.7	20.3	4.7	9.4	7.5	3.3
1955	32.0	16.4	23.3	6.2	10.7	7.9	3.5
				1957-59 weights			
1955	32.2	19.4	24.0	4.4	9.0	7.7	3.2
1960	26.5	19.4	25.0	5.8	10.9	8.6	3.8
1965	20.4	19.7	24.9	9.1	12.5	9.4	4.0
				1965-69 weights			
1965	23.2	23.6	26.8	5.3	6.7	10.8	3.5
1970	19.0	23.0	28.3	8.0	7.4	10.8	3.5
1975	16.7	21.8	31.5	8.8	7.1	10.8	3.3
1976	16.0	21.6	31.3	9.6	7.4	10.5	3.6

weights may change. Of the many ways to approximate the Divisia index in discrete time, the most widely used is the weighted log-change index:

$$\ln (Q_I - Q_{It}) = \sum_i W_i \ln (q_i - q_{it}),$$

where:

$\ln (Q_I - Q_{It})$ is the rate of change of the aggregate quantity index,

$\ln (q_i - q_{it})$ is the rate of change of the output or input components, and

W_i are the relative value shares of each component ($\sum W_i = 1$).

The W_i are calculated by applying the Fisher cross-weight approach, being the mean of base- and current-period shares. This approach is recommended for agriculture by Christensen, and its general use defended by Jorgenson and Griliches, who cite evidence that the cross-weight approximation is unlikely to cause serious problems (*25*).

Nonetheless, current-year weights are expensive to generate and are strongly subject to revision, so almost all official productivity measures are Laspeyres indexes. The problems created by the base-period weights in the context of U.S. agriculture are discussed in detail in a later section.

Productivity and Efficiency

Efficiency in its broad economic sense is usually taken to refer to the value of output from resources of given value. Efficiency refers to the attainment of equality between ratios of marginal products and corresponding factor price ratios in a commonly used narrower sense of the term. Productivity differs in that it refers to relationships among physical units.

The pitfalls of identifying efficiency with physical relationships are illustrated by the standard examples that a motorcycle is not necessarily more efficient than an automobile because it goes farther per gallon of gasoline, or that the supersonic transport (SST) is not necessarily more efficient than a subsonic jet because it gets one to Europe twice as fast. Moreover, economic efficiency in its narrower sense of meeting all the appropriate marginal conditions is not the same thing as productivity. The contrast is most clearly brought out by Schultz (*45*). One of his central points is that efficiency is a characteristic of poor countries in which productivity is stagnant; whereas, tests for allocative efficiency typically fail in an agricultural sector where productivity is growing.

The point here is to recognize possible sources of confusion and not to legislate definitions of productivity and efficiency. It is possible to define efficiency in such a way that it is equivalent to productivity; for example, Kendrick defines "changes in total factor productivity as changes in productive efficiency (*27*)." Fabricant defines productivity as "a measure of the efficiency with which resources are converted into the commodities and services that men want (*13*, p. 1)." He explains that:

> We can become more (or less) efficient in the use of a particular type of resource, say, plant and equipment, as well as of resources taken as a whole. A given volume of products might be obtained from a smaller amount of plant and equipment, used in conjunction with an unchanged amount of labor, land, inventory, and other resources. This would be a real gain. It would be proper to consider it the result of increase in efficiency; and we could measure the increase in efficiency by calculating the ratio of an index of physical output to an index of the volume of plant and equipment. We could also refer to this ratio as a productivity index.

Some aspects of the relationship between productivity and efficiency can be clarified with reference to the isoquants (labeled with Q's) in figure 2. Figure 2 divides agricultural inputs into two classes, capital and labor, although this particular dichotomy is not necessary to the argument. The points on each isoquant represent the combinations of capital and labor which yield a specified output level. Each isocost line (labeled with a C) represents the combinations of capital and labor which may be purchased for a specified cost. A profit-maximizing firm, or a sector consisting of profit-maximizing firms, will desire to operate at a point of tangency between an isoquant and an isocost line.

Assume that a given production function yields isoquant Q_1 in figure 2. The isocost line which is tangent to Q_1 is C_1. The point of tangency, B, shows the efficient combination of capital and labor. A shift in the production function transforming inputs to output is represented in figure 2 by a shift in the isoquants. In particular, the specified output level of isoquant Q_1 can be produced by the input combinations on Q'_1 after the shift. In addition, the output yielded by the B combination of capital and labor after the shift is represented by Q". A movement from B on Q_1 to B on Q" should be attributed solely to the shift in the production function; neither an increase in inputs nor an increase in efficiency in the narrow sense of the term shown played a role in the shift of output from Q_1 to Q".

A change in allocative efficiency can be represented in figure 2 by a movement along an isocost line. Attaining greater efficiency implies movement towards the point of tangency. Such movements may be necessitated by shifts in input price ratios; farmers must shift input proportions to remain efficient, as indicated by shifting points of tangency. A movement from D to B, increasing output from Q_0 to Q_1, should be attributed solely to an increase in allocative efficiency; neither a changed production function nor a net change in inputs helped increase output.

Observed changes in inputs and outputs typically contain elements of all three influences discussed above: allocative efficiency, shifts in the production function, and levels of inputs. Defining and identifying the role of each factor is a complex task which can be done with only limited success in most practical situations.

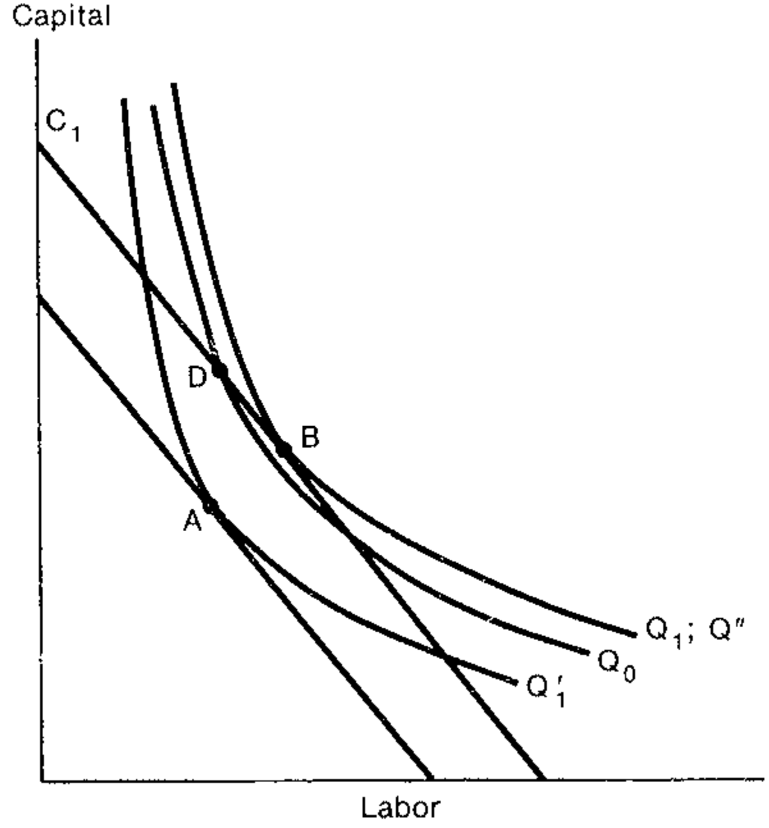
Problems of Empirical Application

The ideal set of empirical tools would enable one to partition observed growth in output into categories with agreed definitions which allow linkage to theoretical contructs. These categories should include allocative efficiency, shifts in the production function, and levels of inputs. However, additional categories, such as scale economies, are necessary. Still other categories might be desirable, such as subdividing levels of inputs into controllable and noncontrollable inputs. Unfortunately, the task cannot be performed in this ideal manner on any data sets other than those produced under very restrictive conditions.

Many analysts, such as those pursuing the production function approach, would prefer that measures of productivity reflect shifts in the production function only and not respond to other factors such as allocative efficiency, quantities of

Figure 2

Productivity and Efficiency



inputs, and scale economies. Peterson and Hayami note that arithmetic or geometric indexes of productivity are measures of shifts in the production function only under the following assumptions (*40*): (1) the economy is operating at the longrun equilibrium under perfect competition, and all factors are rewarded equal to their marginal value productivities, and (2) technical progress is a multiplicative factor of the aggregate production function (implying neutral technical progress).

An alternative to the identification of productivity change with a shift in the production function is the view that the concept of productivity change should encompass the many forces that cause changes in the ratio of outputs to inputs. In this view, a narrower term such as "technological change" should be used to represent shifts of the production function, which is only one of many potential sources of productivity change.

The task force has not taken a position in this definitional issue. In practice, the USDA index of productivity change does and will inevitably continue to reflect the influence of the multitude of factors noted above rather than simply a shift in the aggregate production function. Thus, one of the major tasks confronted by every serious analyst of productivity is to ascertain the factors causing the published productivity index to change, as opposed to assuming the index reflects shifts in the production function and nothing else.

Our discussion of the meaning and concept of productivity and the meaning of alternative indexes intended to measure productivity has raised several difficult but important issues whose practical implications will be explored below. Before turning to an analysis of the existing statistics, however, it is necessary to discuss the uses which may be made of productivity indexes.

USES OF PRODUCTIVITY MEASURES

While their limitations must be kept in mind, productivity statistics are potentially valuable as performance measures. Even when there are substantial doubts about the validity of a particular productivity index, the output and input quantity indexes may be and in fact have been used as raw material in constructing alternative performance measures.

The task force undertook a survey of the uses to which the existing statistics have been and are being put in order to assess how agricultural productivity measures have actually served the purposes for which they are developed. The most important uses are the following: identifying the sources of economic growth; justifying the appropriation of agricultural research funds; estimating production relationships; serving as an indicator of technical change; comparing intersectoral economic performance and justifying price increases.

Identifying the Sources of Economic Growth

Economic growth may be accounted for by increases in the measurable (conventional) inputs and increasing productivity. It is necessary to understand the sources of productivity increase to identify possible ways of fostering economic growth. Griliches emphasizes that to label the unexplained residual change in output as "technical change" does not further our understanding of productivity growth (*20*).

Based on the results of a number of studies of production relations and input quality change in U.S. agriculture, Griliches (*17, 20*) finds that the main sources of conventionally measured productivity increases in U.S. agriculture during the 1940-60 period have been: (a) improvements in the quality of labor because of a rise in educational levels; (b) improvements in the quality of machinery services; (c) underestimation of contribution of capital and overestimation of the contribution of labor to output growth; and (d) economies of scale. The proximate sources of agricultural productivity become fully accounted for when the inputs are adjusted for estimated quality change and the effects of economies of scale are taken into account. Identification and quantification of the sources is an important first step, while the ultimate conclusions and implications depend upon improved knowledge of the economics underlying each source—that is, the costs and returns associated with education and research.

Extremely wide differences in measured agricultural productivity currently exist among countries. An analysis by Hayami and Ruttan indicates that resource endowments, technology, and human capital (broadly conceived to include the education, skill, and knowledge capacities embodied in a country's population) account for approximately 95 percent of the differences in labor productivity in agriculture between a representative group of less developed countries and developed countries (*21*).

Similarly, agricultural productivity differences from one region to another may be investigated by means of product and input indexes as in the Canadian study of Shute (*48*).

The main analytical effort involved in these uses of productivity data is to sort out the various causes of change in the productivity index. As the observed change is partitioned by causal factor, the remaining residual productivity growth is reduced. A complete growth accounting would leave nothing as an unexplained residual. In such growth accounting efforts, the input and output data as raw material are as important as the measured productivity change that one starts with.

Justifying the Appropriation of Public Funds to Agricultural Research and Extension

Griliches introduced explicitly the level of public expenditures on agricultural research and extension as a variable in the aggregate production function (*19*). He found that these expenditures affect the level of agricultural output significantly and that their social rate of return has been high. This and successive studies along related lines have rightly been counted as evidence in favor of public spending on research and extension.

However, it is not so clear what can be inferred from productivity statistics in and of themselves. Indeed, arguments have indicated that either increasing or decreasing rates of productivity growth are an argument for a bigger research budget. If productivity grows, this is said to indicate that the payoff to research has been high, so that further investment is warranted; if productivity fails to grow, this is said to point to insufficient amounts spent on research, so that further investment is warranted. Determining the expected payoff to public research and extension is a complex task whose solution is not readily revealed by productivity statistics, despite the temptation to use them in this fashion. In particular, a slowdown (increase) in the rate of productivity growth is not, by itself, sufficient grounds for increasing (reducing) research and extension expenditures. Again, output and input data provide valuable raw material, but no more than that for an assessment of the benefits relative to costs of research or extension.

Estimating Production Relationships

Another important use of time series of input and output quantities is exploring the production relationships that exist in the agricultural sector. Estimating the aggregate agricultural production function provides helpful information in understanding economic developments in the farm sector, and, as the earlier conceptual discussion suggests, knowledge of production functions aids in constructing meaningful productivity indexes for use as performance measures. Thus, there is a symbiotic relationship between research on production functions and research on productivity measurement, as is well illustrated in the cited work of Griliches. Appropriate measurement of output and input service flows is crucial to both types of endeavor.

Estimated production relationships may also be helpful in generating tests of the performance of the agricultural sector over and above the tests provided by productivity measures themselves. Examples include Griliches's discussion of disequilibrium in the use of inputs in U.S. agriculture, and the alternative approach by Tyner and Tweeten, with further discussion by Shumway, Beattie, and Talpaz (*53*, *47*).

Comparing Intersectoral Economic Performance

Productivity data are sometimes used, as a measure of performance, to compare the productive efficiency of various sectors. For example, Loomis and Barton noted that "agricultural productivity increased at an average rate of 1.6 percent, compared with 2.3 percent for the economy as a whole." (*33*) This comparison encounters two difficulties. First, labor productivity—a partial measure—has been the only measure available for nonagricultural sectors from the U.S. Bureau of Labor Statistics. Second, a net productivity concept which uses the value-added measure of output has been reported by the Bureau of Labor Statistics, while "total factor productivity" which is computed from gross farm output and total inputs has been reported by USDA. Thus, the indexes are not comparable and judgments are apt to be misleading. Nevertheless, in net productivity terms, estimated agricultural productivity during the 1940-57 period did, in fact, grow at higher rates than the national economy. According to Kendrick, the annual growth rate of net productivity during this period was 3.2 percent per year for agriculture, 2.1 percent for the national economy, and 2.3 percent for the private domestic economy (*27*).

Justification of Price Increases

Productivity measures, especially labor productivity in nonfarm industries, have been used in determining whether wage increases are justifiable under Government anti-inflation programs. Besides confounding average and marginal products of labor, this approach involves all the difficulties of partial productivity measurement discussed earlier. It is a misuse of productivity statistics.

There have been other uses, or perhaps more commonly misuses, of productivity statistics in agricultural economics and politics. A striking aspect of the uses is that, on the whole, productivity statistics have not been used to their greatest potential. Nonetheless, research undertaken by agricultural economists frequently involves using the input and output data as raw material. In the view of the task force, this is sufficient reason for substantial investment in accurate statistics. To be more precise, the multifactor index itself is perhaps not so important as the development of reliable measures of agricultural output and corresponding input service flows.

USDA STATISTICS ON AGRICULTURAL PRODUCTIVITY

USDA has constructed and published indexes of farm production and total farm inputs on an annual basis since 1960. Indexes are published for the following seven input groups: labor, real estate, mechanical power and machinery, chemicals, feed and seed, taxes and interest, and miscellaneous. The input groups are aggregated arithmetically by means of base-period price weights (the base period is currently 1967-69), to obtain a total input index. The total output index is divided by the labor input index to obtain a measure of labor productivity, and the crop production index is divided by cropland to obtain a partial productivity measure based on land. However, USDA's most-cited productivity measure is the total output index divided by the aggregate input index—an index of multifactor productivity. USDA's total and partial productivity indexes follow basic procedures originally used in Loomis and Barton with modifications in Lambert and some subsequent adjustments, and are published annually for the United States and 10 regions in *Changes in Farm Production and Efficiency* (*14, 33, 36*).

The procedures used have been outlined in *Major Statistical Series of the U.S. Department of Agriculture*, vol. II, (*59, 60*) as well as in Loomis and Barton, Lambert, and Barton and Durost (*33, 30, 2*). However, the details of the procedures used—sources for each element of basic data, assumptions used to fill in the many data gaps, techniques for estimation between benchmark surveys and extrapolation beyond the latest benchmark, criteria for revising data and changing procedures—have never been available in print.

A full appreciation of the status of and alternatives to the procedures currently followed requires becoming deeply immersed in these matters. Unfortunately, there is no person in USDA or elsewhere who has a full grasp of the details. Different steps are taken in different program areas. The staff charged with developing the productivity indexes (one economist and three statistical assistants) necessarily takes a good deal of the basic input and output data from other program areas within USDA as they come without having any significant hand in their construction. This section lays out not the full detail of the procedures but enough to provide background for an understanding of the problem areas in the USDA productivity statistics and the alternatives available for dealing with them.

Construction of the USDA Productivity Statistics

The data for a calendar year's productivity indexes begin to be available in the latter part of the year. Following the August crop estimates by the Crop Reporting Board (CRB), preliminary farm output indexes are constructed in ESCS which contain both the statistical and main economic analyses in USDA. Preliminary data on input use are developed at about the same time. The preliminary output data are published in *The Agricultural Outlook* (*63*). Fertilizer statistics are available from the CRB, in November, and the process of calculating input and output indexes begins. Further data become available soon after the beginning of the following year. In January, the CRB publishes final estimates of preceding year crop production and data on inventories of grain and livestock numbers as of January 1.

Much of the input and aggregate output estimation is done in the income and finance program area of ESCS in the course of developing farm income estimates. The staff charged with developing the productivity indexes makes necessary adjustments to the data used for farm income purposes, puts them into index form, and aggregates them to both regional and national levels. By May, most of the nonlabor input data are available, though unpublished, from the income and finance program area; final revisions for tobacco and cotton production also have been made by the CRB. Final livestock production estimates follow in June. The productivity statistics staff, after making certain adjustments, compiles these data into the indexes published in *Changes in Farm Production and Efficiency* (*12*), which is typically drafted in July with a target publication date of August for productivity statistics pertaining to the preceding calendar year.

Revision of the indexes is considered almost as soon as the indexes are published. In the latter part of the year, the CRB often revises crop production estimates for the preceding year. For inputs, the indexes for the 3 preceding years are subject to revision. There are typically substantial revisions in production, especially of livestock, on a State basis following the publication of the Census of Agriculture (the latest being the 1974 Census which was published in 1977). Input indexes are also revised back to the time of the preceding Census, where the Census data indicate revision is warranted. Consequently, many annual input series as finally revised are basically interpolations between Census years.

In a few exceptional cases, revisions are made as new information becomes available on production practices or as evidence accumulates of serious error in the existing estimates. For example, in recent years it became apparent that the index values for labor used in tobacco and cotton production were substantially too high, thus adjustments were made. Similarly, the depreciation procedure was revised, because of evidence that depreciation on farm service buildings was being overstated.

Input Indexes

This section discusses the procedures involved in constructing the input indexes, which are an important part of USDA productivity statistics.

Labor

A very important microeconomic element of total factor productivity, and of the crucial data for labor productivity, is the labor input series based on hours per planted acre (for pre-harvest labor on crops), hours per harvested acre (for harvest labor) and hours per unit of output (for livestock). The USDA data on hours of work are produced in the National Economics Division (NED) farm input and services program area of ESCS. The labor input data are not derived from surveys of actual hours of labor or of workers committed to agricultural production. Instead, the labor input is calculated on a "requirements" basis using estimated quantities of labor required for various production activities. The requirement coefficients are obtained on an individual commodity basis by means of consultation with State agricultural experiment station and Extension experts. This was last done on a comprehensive basis in 1964, and before that in agricultural census years. Since 1964, the 1959-64 trends have been extrapolated, with some modifications based on subjective judgments of changes in yields and developments in mechanization. These coefficients are not obtained from sampling or other systematic surveys of farm practices on a prespecified, consistent basis across States and commodities. For commodities and States where insufficient data are available, interpolations are made using nearby States or similar commodities. In 1974, the labor coefficients for the major crops were reestimated from budgets based on the cost of production surveys of the Firm Enterprise Data System (FEDS). These coefficients were first incorporated in the USDA labor input series in 1978, with the value since 1974 being extrapolation of 1969-74 trends, again with some subjective adjustments.

The published estimates of total hours used for farmwork for each of 12 enterprise groups and 10 regions (in the 1977 issue of *Changes in Farm Production and Efficiency*, tables 31-54) are obtained by multiplying labor coefficients by the CRB's estimate of planted acreage (for preharvest labor), production (for harvest labor), or animal numbers for livestock (*12*). Added to this sum is a constant proportion of 15 percent for overhead labor, that is, labor not used in any particular production process. Hours for marketing activities are excluded. The national labor input index is obtained by aggregating over the regions and enterprise groups. Regional labor quantity indexes are weighted by 1967-69 wage rates per hour for all hired labor as published by the CRB in *Farm Labor* (*57, 58*).

The U.S. average hired farm wage rate per hour as estimated by USDA's Statistical Reporting Service (SRS) for 1967-69 is used in aggregating the labor input index with other inputs.[3]

Real Estate

The real estate input index contains three main items intended to measure service flows: an interest charge on land and farm service buildings, depreciation of farm buildings, and a disparate remainder composed of estimated accidental damage to buildings, cost of repairs to service buildings and grazing fees. Farm dwellings are excluded.

In an effort to obtain a constant-quality land series, acres of cropland, pasture, and others are handled separately (as is irrigated/nonirrigated land in 17 Western States). The acreage of the components is reported in the Census of Agriculture. ESCS annually updates the estimate of total land in farms. Percentages in each use category are interpolated between the censuses. Price weights to aggregate to a constant-dollar value of land are provided by NED's Inputs and Finance Branch.

The stock of land and buildings is obtained by adding to the constant-dollar value of land an estimated building value, based on the estimated ratio of building value to land value. In order to exclude the family dwelling, which is not counted as a production item, an estimate of the proportion of all buildings accounted for by dwellings is subtracted. The values currently used for the building/land and dwelling/buildings ratios are 0.18 and 0.54, respectively. These are not base-period values. They are updated annually using estimates provided by the income and finance program area.

A stock/flow conversion is necessary to obtain the service flow of real estate inputs. The conversion is done differently for the equity and debt portions of real estate value. For the equity portion, the ratio of net cash rent (after property taxes) to current value is multiplied by the (base period) constant-dollar value of real estate. The current value of the equity portion is estimated by subtracting the value of outstanding mortgages from the total value of farm real estate. For the debt portion, the constant-dollar value is multiplied by the 1967-69 average mortgage interest to obtain an annual flow.

For buildings, estimated depreciation is added to the service flow. Depreciation is calculated as 2 percent of the constant-dollar value of buildings. The 2-percent figure is less than the figure used in the farm income estimates of NED, based on a judgment by the productivity measurement staff that NED depreciation plus repairs on buildings is too large.

Service flows from public lands (Federal, State, and Indian) are estimated by means of grazing fees paid, using data from the income and finance program area.

The imputed service flow from land diverted from current production under Federal commodity programs is included in the land input index.

Service Flows from Machinery and Mechanical Power

The data available on the stock of motor vehicles and farm machinery and equipment are less solidly rooted in periodic surveys than is the stock of land in farms. The last Census of Agriculture benchmark used provided a machinery stock for 1949. Since that time, the NED income and finance program area has maintained a constant-dollar stock by estimating annual changes using data on purchases from the SRS farm production expenditure surveys of 1955, 1971, and subsequent annual surveys, as well as trade sources. Purchases minus estimated depreciation indicate the change in the stock.

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[3] SRS became a part of ESCS Jan. 1, 1978. The term SRS will be retained for certain data applicable before the reorganization.

The basic service flow from capital goods in this category is an estimate of capital used up, or depreciation, during the current year. The depreciation estimates are provided by the farm finance and income program area. The estimates are based on a declining balance method in which a constant percentage representing the annual rate of depreciation of each type of capital is applied to its estimated value at the beginning of each year. The percentages used are: automobiles, 22 percent; trucks, 21 percent; tractors, 12 percent; and other machinery, 14 percent. The stock values are put in real terms by deflating through a price index. Because automobiles and trucks are used for purposes other than farm production, their stock values must be adjusted to obtain the appropriate farm input index. It is assumed that 73 percent of truck use and 20 percent of automobile use is an input into farm production. These figures are based on the 1971 SRS survey of farm production expenditures. For years prior to 1955, figures of 78 percent for trucks and 40 percent for automobiles are used, based on the 1955 SRS survey.

In addition to depreciation, the opportunity cost of funds invested in capital equipment is included as an input. This flow is estimated by multiplying the farm share of the deflated capital stock value by the 1967-69 interest rate on farm real estate debt.

The machinery input also includes repairs, parts, and tires, for which the income and finance program area provides an estimate of current expenditures. This estimate is deflated by the average of the SRS prices paid indexes for repairs and maintenance and tires. The estimated farm share of automobile and truck insurance premiums and license fees are also counted as a production input. The income and finance program area estimates are deflated by the overall SRS index of farm prices paid. Finally, the mechanical power and machinery input incorporates the income and finance program area's estimates of expenditures on fuel and oil, electricity, custom work, small hand tools, blacksmithing, and hardware. The price indexes used to deflate these items, all from the SRS estimates of prices paid by farmers, are: fuel and oil, the price index for fuels and energy; electricity, the farm cost of electricity per kilowatt hour; custom work and blacksmithing, the price index for farm services and cash rent; small hand tools, the price index for farm supplies.

Agricultural Chemicals

For fertilizers and lime, the basic data used are SRS estimates of tonnage consumption of nitrogen, phosphate, and potash, as published annually in *Commercial Fertilizers* (*55*). Tonnage of lime is obtained from the National Lime Institute. In order to aggregate the plant nutrients, 1967-69 estimated prices are used by SRS for anhydrous ammonia, 46 percent P_2O_5, and muriate of potash (60 percent K_2O). These prices are converted to price per ton of nutrient, the unit of measurement of the consumption data. In earlier years, tonnages of the nutrients were summed without price weights. Currently, the data back to 1965, but not before, have been revised using the 1967-69 price weights.

The input index for herbicides, insecticides, and fungicides is based upon current dollar expenditures on these items as estimated by the income and finance program area. The expenditures are moved by annual adjustments to the benchmarks provided by the SRS farm expenditures surveys of 1955 and 1971 and subsequent annual surveys. For the annual adjustments, prices and shipments are obtained primarily from the annual publication, *Pesticide Review* (*61*).

The productivity measurement staff deflated the estimated expenditures by the SRS index of prices paid for agricultural chemicals, as published in *Agricultural Prices*, for each year since 1965 (*54*). Prior to 1955, an index of lead arsenate, nicotine sulphate, and cube prices was the deflator. Between 1955 and 1965 a price index of copper sulphate; 2, 4-D; and DDT was used. These latter two indexes were developed by the productivity measurement staff, since no other suitable data were available.

Chemicals such as feed additives, growth hormones, defoliants, and other new products are not included as separate items, although some are probably counted in veterinary services and feed expenditures.

Feed, Seed, and Livestock Services

These input items are necessary to account for several complexities in the economic organization of agriculture. Feed, seeds, and some livestock service flows are primarily farm outputs, which are also used as farm input. As intermediate products within the agricultural sector, they should not be counted either as output or input for purposes of productivity measurement. However, those components of feed, seed, and livestock purchases resulting from resources committed in the nonfarm sector are properly counted in inputs to agricultural production.

The basic data on feed are expenditures as estimated by NED's income and finance program area. Purchased feed is divided into three categories: manufactured feed, hay and forages, and grains fed as such. Benchmarks for quantities are obtained from the Census of Agriculture. Annual adjustments are made for manufactured feeds by means of data provided by the American Feed Manufacturer's Association. Annual figures for grains fed as such are estimated from data provided by the grains program area of ESCS.

In order to estimate the nonfarm value added in purchased feed, 1967 Census of Manufacturing data are used to estimate the margin between the farm value of feed crops and the value of manufactured feed. The margin is intended to capture the use of salt, minerals, and other additives, as well as processing and transportation services added in the nonfarm sector. The percentage margin is multiplied by each year's expenditures on feed as estimated in the income and finance program area. Current dollar expenditures are deflated by the SRS estimate of prices paid by farmers for feed.

For seeds, expenditures on purchased seeds as estimated by the income and finance program area are deflated by the SRS index of prices paid for seeds. The nonfarm value added in seeds is estimated by means of a base-period margin as for feed. The margin is estimated from the differences between SRS prices paid by farmers for seeds and received by farmers for crops in 1967-69. There are no prices received estimates for hybrid corn seeds supplied to seed companies, and no margin is calculated. Thus, the entire amount paid for hybrid seed is counted as value added in the nonfarm sector. Individual crops are weighted by relative quantities used in 1967-69. The resulting index is deflated by the prices paid index for seeds. Seeds grown on the farm where used are not counted as an input, nor as an output of the farm sector.

Nonfarm value added in livestock and livestock product transfers are based on income and finance program area estimates of expenditures on baby chicks and turkeys (minus prices received for hatching eggs adjusted for hatchability), milk hauling, and marketing charges on feeder livestock.

Other Service Flows

While the major input categories already discussed account for most of the resources used in agricultural production, there are many minor items which should not be neglected. Collectively they account for about one-fifth of the input service flow into agricultural production. The additional items currently measured in USDA's farm input index include interest, taxes, dairy supplies, insurance, irrigation, and cotton ginning.

Interest

Foregone returns to funds invested in real estate and machinery are incorporated in the input service flows for those items. Other capital items which receive similar treatment are inventories of livestock and crops and operating capital. Livestock inventories are the average of each year's beginning and ending quantities valued at 1967-69 prices received, all data from SRS. Crop inventories are estimated as half the January 1 stock estimates from SRS. The service flow is estimated by multiplying the constant-dollar values times the 1967-69 mortgage rate of interest. Operating capital is measured as demand deposits of farmers as estimated in NED, deflated by the overall SRS index prices paid by farmers. The 1967-69 mortgage interest rate is again used to convert the stock to a flow.

Interest on nonreal estate debt is added as a separate service flow item, using estimates of total interest paid from the income and finance program area. Because this debt is presumably for the most part already counted in the value of inventories and machinery service flows, the only additional estimated service flow is the difference between the mortgage interest rate and a short-term interest rate in the 1967-69 base period times the debt outstanding.

Taxes

Real estate and personal property tax payments, estimated by NED's income and finance program area, are counted as a service flow into agricultural production. The intention is to reflect intangible inputs such as education, farm-to-market roads, and research. The increased importance of State sales and income taxes is not reflected here. However, no data are available for State sales and income taxes paid by farmers.

Real estate taxes are adjusted to exclude dwellings. The current dollar expenditures are deflated by the SRS index of taxes published in *Agricultural Prices* (*54*). Personal property taxes are deflated by the index of purchases of goods and services by State and local governments from the Bureau of Labor Statistics.

Dairy Supplies (Includes Detergents, Pails, Filters, and Other Items)

The income and finance program area provides current expenditures, which are then deflated with the SRS index using changes in prices paid for detergents (through 1976 when they stopped collecting the data). Since 1976, the detergent index has been moved with the index of prices paid for production items. Capital items such as pipelines and bulk tanks are not included due to lack of data. Some of these items are captured indirectly in service building values.

Insurance

Fire and wind insurance, hail insurance, and Federal crop insurance are included as input service flows. The income and finance program area provides current expenditures on a net basis, that is, premiums paid by farmers minus indemnity payments received by farmers. Expenditures are deflated by the SRS index of prices paid for building and fencing materials for fire and wind insurance, and by the index of prices received for all crops for hail and federal crop insurance.

Irrigation

Operating and maintenance expenditures on irrigation equipment are obtained from the income and finance program area. However, the only data specifically relating to irrigation are the fees paid to public and private sellers of water. Use of electricity and fuel for pumping are included elsewhere. The productivity measurement staff deflates these expenditures by a price index for these services obtained from the Bureau of Reclamation. No service flow is included from the inventory or depreciation of irrigation equipment, or operator's time spent on irrigation activities.

Cotton Ginning

This is estimated as the production of cotton in bales times the 1967-69 cost of ginning per bale, which yields a quantity index of cotton ginning services. Ginning costs per bale are provided by ASCS.

Other input items included are: expenditures on containers (baskets, bags, crates), binding materials, veterinary services, and the farm share of the telephone. The expenditure data are obtained from the income and finance program area and are based on the SRS farm expenditure surveys as benchmarks. Veterinary services, which include artifical insemination, are updated annually using data supplied by the Dairy Herd Improvement Association. They are deflated by SRS prices paid indexes for the closest category of items available.

Output Index

Two alternative approaches measure output, the gross or net (value added) concepts. A gross output series includes all of the final output of a sector. A value-added output series is an attempt to measure the output attributable to the resources originating within the sector; intermediate inputs are excluded. The farm sector may be defined in terms of what inputs are counted as originating in it. Presumably the total input series for a value-added measure would include only farm labor, land, and other fixed capital. Service flows from fertilizer, pesticides, and other purchased inputs would be subtracted from output and not counted as inputs.

The USDA farm output series is a gross measure of output but subtracts farm-produced inputs, feed used, hatching eggs, and some seed. The basic idea is to consider U.S. agriculture as a single large farm, so that output excludes intermediate products produced and used within the "farm." Farm output includes the production of farm products in the calendar year in which they are produced. The data for crops are as reported by the CRB. The source of the data on animal products is also from the CRB. In all cases, the output data are intended to measure farm production, so that meat output is estimated weight gained on farms and feedlots, not meat marketed. The inclusion of meat added to the capital stock of the breeding herd is, in principle, offset by use of cattle inventories on the input side. Production of some minor crops, livestock by-products, and farm forest products is not reported by the CRB and is not included in farm output. The items included are thought to account for 90 to 95 percent of all farm production.

Aggregation

The procedures described above provide for an annual quantity figure for each product and input group. Aggregate agricultural output and input indexes are constructed by means of price weights. The price weights are estimated average prices for the 1967-69 period. The price weights for products are the SRS prices received by farmers. Base period quantities times prices yield the quantity-price aggregates. The 1967 base period quantity-price aggregates for components of the farm input index are shown in appendix tables 1 and 2. For 1978, the quantity produced of grains, for example, times the 1967-69 price of grains is the 1978 quantity-price figure. Adding the figures for all crops yields the 1978 quantity-price aggregate for crops. This aggregate is then divided by the 1967 quantity-price aggregate to generate the index number for crop production (1967 = 100) reported in *Changes in Farm Production and Efficiency* (*12*). Similarly, the price-weighted quantities of livestock products are summed to yield a quantity-price aggregate for livestock production. To obtain aggregate agricultural production the estimated price-weighted quantities of crop production used in livestock production are subtracted from the sum of the quantity-price aggregates for crops and livestock.

Analogous procedures are followed to obtain quantity-price aggregates for each input group, which are then summed to obtain the aggregate agricultural input index, again put on a basis of 1967 = 100.

The multifactor productivity index is the aggregate output index divided by the aggregate input index times 100.

The base period used for these weights has periodically been changed because the relative prices of inputs and products change, and because new inputs and qualitative changes in inputs result in substantial cumulative trends in the price weights. The base periods currently in use are:

Computation period	*Price-weight base period*
Prior to 1940	1935-39
1940 to 1955	1947-49
1955 to 1965	1957-59
1965 to present	1967-69

The use of different weights for different periods means that the indexes are not exactly the same when comparing, say, 1950 and 1976. The extent to which changing price weights induced changes in the relative importance of the different input groups appears in table 1. The relative importance of inputs in the last year of each computation period is shown as implied by both the old and new sets of price weights. Relative importance is measured as the quantity-price aggregate for the individual items divided by the quantity-price aggregate for all inputs. In the year when the base period is changed, the index values for each major input group and the aggregate index value are "spliced," that is, set so that the values are the same under both the old and new weights. Thus, the differences shown in table 1 in the two alternatives for relative importance in 1939, 1955, and 1965 show the effects of price-weight changes only.

NON-USDA MEASUREMENT OF AGRICULTURAL PRODUCTIVITY

Related work on agricultural productivity is explored in two areas: experience of other countries and work by researchers outside USDA on U.S. agriculture. The purpose is not to provide a comprehensive exposition of the measurement procedures but to help in assessing alternative approaches to measuring U.S. agricultural productivity.

Experience of Other Countries

This section discusses the methodologies used to construct agricultural productivity indexes by selected countries, including Canada, Japan, and those associated with the Organization for Economic Cooperation and Development (OECD).

Canada

Measurement of aggregate agricultural productivity in Canada was initiated in 1961 in the Economics Branch, Agriculture Canada. The procedures followed are generally similar to those used by USDA in computing indexes of farm output, input, and productivity. The computations are constant-dollar, base-weighted indexes. Agriculture Canada, in its latest published report on productivity, uses 1961 prices as weights to aggregate inputs and outputs for the most recent subperiod. Total inputs include those provided by the farm sector and those purchased from the nonfarm sector. The inputs provided by the farm sector include operator and family labor, depreciation of real estate and machinery, and interest on investments in livestock and other capital items. Purchases from the nonfarm sector include building and machinery repair, hired labor, purchased feed, seed, fertilizer, and other inputs such as insurance, pesticides, and taxes.

The primary source of data for computing these indexes is the national statistical agency, Statistics Canada. The indexes of inputs are computed using estimates of farm expenses adjusted for price change using the Farm Input Price Indexes and other prices indexes. The index of farm output is computed by Statistics Canada and published annually in *Index of Farm Production* (*50*), Catalogue No. 21-203. Census of Agriculture data are also used.

The labor input data are annual averages of 12 monthly sample surveys reported in Canada's *The Labor Force* (*9*). There are three significant differences between the labor data of Agriculture Canada and those of USDA. First, while USDA relies upon labor requirements coefficients from budgets, Agriculture Canada makes use of sample surveys. Second, while USDA estimates overhead labor input (for example, management) by assigning a constant proportion of 15 percent to the variable labor inputs, Agriculture Canada obtains estimates of overhead labor inputs directly from the 12 monthly surveys. Third, Agriculture Canada separates labor input into farm operators, unpaid family labor, and hired farm labor, each price-weighted separately, instead of lumping together the total hours used for farmwork as USDA does.

Real estate inputs include both owned and rented real estate and include interest on investment in land and building, depreciation and repair on buildings, property taxes and fencing maintenance, all valued at 1961 prices. Different classes of land (such as irrigated land versus dry land) are not treated separately. (In Canada, irrigated farmland is less than 1 percent of the total area in farms, so that the impact of trying to value it separately would likely be negligible). Agriculture Canada uses a different procedure from USDA in converting land value to an annual flow of real estate services. First, the same stock/flow conversion rate is used in Canada for all farmland and buildings regardless of the debt status (for example, mortgaged land vs equity in land). Second, there are differences in methods used to estimate service flows from farm buildings. Third, Agriculture Canada includes property taxes in the real estate service flow, while USDA counts tax payments as a separate input item. Fourth, Agriculture Canada, unlike USDA, does not include land idled for program purposes in the land input series. (Actually, little land in Canada has been idled for program purposes. The one exception was the Lower Inventory for Tomorrow—L.I.F.T.—program in 1970. This lasted only 2 years, and the main effect was felt in 1970.)

Farm machinery and equipment inputs include interest on machinery investment, depreciation, repairs, fuel, oil, lubricants, hired custom work, and other operating expenses, presumably including automobile and other similar vehicles for farming purposes. Unless the Census of Agriculture in Canada provides better data on the inventory of machines and equipment with regard to age, size, and quality than is available in the United States, Agriculture Canada, and USDA, both suffer from the lack of quality data on farm machinery and equipment inputs. Unlike USDA, Agriculture Canada treats the farm share of electric power as part of the "Miscellaneous Capital Inputs" or "other inputs" category, discussed later.

Purchased feed and seed inputs refer to inputs of feed, seed, and nursery stock purchased by farmers from nonfarm sources. USDA and Agriculture Canada both recognize that conceptually the farm value portion of feed, seed, and livestock purchases should be excluded in the input series, since the farm costs of producing feed, seed, nursery stock, and livestock have been accounted for through the charges for farm real estate, labor, and other inputs. However, there are differences in practice. The USDA feed, seed, and livestock purchase series refer to the nonfarm value-added portion of direct feed, seed, and livestock purchases. Agriculture Canada does the exclusion in an arbitrary fashion due to difficulties in adjusting current statistical sources along these lines and the lack of data on margins even as good as the present USDA data. This is thought to overstate the share of inputs in the form of feed, seed, and nursery stock purchases as a proportion of total inputs, since part of the farm value portion of these raw materials may still be included.

Fertilizer, limestone, and other inputs account for the rest of the input series. The index of fertilizer and limestone refers to total consumption of commercial fertilizer, both fertilizer materials and mixed fertilizers, together with agricultural lime and limestone (including marl). "Other inputs" include interest on investment in livestock and poultry, interest on investment in purchased feeder livestock (purchased through commercial channels, that is, excluding interfarm sales and transfers), artificial insemination fees, breed association fees, veterinary services and supplies, hired custom work by nonfarm operators, electricity, telephone, insurance, pesticides and herbicides, containers, twine, irrigation water, levies and tools, small hardware, and so on. Marketing expenses are included up to the point of transfer of ownership of the output. However, in some cases such as milk, the price received by the producer is net of pickup costs and certain other charges.

Japan

In "Growth Rates of Japanese Agriculture, 1880-1965," by Yamada and Hayami, farm output is defined as total production in agriculture minus agricultural intermediate products (66). Total production is the sum of rice, other field crops, sericulture (cocoon) and livestock, all measured in 1934-36 constant prices at the farm gate. The agricultural intermediate products include the parts of agricultural products used as inputs for agricultural production such as seeds and feeds. After examining a variety of Laspeyres and Paasche indexes, including a chain of price-weight base periods which generally involves splicing input and output indexes, Yamada and Hayami show that various aggregation methods yield similar results. For convenience, individual farm output are aggregated by 1934-36 average constant prices.

Labor, land, fixed capital stock, and nonfarm current inputs are the four farm inputs. Labor is measured in terms of number of workers in agriculture; male and female workers are compiled separately. Data on hours of labor are not available. Land is measured in terms of arable land, paddy, and upland field areas. The fixed capital stock includes livestock and perennial plants, machinery and implements, and farm buildings excluding residential houses. Aggregation is done using 1934-36 prices. The fixed capital input seems to combine stock and flow concepts in the same measure. Nonfarm variable inputs are the current inputs in agriculture supplied from the nonfarm sector. They include fertilizer, agricultural chemicals, feeds processed by domestic industry (such as fish meals and oilseed cakes) and fuels and electricity, again aggregated using 1934-36 prices.

Factor share weights for each input are used to aggregate the labor, land, fixed capital, and nonfarm current inputs into a total input index. Yamada and Hayami found that the total input index is sensitive to the choice of factor-share weights. As a result, they use a chain-linked Divisia index formula:

$$I_t = \left(\sum_i W_{io} \frac{q_{i1}}{q_{io}} \right) \left(\sum_i W_{i1} \frac{q_{i2}}{q_{i1}} \right) \cdots \left(\sum_i W_{i,t-1} \frac{q_{it}}{q_{i,t-1}} \right),$$

where:

I_t is the total index at period t,
q_{it} is the quantity of i-th input at period t, and
w_{it} is the factor share of i-th input in the total cost of production in current prices at period t.

The factor-share weights (W_{it}'s) are calculated for every 5-year interval. For example, factor shares employed for the year 1955 are 1955-59 averages. The same factor shares are used to aggregate individual input indexes into a total input index for each succeeding year of the 1955-59 period. A 5-year moving average of total output and total input indexes is employed to minimize the effect of weather variation on the measure of total productivity. Thus, the Japanese statistics differ from the United States and Canada in that individual output indexes in Japan are aggregated by Laspeyres, while input indexes are aggregated by the Divisia index with the factor-share weights calculated as 5-year averages.

Organization of Economic Cooperation and Development (OECD)

In *Concepts and Productivity Measurement in Agriculture on a National Scale,* J. Horring reported various productivity measures for OECD nations (25). The measures of outputs and inputs differ considerably among the 17 countries.

Many OECD countries, such as The Netherlands, follow the United States in using both gross and net farm outputs in measuring physical volume of output. On the other hand, the United Kingdom measures gross farm output only. Farm output includes sales of cereals and other commodities, which eventually return to the farm sector after handling and processing for use in feeding. Individual output indexes are weighted by constant prices for pairs of years, with successive pairs of years valued at the prices of the first year of the pair.

To aggregate input indexes, Austria, Belgium, Denmark, and Sweden all use base-period price weights for aggregation. The United Kingdom, however, uses a chain-link method, which allows changing weights for each pair of years, consistent with the United Kingdom's output aggregation. Total inputs include purchased feed which originated in the farm sector, depreciation of tenant's capital (but excluding interest on tenant's capital), and labor of the farmer and his wife.

Labor productivity is measured by some OECD countries as output per man-hour, man-day, or man-year, and output per worker by other countries. Multifactor productivity is reported by Austria, Belgium, Denmark, France, Sweden, and the United Kingdom.

Work Outside USDA on Measuring U.S. Farm Productivity

The following section examines measurement of U.S. farm productivity by specialists in the private sector, as well as productivity analyses by other Federal agencies.

John Kendrick

In his two books on measuring productivity, Kendrick uses two measures of farm output: gross output and net output (real value added). Each is based primarily on information supplied by USDA (*28, 27*). The output index is used to compute output per man-hour comparison by major types of livestock and crop production.

The U.S. Department of Commerce measure of gross farm output is obtained by summing the deflated value of the following items: cash receipts from farm marketings, commodity credit corporation loans, net change in farm inventories, farm products consumed directly in farm households, and gross rental value of farm homes. For comparability with the farm output index of USDA, Kendrick used the 1939-base deflators for years prior to 1940 and the 1947-49-base deflators from 1940 through 1952. In 1961, Kendrick used 1958 weights for years beginning in 1953. The weighting system for inputs is consistent with that of output.

Kendrick's gross farm output measure is "more gross" than that of USDA. Kendrick includes the production of seeds and value of feed consumed. Thus, his gross farm output shows slightly more increase over the period 1910-53 than USDA series on farm output. In terms of the base weights, USDA used 1935-39 price weights for the period prior to 1940; 1947-49 price weights for 1940-55 period; 1957-59 price weights for the 1955-65 period; and 1967-69 weights for the period beginning 1965 to present.

Kendrick's net farm output is gross farm output less 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 expense. Some items represent market purchases by farmers from each other, but most of them represent purchases from the nonfarm economy. Net farm output thus represents the value added by farming to the national output. Estimation of net output is particularly significant in the farm sector, because a large relative increase in purchases from other industries has resulted in net output rising significantly less than gross farm output (table 2).

The process of computing net farm output proceeds in two steps. First, gross output and intermediate products consumed are estimated for subperiods by using the various base-period price weights. Second, net farm output is computed by subtracting the intermediate products consumed from the gross output.

On the input side, Kendrick includes only labor, real estate, machinery and equipment, and inven-

Table 2—Gross and net farm output, selected years

Year	Gross farm output	Intermediate product consumed	Net farm output	Ratio of net farm output to gross farm output
		1958 billion dollars		
1929	23.8	5.5	18.4	77.3
1948	31.5	11.0	20.5	65.1
1958	37.6	15.1	22.5	59.8
1966	42.7	18.6	24.2	56.7

tories for crop and livestock. He excludes purchased inputs, taxes, interest, and insurance. Citing a likely downward bias of labor requirement coefficients obtained from USDA, Kendrick has adjusted USDA man-hour estimates upwards by 10 percent.

The basis for the land stock is total acres of land in farms as reported in the Census of Agriculture. For 11 Western States, acreages of irrigated, dryland farming and gazing land were weighted by the estimated value per acre of each in the base period. For the other 37 States in the continent, the base-period value per acre of each of improved and unimproved land in each State is calculated and applied to the number of acres of each type of land as reported by States in the Census of Agriculture.

Kendrick handles inventory inputs quite differently from USDA, as noted earlier. For livestock, he multiplies numbers of livestock as of January 1 of each year estimated by ESCS by average value per unit. Crop inventory volumes also are weighted by base-period average prices by State.

Kendrick aggregates labor and capital inputs by using market-price weights in his first publication. He uses factor-share weights to aggregate input categories for a chain of subperiods in both publications. The basis for the factor share computations is estimated national income originating in farming. Based on this information, total labor compensation, an index of man-hours, total capital compensation, and an index of real capital are used to compute unit labor and unit capital compensation and the factor shares. Kendrick used average prices in the boundary years of the following subperiods: 1919-29; 1929-37; 1937-48; and 1948-53. For the final period beginning 1953, he has used 1958 weights.

Kendrick argues that the use of net output (value added in agriculture) contributes to the consistency of the productivity estimates with those for other sectors. This approach would reduce the apparent rate of productivity advance in farming. For example, during the period 1955-66, total factor productivity based on gross farm output measure grows at an annual average rate of 4.4 percent, while productivity based on net farm output grows at a rate of 3.4 percent.

Zvi Griliches

Concerned with changes in quality and other aspects of input measurement, Griliches adjusted the official USDA input and output indexes for U.S. agriculture for 1940 and 1960 (*20*). The major input adjustments concern labor-force quality, bias in the deflators, differences in the concept of capital services, and other quality changes, mainly the fertilizer and lime index and the "other inputs" category.

To allow for changes in labor force quality over time, Griliches adjusts the labor man-years figures by multiplying them by an "index of education per man." This index is computed by weighting year-of-schooling-completed classes of rural farm males by the weighted average 1950 income of all U.S. males in each schooling class. Additional adjustments for change in the age, sex, and race distribution of the agricultural labor force were found to be of negligible importance, and thus were not included in the final analysis.

Bias in the deflators is primarily a matter of machinery input estimates, the bias resulting from the fact that the USDA indexes of prices paid by farmers for machinery and motor vehicles have drifted upward over time relative to other similar price indexes (for example, the consumer price index of new automobiles and the comparable wholesale price index components for motor trucks and other machinery). The adjustments made to counteract some of these biases consisted of computing the change in the USDA price index relative to the better-specified price index for each of the machinery categories (automobile, motor trucks, tractors, and other farm machinery). These relative indexes were averaged using 1947-49 gross investment in the respective categories as weights, and the resulting index was used to inflate the USDA estimates of farm gross investment in motor vehicles and farm machinery from 1947 to 1960.

With respect to capital services, the USDA official input measure at that time used rates of depreciation averaging about 16.5 percent per year. Griliches argued that these rates were too high and did not accurately measure the current flow of services. Griliches points out that the USDA official measures assume that the flow of annual services from a machine falls by more than half in the first 4 years of its lifetime, and that only about 16 percent is left after about 10 years. He uses a new measure of depreciation as an alternative, which assumes that services are constant during the first 15 years of life of a machine and then fall to zero thereafter.

The USDA fertilizer and lime index at the time of Griliches's study converted tons of fertilizer into units of plant nutrients (nitrogen, phosphoric acid, and potash) and then simply added them up, ignoring differences in their relative value. Griliches substitutes a price-weighted plant nutrient measure. The weighted measure differs from the USDA unweighted measure by giving a higher weight to fertilizer mixtures that contain more nitrogen, which has become increasingly important over time. USDA practices have since been changed to conform with Griliches's procedure.

Griliches's adjustments result in a substantial change in the rate of measured productivity growth between 1940 and 1960. The items discussed above reduce the percentage increase in multifactor productivity from 42 percent in the USDA statistics for this period to 29 percent in Griliches's calculations (*20*). Further changes in measured productivity resulted from output adjustments and factor weights derived from estimated production function coefficients.

Only the fertilizer input calculation has been altered of the areas in which Griliches's work suggested that changes would be desirable in USDA procedures. Although some changes have been made in the SRS machinery price index, it still does not constitute a constant-quality index. The SRS price index continued to rise faster than Bureau of Labor Statistics machinery prices. The problem of the depreciation pattern appropriate to capture service flows from capital items has been investigated in further detail in Penson, Hughes, and Nelson (*39*).

Gossling and Dovring

Gossling (*16*) and Dovring (*11*) suggested the concept of aggregated labor productivity to answer the question: What is the benefit to the community at large of technical and economic changes in agriculture? Arguing against the inadequacy of both gross and net productivity measures in answering the above question, they propose an alternative that explicitly takes into account the effect of sectoral interdependency.

Aggregated labor productivity is designed to measure the farm sector's output (measured at constant prices) per unit of "aggregated labor," that is, direct farm labor plus indirect labor used for production and servicing of the nonfarm inputs of the farm industry. Gossling attempts to measure the ratio of net agricultural output of products used within the farm sector to aggregated direct and indirect (nonagricultural) labor. The Dovring index, a shortcut approach, is the ratio of gross farm output to estimated direct and indirect labor. The two indexes are in substantial agreement as to the magnitude of long-term productivity changes.

Included on the input side are all productive goods and services represented not by their money value but by the amounts of human labor used to generate them. Excluded among conventional inputs are rent on land and capital services. Index-number problems do not arise on the input side, since all conventional inputs (other than rent and interest) are converted to a labor equivalent using current-year prices and wages for aggregation.

The idea of aggregated labor productivity has not made any impact on USDA's productivity measurement. The task force considered briefly the merits of this approach but could not conclude that it had strong practical or conceptual advantages over a multifactor productivity index—and it retains the disadvantages of being a partial productivity measure.

Bureau of Labor Statistics

The Bureau of Labor Statistics (BLS) of the U.S. Department of Labor is the official source of U.S. Government statistics on productivity for the nonagricultural sector. The BLS has developed measures of output per man-hour for the total private sector and the farm and nonfarm sector annually from 1909 to the present. These measures refer to the ratio of gross national product (GNP) originating in the private or individual sector to the corresponding hours of all persons employed. GNP originating in a sector is a value-added concept, that is, the USDA gross production figure minus costs of purchased inputs. Indexes of output per man-hour refer to the constant-dollar value of goods and services produced per man-hour.

PROBLEM AREAS IN USDA'S MEASUREMENT OF AGRICULTURAL PRODUCTIVITY

The measurement of productivity involves many conceptual and practical issues which have never been resolved satisfactorily either by general economists or in the particular context of agriculture. These issues are explored in this section with reference to USDA's measurement of agricultural productivity. Recommendations for change are postponed until the complete set of problem areas has been laid out.

Areas in which the task force found problems in the measurement of U.S. agricultural productivity follow.

1. Definition of the agricultural sector.
2. Gross versus net productivity.
3. Quality change in output and inputs.
4. Index number (aggregation) problems.
5. Stock/flow problems.
6. Measurement of nonconventional inputs:
    - Water,
    - Environmental resources,
    - Public infrastructure,
    - Insurance, and
    - Governmental regulation.
7. Data gaps.
8. Commodity-specific productivity measurement.

Almost all of these areas involve both conceptual and practical problems. Conceptual problems arise when there is ambiguity in the choice of what to measure. Practical problems arise when there is an impediment to measuring what we want to measure. Many problems of both kinds have been pointed out, and remedies suggested, by agricultural economists over the past 20 years.

Definition of the Agricultural Sector

The USDA productivity statistics, and this report, are concerned with productivity for a narrower entity than the entire food and fiber sector of the economy. While drawing the exact boundary involves many difficult choices, what we wish to include is the productivity of the activities traditionally located on farms which are directed at producing the traditional farm commodities. What we wish to exclude are, first, activities "downstream" from farming—basically marketing and processing functions, and second, activities "upstream" from farming, which provide the inputs used in agricultural production.

Increase in productivity in either the marketing or farm input sector can have a substantial impact on the agricultural production sector, but such increases do not contribute intrinsically to agricultural productivity in the narrow sense of shifting agricultural production functions. For example, technical innovation in tractor assembly, which made it possible for farmers to purchase the same tractor at a lower price, would not constitute an increase in agricultural productivity, even though the supply function of agricultural products would shift (production costs would be lower). On the other hand, an innovation which produced a tractor that sold at the same price but would produce more power with the same amount of fuel would constitute an increase in agricultural productivity. The second case is an innovation which permits the agricultural production process to generate more output. The first case is an innovation making it possible to produce more tractors with the same inputs into that activity.

This distinction becomes difficult to apply in some cases, and indeed forces us to regard some of the most important innovations in terms of impact on agriculture as not being a matter of agricultural productivity at all. For example, the innovations that permitted the substantial fall in the real price of nitrogen fertilizers since World War II resulted in increased crop yields, and thus affected agricultural production greatly, but did not, strictly speaking, constitute an increase in agricultural productivity. The events involved a movement along the crop production functions, not shifts in them. An analogous event would be a relaxation of immigration and fair labor standards legislation (minimum wages) as they affect agricultural labor. This would result in many significant changes in farm production practices but would not constitute a change in productivity in the narrow sense of the term.

The previous two paragraphs reflect the narrower view of productivity, according to which productivity changes are identified with a shift in a production function. This view is helpful in growth accounting when it is necessary to partition the sources of agricultural output growth among inputs and among various causal factors. The multifactor productivity index will increase when tractor services become cheaper, for whatever reason.

On the marketing side, there is no difficulty with the idea that, say, the development of improved retail packaging materials is distinct from an increase in agricultural productivity. Again, the boundary becomes more difficult to draw as we move toward the farmgate. The cotton gin, despite its historical importance as an influence on agricultural production, is not ideally a matter of agricultural productivity. If better roads result in reduced milk-hauling charges, it is not a matter of agricultural productivity. But what about the introduction of bulk-milk cooling and holding tanks? They would, in part, constitute an agricultural productivity gain in requiring less total input to get milk to the standard farmgate condition; but, in part, they are a marketing innovation. Finally, consider preparation of fluecured tobacco for market. Use of bulk-curing barns and the replacement of hand-tying of tobacco leaf by machine-tying are two of the most important innovations in this industry. Whether they are regarded as an increase in the productivity of agricultural production or as productivity in marketing/processing seems quite arbitrary. There is no strong reason to prefer one approach to the other.

Whatever the preferred boundaries of the farm sector, the availability of data forces certain choices that do not conform to the conceptual ideal for agricultural productivity measurement. For example, cotton is priced on a lint basis for aggregation to the constant-dollar total farm output. Therefore, cotton ginning charges are included as an input, and technical improvements in cotton ginning would increase measured agricultural productivity. Similarly, the pricing of milk at the plant leads to counting milk hauling as an agricultural input. The characteristic of much of the data that leads to these problems is its generation on an establishment as opposed to a product basis. Our consideration of this distinction benefited from discussion of a similar issue in Brandow, G.E., and others, *Review and Evaluation of Price Spread Data for Foods*—the report of a task force jointly sponsored by the American Agricultural Economics Association and the U.S. Department of Agriculture. The establishment orientation is particularly strong in the farm income and finance program work, which is the source of so much of the input data. The focus is on the income of farms, not on income produced by the production of agricultural commodities.

The establishment approach is based upon the longstanding equating of farm and agriculture in the minds of both the general public and analysts. The title of the USDA publication on productivity, *Changes in Farm Production and Efficiency*, is clearly a reflection of an establishment orientation. One of the advantages of this approach is that most people have an intuitive feel for what a farm is and what a farmer does, although these perceptions vary. Another advantage is that many survey and census data are generated on an establishment basis.

As a practical matter, any of several boundaries between the agricultural and nonagricultural segments of the food and fiber sector would be satisfactory so long as the boundary was consistent in the activities it separated. The primary disadvantage of the establishment approach is that the functions performed by farms change quite rapidly as time passes. The examples are numerous and important. A short time ago, most dairy farmers kept bulls to impregnate cows, but now most farmers purchase artificial insemination services from a nonfarm business. Row crop producers used to cultivate fields to remove weeds but now purchase herbicides which are applied while planting. Nonfarm buyers of many fruits and vegetables now perform production activities on farms which were once left to farmers. In some cases, the transformation of production practices and establishments has been so complete that the traditional farm has disappeared for all practical purposes—broilers being the most common example.

Adherence to an establishment definition for productivity measurement leads to shifts in productivity merely due to changes in the activities encompassed by the establishments. The nature of inputs and output changes, partly due to shifts in the stage of production at which they are purchased or sold. The resulting impacts on productivity measures may be substantial when timespans covering a decade or more are used in the analysis as is common. Thus, the analyst must determine how much of the measured change in productivity is due to shifts in the activities included in the sector before turning to more basic questions of whether certain functions are performed more productively in current than past periods.

The product approach, on the other hand, proceeds by specifying certain production activities, such as preparing seedbeds, impregnating cows, and feeding broilers, as included in the agricultural sector regardless of the nature of the establishment performing these functions. These same production activities are then included in the sectoral measures as time passes. The principal advantage of the product relative to the establishment approach is that the resulting measures of productivity are easier to interpret because of the relative stability of the sector so defined; adjustments to remove the effects of the changing nature of establishments are made at the outset of the measurement process rather than left to the analyst to disentangle. The principal disadvantage of the product approach is that data are often reported on an establishment basis necessitating adjustment of available transaction prices to find the appropriate value at the interface of the agricultural sector with other sectors. For example, if agriculture includes growing broilers but not slaughtering and shipping them to retail outlets, then processing and shipping charges must be subtracted from observed wholesale prices to derive an appropriate agricultural broiler price or unit value.

Current ESCS practice is a mixture of the establishment and product approaches. Some production activities, such as feeding broilers and harvesting vegetables, remain within the boundaries of the agricultural sector despite their being assumed by nonfarm firms. Others, such as impregnating cows and controlling weeds, are allowed to move out of or into the agricultural sector as current farm practices change. We believe there is room for a more consistent and useful boundary to be drawn than is currently used.

Gross Versus Net Productivity

Closely related to the issue of defining the agricultural production sector is the question whether to measure productivity in a gross or net (value-added) sense. The current USDA statistics relate gross output to all inputs used in agricultural production. The productivity statistics typically generated for the nonfarm sector use value-added or net output, which is obtained by subtracting the value of purchased (intermediate) inputs. Net productivity is then measured as net output divided by inputs originating in the sector, that is, those not deducted from gross output.

One difficulty with net output is that there are different degrees of "netness," according to which factors of production one wishes to count as "originating in agriculture." Presumably, any measure of the net output of the agricultural sector would involve subtracting the value of fertilizer, seed, and other purchased inputs from the (constant-dollar) value of output. Whether the service flow for machinery would be subtracted depends on how "net" one wishes to get. Manufacturing value added is usually taken to include value added by a factory's machines as well as its labor force. Similarly, we would not subtract a farmer's land, buildings, or owned machinery. However, it might be tempting to subtract rented machinery or hired custom work from both output and input; the value-added approach tempts us to an establishment, as opposed to a product, approach to drawing the boundaries of agriculture.

While gross productivity seems a more suitable product-based productivity concept at the sectoral level, the fact remains that one of the uses of agricultural productivity statistics is to compare the difference in the growth rate of productivity between the farm sector and the overall economy. This creates a problem of noncomparability, since nonfarm outputs are measured in terms of value added. The rate of productivity change is, in some measure, dependent on the level of aggregation chosen for analysis. An increase in the importance of intermediate inputs will tend to increase the ratio of net output to original inputs; net productivity has some of the characteristics of a partial productivity index. The effect on measuring productivity may be significant for industries such as poultry where purchased feed dominates the inputs and represents a very large part of the output value. Comparison of USDA total-factor productivity, which uses the gross farm output concept, with productivity of the general economy thus can be misleading.

The work of Gossling and Dovring is a combination of shifting the boundary of agriculture and moving toward a net concept. The boundary of agriculture is moved "upstream" to reach labor used in producing farm inputs such as tractors, and even to labor used to produce steel to be used in producing tractors. No nonlabor inputs are counted, however, even in agricultural production activities themselves. The output measure remains gross. This index will tend to rise whenever technical progress occurs in the agricultural production sector, the agricultural input sector, or the sectors which supply goods and services to the agricultural input sector (steel, computers, for instance).

Overall, we believe the best approach is the gross output/total input concept that USDA currently uses in terms of clearness of meaning and applicability to concerns that people have when they ask about agricultural productivity.

Unfortunately, it is not easy to give gross output an unambiguous meaning in agriculture, because one very substantial agricultural product (feed) is an input into another agricultural activity (livestock production). Indeed, if one were starting from a strictly product, as opposed to an establishment, basis, it would make more sense to consider agriculture as two separate industries, one "upstream" from the other. However, given the historical basis for treating agriculture as a single entity, and the fact that crop and livestock production activities remain intertwined to a substantial even if decreasing degree, there is really no alternative to constructing an overall index of agricultural productivity.

As discussed earlier, current USDA practice is to subtract an estimate of farm production that is used as an input on farms from agricultural output. The result is that the USDA gross output index is, in part, a net product index. The main alternative approach is to use a fully gross output measure that includes all agricultural production, including crops used as feed. An objection is that this approach double-counts feed crops—once as crop production and again as embodied in livestock output. However, this problem can be handled by including feed as an input as well as an output. While it appears incongruous to count the same item as an input and as output, this approach is no less logical than the current netting out of feed.

Whatever approach is taken, the problem remains that agriculture consists of activities at two distinct stages of food production, and no conceptually neat procedure exists to combine them into one index. The current approach has a cosmetic appeal in that the troublesome component—farm-produced feed—simply disappears from view. But the fully gross approach has two practical benefits: (1) the data used to net out farm-produced feed are dubious in many respects, and (2) the fully gross measure facilitates growth accounting by means of production functions or other methods. For example, if the quality of grain for feed improves, this source of productivity gain can be identified as such using the more gross measure but not if grain for feed is netted out. And if one wishes to study the role of feed in the production process for agricultural products, one needs a feed input data series, which USDA's current approach does not provide.

Quality Change in Output and Inputs

Quality change in output creates conceptual problems somewhat analogous to that created by a changing boundary between the farm and food-marketing sectors. A change in the average moisture content of grain at time of sale is a quality change at the farmgate. The product approach to defining the agricultural sector suggests a choice of a particular moisture level to define the output, regardless of whether drying to that stage is done on farms or not. However, many qualitative aspects of output cannot be handled in this manner, even at the conceptual level. For example, in any particular year, beef production consists of farm production of various grades of meat (on the hoof). A change toward, say, grass-fed beef changes the meaning of livestock output. The appropriate conceptual approach is clear enough for this type of problem, although it is often not practical to apply. One should not treat head of cattle or pounds of meat as a homogenous product, but instead there should be separate categories, such as pounds of choice beef and pounds of good beef, which would then be aggregated to obtain an index of beef production with appropriate weights reflecting the quality differences.

Unfortunately, some problems of quality change cannot be handled by breaking the product into quality-constant components. These problems arise when new qualitative characteristics appear. An example is the adoption of new tomato varieties developed for use with mechanical harvesting machinery. An even more dramatic historical example is the force-feeding of geese to obtain livers for *foie gras.* At the conceptual level, even this problem can be solved by the ingenious device of "hedonic" price indexes, in this case applied to quantities (*18*). Hedonic weights attached to old-fashioned and new tomato varieties would let us aggregate to a constant-quality tomato production index, even if the quantities of some components are zero in some periods. However, we are very far from a practical solution in all these instances.

Quality change in inputs creates a somewhat different problem. We may not want a constant-quality input index because sometimes what we mean by an increase in productivity is an increase in input quality. For example, we could treat hybrid seeds as improved-quality, open-pollinated seeds, and count them as separate inputs in the production function or else attempt to quality-adjust all seeds to make a single index. A more appropriate approach is simply to add to the seed input an index of the nonfarm input services involved in supplying hybrid seed, which is the current practice. This is precisely the idea behind the current approach. In fact, however, the output of hybrid corn seeds is currently omitted from the output index but is included as an input, since total expenditures on seeds are counted as an input. Then an improvement in the quality of hybrid seeds, which increases output over and above the price paid by farmers for the improved services, will show up as an increase in multifactor productivity. One of the principal uses of multifactor productivity indexes derived in this way is for purposes of growth accounting—to try to apportion the observed multifactor productivity increase to improvements in inputs, better information or management, economies of scale, or other variables.

Similar problems arise with the quality of the labor input. There are two quality problems. First, the farm labor force consists of operators, farm laborers, and family members of varying age and sex. Attempting to differentiate among the weights applied to children, persons over 65, and prime-age males seems reasonable, although there are undoubtedly problems in estimating the appropriate weights. Griliches provides an approach worth considering (*19*). Second, differences in skills attributable to education may vary over time.

The importance of incorporating quality into the labor-input measure differs for two different uses of productivity statistics. For explaining long-term trends, changes in the quality of labor would be very important to capture, for example, a trend towards better education of owner-managers compared with hired laborers, or a trend towards higher skill levels for all workers. Considering changes in trend, little or no distribution on the rate of productivity growth is likely to result from failing to account for improvements in the schooling system. On the other hand, the capture of shifts in the composition of the labor force between age groups or the hired relative to operator labor, may remain important. Moveover, no widely accepted approach to incorporating these differences into the labor input appears to exist. At our current state of knowledge, the contributions of education are probably best left as a research problem in growth accounting, that is, let the labor input *not* be changed by increases in skills so that the increases will show up as an increase in multifactor productivity (*40*, pp. 498-500).

Quality measurement issues abound in the purchased input categories, particularly pesticides, tractors, and other machinery.

Index Number Problems

Index-number problems arise from the necessity of aggregating products and inputs to obtain a multifactor productivity index in a world in which relative prices change. It is a conceptual problem in the practice of productivity measurement; indeed, it is the major problem in that it is not completely solvable even in theory, no matter which data we may have at our disposal. The areas where index-number problems have the potential to cause problems for agricultural productivity measurement include: aggregating products to obtain an output index, aggregating pest control chemicals to obtain a pesticides index, aggregating plant nutrients to obtain a fertilizer index, aggregating land classes, aggregating miscellaneous inputs, and aggregating input categories to obtain a multifactor input index.

Aggregation of Products

The problem for output may be illustrated with reference to crops and livestock. Suppose we are interested in comparing productivity in 1965 and 1955, and for that purpose we want an aggregate output index. Using 1957-59 price weights, the results obtained appear in panel A of table 3. Crops increase 20 percent; livestock increases 13 percent; and the aggregate increases 16 percent. The results for 1967-69 price weights are shown in panel B. The crop and livestock components still increase by 20 percent and 13 percent, but

Table 3—Example of output aggregation

Year	Total crops	Total livestock	Aggregate output[1]	Index
		Billion dollars		
1957-59 price weights:				
1955	18.1	17.9	36.0	100
1965	21.8	20.0	41.8	116
1967-69 price weights:				
1955	21.0	19.6	40.6	100
1965	25.2	27.2	47.4	117

[1] This aggregate is "more gross" than USDA's farm output because it does not subtract feed, seed, and livestock, which are intermediate goods within agriculture; for example, feed fed to livestock.

the aggregate increases 17 percent. The slight increase in panel B compared with panel A reflects slightly higher relative prices for crops than for livestock in 1967-69 compared with 1957-59. The sensitivity of the aggregate index to the chosen base-period prices is nowhere near as great as in the earlier poultry example with changing input price weights.

The relative stability of results in the output index is due to (a) the similarity of rates of growth of output of the different products, and (b) the lack of dramatic changes in the relative prices of products. Either (a) or (b) is sufficient to yield a stable aggregation result. For example, even though the relative prices of crops and livestock have changed dramatically in recent years, so that 1967-69 price weights would differ substantially from 1975-76 price weights, the aggregation process will yield the same growth rate of aggregate output if crops and livestock output are growing at roughly similar rates. Similarly, even if crop and livestock output were growing at vastly different rates, the aggregation would be stable if relative prices were relatively stable.

In general, we should expect to find an association between differing rates of growth of output categories and differing relative prices of the categories, so that a rapidly changing sector of the economy will tend to generate index-number problems. Nonetheless, the aggregation of U.S. agricultural output for most periods does not cause anything like the index-number problems generated by the input indexes.

Pesticides

The aggregation is done not by the productivity measurement staff in ESCS, but by the agency's statistical unit in constructing the price index of pesticides. Current-year values of expenditures are deflated by the price index to estimate current-year quantity, for example, the 1975 quantity:

$$(Q{\cdot}P)_{1975} / P_{1975} = Q_{1975}.$$

The ESCS price index is a Laspeyres index with quantity weights. The index number problem arises in comparing 1975 with, say, 1970 as follows. Let there be two pesticides, A and B. Suppose that P_A has fallen between 1970 and 1975, and the use of A has risen substantially, but that P_B has remained constant and its use has risen only slightly:

	A	P_A	B	P_B
	Million pounds	*Cents per pound*	*Million pounds*	*Cents per pound*
1970	450	30	600	25
1975	800	15	800	25

Consider a price index based on 1967 quantity weights, which are assumed to be $A = 300$, $B = 500$, with $P_A = 40$ and $P_B = 30$ in the base year. Then the price indexes for 1970 and 1975, compared to 1967 = 100, are:

	Price index
P1967 : $(300 \times 40 + 500 \times 30 = 27{,}000)$ →	100 (for reference)
P1970 : $300 \times 40 + 500 \times 25 = 21{,}500$ →	80
P1975 : $300 \times 15 + 500 \times 25 = 17{,}000$ →	63

Expenditures are:

1970 : $450 \times 30 + 600 \times 25 = 28{,}500$
1975 : $800 \times 15 + 800 \times 25 = 32{,}000$

Expenditures deflated to obtain quantities are:

	Q index
Q1967 : $(27{,}000/1 = 27{,}000)$ →	100 (for reference)
Q1970 : $28{,}500/0.80 = 35{,}625$ →	132
Q1975 : $32{,}000/0.63 = 50{,}794$ →	188

The increase of 42 percent between 1970 and 1975 in the pesticide Q index is a weighted average of the 78 percent increase in A and the 33 percent increase in B between those years. But what if we had used 1975 quantity weights instead of the 1967 quantities? Then the price indexes would have turned out to be:

	Price index
P'1967 : $800 \times 40 + 800 \times 30 = 56{,}000$ →	100
P'1970 : $800 \times 30 + 800 \times 25 = 44{,}000$ →	79
P'1975 : $800 \times 15 + 800 \times 25 = 32{,}000$ →	57

And the deflated expenditures would have been:

	Q index
Q'1967 : 27,000 →	100
Q'1970 : $28{,}500/0.79 = 36{,}076$ →	134
Q'1975 : $32{,}000/0.57 = 56{,}140$ →	208

In sum, the use of a Laspeyres pesticide price index tends to understate the rate of increase of pesticide use, and hence to overstate the rate of growth of multifactor productivity. These calculations are only illustrative but give a qualitative picture of the kind of bias in the quantity indexes. Note that the direction of bias is the same whether pesticide prices, in general, are rising or falling. The bias depends only on the relative use of the pesticide increasing whose relative price has decreased. In addition, note that the alternative indexes, Q' and P', are also biased but in the opposite direction.

There have been drastic changes in the quantity weights in the pesticide price index unlike the price weights in the product aggregation case. The preceding example considerably understates them. Indeed, as mentioned previously, there have been three different sets of pesticides used in the weighting for different time periods; in other words, an original set of weights has gone to zero and been replaced by new weights which were originally zero.

The rapid changes in pesticides suggest that no Laspeyres weighting scheme for either prices or quantities will be very satisfactory. A natural alternative is the use of a Divisia index. ESCS has annual data on prices of particular pesticides, and the income and finance program area has annual estimates of quantities. This approach would be applied to the pesticide example above as follows. The rate of increase of A between 1970 and 1975 is 78 percent, and the rate of increase in B is 33 percent. These rates of change are the difference divided by base-period value. Use of natural-log changes would eliminate the effect of base-period value. The share of A in pesticide expenditures is 0.47 in 1970 and 0.38 in 1975 or an average of 0.425. Thus, the (approximation to the) Divisia index of rate of growth of all pesticides between 1970 and 1975 is:

$$0.425 \times 0.78 + 0.575 \times 0.33 = 0.52$$

The corresponding figure for the Laspeyres index was 42 percent $(= 188/132 - 1)$, and the growth rate was 55 percent $(= 208/134 - 1)$ for the Paasche index (1975 quantity weights).

As discussed earlier, another index often suggested for coping with changing weights due to relative price changes is the Fisher ideal index. This index uses the mean of base-year and current-year weights. Thus, the pesticides price index in the preceding example would be:

		Price index
$P''1967 : 550 \times 40 + 650 \times 30 = 41{,}500$	$\longrightarrow$	100
$P''1970 : 550 \times 30 + 650 \times 25 = 32{,}750$	$\longrightarrow$	79
$P''1975 : 550 \times 15 + 650 \times 25 = 24{,}500$	$\longrightarrow$	59

The corresponding deflated expenditures are:

		Q index
$Q''1967 : 27{,}000$	$\longrightarrow$	100
$Q''1970 : 28{,}500/0.79 = 36{,}076$	$\longrightarrow$	134
$Q''1975 : 32{,}000/0.59 = 54{,}437$	$\longrightarrow$	201

The percentage increases in the measured input between 1970 and 1975 from the various indexes are:

	Percent
Laspeyres:	42
Paasche:	55
Divisia:	52
Fisher:	50

The Laspeyres and Paasche indexes are at the boundaries of the possible "correct" range, but there are no grounds to prefer the Divisia or Fisher indexes relative to one another. The Fisher index is naturally well-suited for comparing 2 years so far apart that their weights are drastically different. The Divisia index is suited to calculating yearly increments when factor shares are relatively stable.

Fertilizer

The index-number problem takes a different form for fertilizer in that quantity data for each year are aggregated by means of base-year price weights (as is the case for the aggregation of output). There may well be bias in the measured growth of the fertilizer input, but it is in the opposite direction from the bias in the measured growth of the pesticide input. Consider the data for 1960 and 1970 for an instance of the index-number problem in the fertilizer input. The quantity data are:

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
		Million tons	
1960	2.74	2.57	2.15
1970	7.46	4.58	4.04

The quantity indexes using 1957-59 SRS price weights are:

		Q index
$1960 : 2.74(149) + 2.57(82) + 2.15(52) = 731$	$\longrightarrow$	100
$1970 : 7.46(149) + 4.58(82) + 4.04(52) = 1689$	$\longrightarrow$	232

The quantity indexes using 1968 prices weights are:

$1960 : 2.74(86) + 2.57(75) + 2.15(48) = 532$	$\longrightarrow$	100
$1970 : 7.46(86) + 4.58(75) + 4.04(48) = 1180$	$\longrightarrow$	222

Because nitrogen's relative price fell while its use grew relatively fast — a natural outcome — the 1957-59 (Laspeyres) price weights give a growth rate of the fertilizer input which is biased upwards, that is, an implied growth rate of productivity which is biased downwards. Thus the biases in pesticides and fertilizers will tend to offset one another, although an exact offset would be extremely lucky. As was the case with pesticides, there are available estimates of both prices and quantities each year, so that Divisia indexes could be constructed.

The other categories of purchased inputs are almost all measured by means of deflated expenditure data, so that their rate of growth tends to be understated, like pesticides, and the resulting productivity growth overstated.

Aggregate Inputs

In the aggregation of all the input classes to obtain the multifactor-input index, price-weighting of quantities is used (even for items like pesticides where quantity-weighted price indexes stood as a deflator to obtain the quantity index). The main relative price change among the broad aggregates over the longer term has been the increase in the relative price of labor. Since this increase has been accompanied by a dramatic decrease in the relative importance of labor (table 1), the stage is set for a serious index-number problem, as the poultry example in an earlier part of this report indicates. While it would pose more difficulties than in the pesticide and fertilizer cases, because of the lack of annual data for both quantities and prices, the use of Divisia indexes for estimating the growth of total input should be considered.

Stock/Flow Problems

Although service flows are the appropriate input measure for capital items, the flows are not observable for most natural and reproducible durable resources used in agricultural production. The exceptions in the USDA productivity statistics are the services of public lands used for grazing and custom work hired. The conversion from a capital stock figure to an estimated service flow requires the use of a rate, the choice of which can make a substantial difference in the estimated input index.

Input flows for the provision of machinery services include the services devoted to repairs and maintenance, depreciation (machinery "used up") during a particular period, and the opportunity cost of funds tied up. The latter two involve the use of conversion rates from stocks to flows. Penson, Hughes, and Nelson have found evidence that the USDA depreciation calculations for farm tractors are inappropriate for reasons basically similar to those cited earlier by Griliches (*39*). Their results imply that a more accurate depreciation pattern would make a substantial difference in the time series of annual service flows from tractors, although it is not clear that the USDA approach to depreciation systematically overstates or understates the growth of machinery services in the post-World War II period. Careful attention should be given to depreciation patterns and lifetimes of capital items because some important technical advances can occur via increased durability of equipment. Conversely, new types of machinery may, when first introduced, be less durable than established lines of equipment. An important element of a research program in measuring agricultural productivity should be periodically to reexamine the fixed rates (12 percent for tractors and 14 percent for other machinery are now used).

The depreciation measurement problem may be even more serious for farm service buildings. The 2 percent currently used may be appropriate for traditional barns and sheds, but in the livestock sector many recent innovations involve service flows included in this category. The 2 percent probably understates the annual service flows from equipment such as milking parlors, bulk milk tanks, automated feedlots, harvestores, grain handling and drying equipment, waste handling equipment such as gutter cleaners, pathogen-free hog farrowing barns, and modern broiler and egg-laying facilities.

Depreciation of land is not measured as a service flow. Records for some farms in eastern Washington show that diligent soil conservation measures conducted on the same farms for about 20 years have provided significant yield increments (+20 percent) over nonconservation farms. Research on the possibilities for a measure of land depreciation, or at least the possibility of including resources devoted to conservation activities as part of the land input, would be worth undertaking.

The use of a market interest rate for the opportunity cost of funds invested in land or machinery seems the best feasible approach, but two conceptual issues have practical implications: first, the use of a real versus a nominal rate, and second, the use of a base-year versus a current-year rate. These stock/flow conversion issues are most notable for land, although they apply to some extent to reproducible capital.

The mortgage interest rate is the flow that a purchaser of land using borrowed funds lays out in order to capture both the current flow of real returns in the form of products produced and the nominal increase in the value of land. The latter should not be counted as part of the service flow of land for use in measuring productivity. A real rate of interest is the appropriate concept. Since the expected rate of inflation has probably accounted for at least half of the nominal rate of interest in the past few years, the service flow from mortgaged land would be substantially overstated in years to come.

In earlier years, when the nominal interest rate and inflation were both much lower, the observed nominal rate on mortgage interest charges was probably a reasonable approximation. The overstatement in the growth of the land input series is moderated because a base-period interest rate is used, not each year's current value. Nonetheless, a problem persists when comparing years where different base-period weights were used for aggregation.

The rate of interest on mortgages issued in 1969, at around 7 percent, was about 1.5 percent above the rate in 1957-59, the previous base period. The increase in the interest rate is probably almost entirely due to expectations of a higher rate of inflation in the latter period. Yet, it results in an increase in land's estimated weight in aggregate agricultural inputs of about 1.5/5.5 = 27 percent in years using the 1967-69 base compared to the land input using the 1957-59 base period. Unfortunately, good estimates of real long-term interest rates do not exist. Rather than use a procedure which is known to introduce error, one could argue plausibly that a single interest rate of perhaps 3 to 4 prcent should be used throughout the whole data series, not being changed even when the base-period weights are changed.

An alternative to the use of a real long-term interest rate is the ratio of cash rent to land value. The ratio of base-period cash rent to the constant-dollar land stock for the base period could be used to put the ratio in the appropriate real terms. This is, in fact, the USDA procedure for the equity portion of real estate. This procedure should be applied to all real estate, and could be explored for capital equipment also, perhaps using custom rates as a basis for base-period flow/stock ratios. In any case, there appears to be no reason for the current procedure of using different conversion rates for the equity and mortgaged portions of real estate. The service flow from a given acre of land should be the same regardless of commercial liens on it.

Nonconventional Inputs

Education, research, and extension are the most often discussed nonconventional inputs in the growth accounting literature. But there are others which are closer to conventional measured inputs that will be considered first.

Water

A significant share of the Nation's crop output comes from irrigated lands. Moreover, the portion of the Nation's total cropland receiving irrigation water is increasing rather rapidly. Irrigation was once thought to be necessary or practical only in the arid regions of the West. Now Nebraska has the highest rate of irrigation development. Irrigation is spreading throughout the Corn Belt and extending from Florida to Maine. Farmers have explicitly recognized the productivity of more water in agriculture. The trend of the water input is rising, while acres of cropland decline.

Should USDA, in its measure of agricultural productivity, give explicit recognition to water as a factor of production? If so, how should this be accomplished? Currently, the contribution of water in agricultural production is embodied in measures of land values. The cost of obtaining and using water (the only cost in most cases, since water rights are generally not sold to individuals) is reflected in production cost budgets or in land values. Though a value measurement for water on a par with that for labor or capital is not easily obtainable at this time, its consumptive use as a measure of input quantity is readily available. Physical input measures could be obtained as accurately as those for labor.

Measurements of labor inputs to agriculture are now based on engineering estimates of labor used in performing various tasks in crop and livestock production. Water quantities could be measured in a similar manner, but probably more accurately. The U.S. Department of the Interior's Bureau of Reclamation and several States have also published estimates of water used in agriculture. Thus, it would be easy to include such a measure in the USDA series on productivity in agriculture.

The valuation of the resource to obtain appropriate weights for aggregation with other inputs poses greater difficulties. Currently, most irrigators pay only for the cost of getting water from its source to its point of use, but pay nothing for the water itself. The situation is similar to that which existed for some frontierland during the middle 19th century. Nonetheless, many situations are developing in which irrigation water is not free; hence, it is not correct to assign it a zero weight in aggregate inputs (unlike other production necessities such as sunlight, carbon dioxide, and oxygen).

The current USDA statistics on the water input include fees paid to public water projects, but these undoubtedly understate the market value of the water. LeVeen provides much of the relevant data for California (*32*). However, There are no estimates of service flows from stocks of irrigation equipment, nor are there data on maintenance and repairs of irrigation works and equipment.

Environmental Inputs

Besides water, agricultural production makes use of other "free" natural resources, which may be favorable to productivity calculations. The most important are the use of the atmosphere and waterways as means of waste disposal. External costs imposed on the nonfarm sector in the form of fish kills, unpleasant odors, or poisonous fumes should be either subtracted from agricultural output or counted as an agricultural input.

On the whole, while incorporation of externalities into agricultural productivity measurement is not yet feasible, this is clearly an area that merits close monitoring in the future. It might also be a promising research area for individuals interested in productivity measurement.

Public Infrastructure and Taxes

This is one area of nonconventional inputs where the USDA statistics may go too far in the direction of inclusion. The flow of public services financed by property taxes is probably not predominantly an input into agricultural production. The portion that goes into police and fire protection is properly, in part, a service flow to agriculture. The portion that goes to roads helps productivity to get purchased inputs more cheaply in place, but is more properly a service flow to marketing rather than production. The portion that goes to education should have some effect through the quality of labor. However, the lags are so long and the production function of skills so difficult to estimate that if labor quality is to be incorporated, measuring years of schooling of the farm labor force would be preferable to including taxes paid by farmers. Finally, the public service flows (research and extension activities) that affect agricultural production most directly are generally not financed by property taxes.

The inclusion of taxes as an input is one of the problems arising from the use of data to measure agricultural productivity, though not gathered primarily for that purpose. In particular, most of the input flow data are put together for the primary purpose of estimating farm income. However, some costs which are necessary for income measurement are inappropriate, or at least need careful adjustment, for use in measuring input service flows, such as taxes. Interest payments cause similar problems with land.

Insurance

Expenditures on insurance premiums and self-insurance by means of precautionary steps in farm production are clearly relevant to income accounting, but their appropriate role in productivity measurement is problematical. Some expenditures of real resources in self-insurance are input service flows that should be included in a production function. For example, a wheat grower may maintain his own combine, even though he intends normally to have his grain custom-harvested. It is a precautionary measure in case the custom-harvesting services are not available when needed. In many years, this and similar precautionary machinery will not be used. The expected value of the harvest is increased by the precaution, thus, it is a true productive input and should be counted in the farm input series, as it currently is. The same is true for many other cases of apparent excess capacity.

However, expenditures on, say, fire insurance premiums do not, in and of themselves, contribute to production. They are basically a risk-reducing side bet that the operator makes with the insurance company. It is true that the existence of insurance may influence production decisions, and indeed many producers would probably be in a different line of business if insurance of one kind or another were not available. The task force ended up uneasily endorsing the counting of insurance premiums as an input item, again as the current USDA procedures do. However, counting the premiums as an input entails counting indemnity payments as an output. This is currently accomplished by measuring the insurance premiums as net premiums paid (aggregate premiums minus aggregate indemnity payout).

The USDA accounting, however, does not include the net premiums on publicly-provided insurance under the Disaster Payments Program or other emergency disaster relief programs. Consistency suggests that these programs should be taken into account if private insurance is. The result is an addition to output (or a negative input), since aggregate indemnity payout exceeds premiums (often zero) in these programs. The effect on productivity measurement could be substantial, since the net payout has approached $1 billion in just a few years, notably 1974.

Governmental Activity

Some governmental regulations or restrictions reduce agricultural output from given input services. It does not seem unreasonable for the results to show up as a reduction in measured productivity. Yet some programs create conceptual difficulties, most notably acreage set-asides or land retirement programs. Should idled land be included in the land input series, as USDA does? Inclusion of set-asides will show a reduction in productivity which is misleading in that the production function has not shifted. On the other hand, exclusion of set-asides would tend to show a misleading increase in multifactor productivity to the extent that set-aside land would have been fallowed or idled otherwise, or is subpar acreage. Ultimately, the choice depends on the use one wishes to make of productivity statistics. The task force is divided on which is the least bad choice for an official USDA productivity measure. Consistency suggests, however, that if USDA continues to include set-aside land in the input series, then something should be included on the output side as the product of the land which the government is renting from farmers.

Regulatory activity, which is aimed at environmental goals or at the health or safety of consumers or farm workers, also creates difficult problems. The additional input services required by these regulations may legitimately be added to the input series. Again, to be consistent, the output series should show the resulting improvements in environment or health or safety. Unfortunately, the further one goes on this route, the further one departs from measuring agricultural productivity as such. The joint productivity of agriculture and other socially valued goods is measured instead. This changes the meaning of the exercise, perhaps significantly. Ideally, the best approach might be to count the environmental or health damage in the absence of regulation as a real resource cost of agricultural production, that is, as environmental inputs. Then new regulatory restrictions will increase (reduce) agricultural productivity, if the increased input services necessary to attain the same output are less (greater) than the reduced environmental damage inputs. We are far from being able to put such an accounting scheme into practice.

Data Gaps

Business-cycle research has been criticized as "measurement without theory," a shortcoming not unknown in agricultural economics. The opposite deficiency, "theory without data," is more commonly laid to general economists. Various aspects of economic research on productivity can be debited on both accounts, but perhaps most serious of all in practical productivity statistics is a third shortcoming, "measurement without data."

The development of any time series of economic statistics inevitably requires shortcuts and omissions due to unavailability of data. And even when data are available, they often are only crude proxies for what we would really like to have. The measurement of productivity is especially vulnerable to these problems, because for multifactor productivity we want statistics on all output and all conventional inputs. Some items in both categories are not covered at all, and others only in a sketchy fashion. These gaps exist at the national level, and for some smaller geographical areas, are even worse.

This section considers data gaps only at the national level, and only considers the most serious problems; for example, one could imagine better measurement of the farm family labor inputs via surveys, and a better accounting for land quality, such as not counting all land used to grow crops as equivalent. Nonetheless, on land and labor, the data are in so much better shape than for some other inputs that the virtues of the SRS labor and land figures far outshine their shortcomings. In the ESCS labor requirements series, constructed independently of SRS, data gaps exist; however, since we are going to recommend against continued use of the requirements approach anyway, these gaps will not be taken up in this section.

Real Estate

The most serious gaps involve the service buildings, including the equipment kept in these buildings. There are no recent survey data on these items. The number of all buildings is estimated by multiplying the constant-dollar value of real estate by a percentage based on 1964 Census of Agriculture data. Data on service buildings relative to all real estate are obtained from the 1971 SRS survey of production expenditures. The figures for depreciation of buildings are also estimated on a tenuous basis.

Machinery and Power

Perhaps the most amazing gap in all the output and input data is the lack of information from sampling surveys of the stock of machinery. The 1974 Census of Agriculture asked about numbers of the major kinds of machinery and whether they were manufactured in the last 5 years, as well as the market value of the aggregate of all machinery (including automobiles and trucks) on the farm. These data may help construct a benchmark, but more detail is necessary, such as power of tractors and capacity of combines. Even these data are not currently used in the USDA input series, and the 1949 benchmark reaches too far back.

On cars and trucks, fixing the farm share at 20 and 73 percent, based on a 1971 survey, is arbitrary. Current estimates should be developed. Finally, little progress has been made since Griliches and Fettig in measuring the quality of farm machinery (*17*, *14*). This is a most important item, because so much of technical change in agriculture has involved qualitative changes in machinery.

Agricultural Chemicals

The quantities and prices for the basic chemical commodities seem in a satisfactory state (that is, cost-efficient in that further improvement would be very expensive). The big gap, for both fertilizers and pesticides, is information on use in agricultural production. The data on resource use pertain to total disappearance of these inputs, and the proportion used for forestry, home gardens and lawns, public landscaping, and others is surely not neglible, but its magnitude is unknown.

New chemicals in the livestock industry—antibiotics, growth stimulants, aids to the digestion of roughage—as well as such crop control chemicals as defoliants, are not satisfactorily treated in current accounting. They may be captured in feed and veterinary expenditures, but this is too crude an approach for these inputs, which may play a very important role in recent and future agricultural productivity changes.

Feed and Seeds

The data on nonfarm value added in feeds and seeds are very sketchy. For feed commodities, the indirect estimation of nonfarm value added by subtracting prices received by farmers from prices paid by farmers for manufactured feeds is a rough approximation. It may be especially unsuited for soybean meal and other feed products jointly produced with agricultural products which do not reenter the farm sector. For seeds, data on prices received by farmers for hybrid corn seed do not exist, and seed corn is counted as an input but not an output. This results in underestimation of productivity compared with time periods prior to the introduction of hybrids. On the other hand, small grains seed grown on farms where used is not subtracted from output, hence overstating productivity.

Livestock

The importance of livestock as a capital item is recognized in the interest change on livestock inventory. However, the longer lived capital invested in the breeding herd is not fully captured in the USDA statistics. The base-period prices value breeding animals predominantly by their cull (slaughter) value. Valuing additions to the cattle breeding herd at prices more nearly reflecting their actual value as capital items would tend to increase measured output. On the other hand, the element of depreciation of the breeding herd, which shows up as a decline in price to slaughter value as animals become older, is also omitted from the USDA statistics. Including this depreciation would add to measured inputs.

Other Inputs

One of the chief data gaps is the absence of good information on the stock of irrigation equipment and associated services in repair and maintenance. Many of the minor inputs measured by deflated expenditure data involve either lack of data on the expenditures or an inappropriate deflator. For example, veterinary services are deflated by the SRS index of all farm production items, interest, and rent. The rationale for deflation is to obtain a quantity figure for the i^{th} input by dividing expenditures, P_iQ_i, by the input price, P_i, that is: $P_iQ_i/P_i = Q_i$. When P_i in the denominator is replaced by a price index $\bar{P}$, a measure of Q_i does not result from deflation.

Finally, there are several conventional inputs for which no data are included at all in the USDA indexes. These include legal services, soil testing, accounting services for business and tax purposes (whether done by the operator or hired). And if a farm share of the telephone is counted as an input to agricultural production, so should be the farm share of the dwelling, serving as the part that constitutes office space, record and equipment storage, and clean-up areas. While some of these items may be quantitatively minor, those listed are all more important than some currently included in the input series such as blacksmithing, containers, and binding material.

With respect to nonconventional inputs—public infrastructure, skills of farm operators, environmental inputs—the pressing problem is not one of filling data gaps. The priority task is conceptualizing what we want to measure precisely enough to be measured.

Disaggregation of Productivity on a Commodity Basis

USDA currently publishes labor inputs and a labor productivity index for individual enterprises. A possible approach to satisfy demand for more information on productivity would be the calculation of multifactor productivity indexes for individual commodities; for example, the production of corn would be divided by an index of all conventional inputs used in corn production—and similarly for other commodities such as beef, wheat, tobacco, and cotton. These multifactor productivity indexes would supplement the common partial productivity measures such as crop yield per acre and pounds of meat per pound of feed.

A major problem with disaggregation on a commodity basis is the lack of independence of commodity production. In many areas, farmers find it advantageous to pursue a mix of enterprises for such reasons as soil fertility, soil moisture, disease control, pest control, weed control, and dispersing and lowering peak seasonal labor demands. Measures based upon an index of the total output of the enterprise are more meaningful than indexes reflecting only one product when interdependencies exist. This is the case, since changes in the technology of producing a given commodity may be partially reflected in changes in the output of other commodities.

The arbitrary nature of the allocation is another major problem with disaggregation of those inputs shared among the production of several commodities. The purest example of this dilemma is the allocation of the management input among the several enterprises included on a farm. The necessary allocations for other items such as tractors and other multiple-use equipment would be only slightly less arbitrary and troublesome. Economic theory suggests that arbitrary allocations of inputs among joint products is not helpful in making decisions and may often lead to misconceptions capable of producing bad decisions.

Finally, data gaps which may be tolerable in measuring aggregate productivity often become much more severe in the context of a single commodity. Almost all the innovations in dairying, for example, of the past 40 years are handled by more or less crude approximations which would make a multifactor dairy productivity index a very arbitrary number. As another example, the current practice of counting farm inputs used in producing hybrid corn seed on the input side, and then counting the purchased seed corn as an output, is too incorrect for a corn productivity index, even though the effect is so minor as to make no difference in measured aggregate agricultural productivity.

SUMMARY OF PROBLEMS

The problem areas in the measurement of agricultural productivity are so widespread and, in some cases, potentially so serious, that one might ask if published USDA productivity statistics are capable of telling us anything at all. However, many of the data gaps and shortcuts may well have negligible quantitative significance, and even significant errors may tend to cancel out. The only way to get a meaningful appraisal of the importance of the problem areas is to try out alternatives that cover the range of our uncertainty about weighting and index values for outputs, and see how much difference it makes in measured productivity growth. Some such experiments have been accomplished in several ways.

The seriousness of the index number problem in aggregating the broad input categories can be gauged by contrasting the results with base-period and current-year weights. It turns out that the base-period (Laspeyres) weighting has tended historically to bias the measured rate of productivity growth downward as we move far past the base period. This result, unlike the case of a Laspeyres price index, cannot be forecast deductively because the productivity index is a ratio of two indexes. While the output index is unambiguously biased downward, the input index's bias cannot be forecast deductively because some inputs use Laspeyres quantity indexes, and others use expenditures deflated by Laspeyres price indexes. The multifactor productivity index using 1957-59 weights shows a slowdown in measured productivity growth which is somewhat moderated when 1967-69 weights are introduced. The 10-year old 1967-69 weights suggest that aggregation bias may be understating current multifactor productivity by 1 to 3 points, which would imply an understatement of the rate of productivity growth since 1967 to 5 to 15 percent. Some earlier comparisons show substantially larger biases. Loomis and Barton found that the total input index increased about 25 percent between 1940 and 1958 when 1935-39 price weights were used (*33*). The increase in the same index for the same period was less than 5 percent with 1947-49 weights.

The difference made by the "requirements" approach used in ESCS to measure labor input can be estimated by comparing the results that would have been obtained if the SRS or the BLS farm labor survey data had been used. Comparing 1975 with 1960, the BLS hours are 1.35 times the SRS hours in 1975, and 1.27 times the SRS hours in 1960. Using the relative importance of labor in the overall input index of 0.167 in 1975 and 0.265 in 1960, moving to a total input index based on BLS labor data would have increased the total input index by 5.8 percent in 1975 and by 7.2 percent in 1960. Thus, instead of decreasing by 1 percent between 1960 and 1975, the total input index would have decreased by 2 percent if the BLS labor data had been used.

An alternative way to arrive at this result is to note that the BLS labor input declined by 56 percent between 1960 and 1975, while the USDA labor input declined by 62 percent. With a weight of labor in total inputs of about one-sixth, the 6-percent difference in the rate change of the labor input generates a 1-percent difference in the rate of change of total input. This is a small difference; measured productivity growth, which is 28 percent using the SRS labor series between 1960 and 1975, would have been 29 percent if BLS data had been used. On the other hand, if the SRS data were employed on total farm employment, the measured labor input would have declined only 48 percent between 1960 and 1975, and multifactor productivity would have increased by 30 percent.

Sensitivity tests were made on the treatment of the land input to examine the consequences of alternative treatments of set-aside land or other land idled under government programs. The first important land-idling program was the Soil Bank, which started in 1956. This program was followed by shorter term voluntary diversion and set-aside programs. The set-aside program ended after the 1973 crop year and was reinstated in 1978. The effect of leaving diverted acreage out of the input series would have been to increase measured productivity on average just under 2 percent during the 1956-59 period and just over 4 percent during the 1960-73 period (compared to the official USDA multifactor index which includes diverted acreage). The differences varied from 1 percent in 1956 to 5.4 percent in 1962. An alternative land series was constructed for the period 1950 to 1976 containing only cropland used for crops in place of total land in farms. Land idled for program purposes was not included in the land input.

The alternative land index was higher in the 1950s and 1970s but essentially the same in the 1960s, compared with the official index which incorporates permanent pastureland, cropland used for pasture, and program-idled land. Thus, the alternative rate of productivity growth is slightly higher comparing the 1960s to the 1950s but slightly lower comparing the 1960s to the 1970s.

The greatest potential for changing the measured growth rate of productivity probably lies with the new and improved inputs included in farm buildings, machinery, and chemicals; there are offsetting biases in pesticides and fertilizers. Preliminary sensitivity tests suggest that the bias in pesticides may be quantitatively less than the bias in fertilizer, so that the net effect is to overstate the rate of growth of agricultural chemical inputs, understanding the growth rate of multifactor productivity.

For machinery, it is possible to obtain an indication of the quantitative significance of quality change by comparing the former SRS farm machinery price index with the BLS price index for the same category of goods. The former SRS price index is used to deflate estimated expenditures on machinery in calculating USDA's index of machinery inputs, but the former SRS price index is not quality-adjusted. The BLS, on the other hand, attempts to make quality adjustments in its price index. The difference between the SRS "tractors and self-propelled machinery" price index and the most nearly comparable BLS price index has widened considerably in recent years (fig. 3). Griliches explored this problem and found, among other things, that between 1950 and 1960 the ratio of USDA's to Fettig's quality-adjusted tractor price index increased by about 1 percent per year (*20*). In other words, if the SRS and BLS price indexes are set equal in 1950, the SRS index exceeds the BLS index by about 10 percent in 1960. Making a similar comparison for the 1967-77 period, we find that the SRS price index has grown at about a 2-percent-per-year faster rate than has the BLS index. The SRS index exceeds the BLS index by about 20 percent for 1977, if the SRS and BLS indexes are set equal in 1967. Thus, the downward bias in USDA's measurement of the rate of productivity growth in the machinery input (and the corresponding overstatement of the rate of productivity growth) may be twice as large in recent years as it was during the 1960's.

No quantitative evidence on measurement error exists for irrigation equipment and equipment housed in service buildings. It does seem that the amount of factor services is being understated in the current statistics, but it is not clear that the bias is increasing over time. Even if it is not, the increasing importance of these inputs means there is a tendency for the growth of total inputs to be understated, and hence, productivity growth to be overstated.

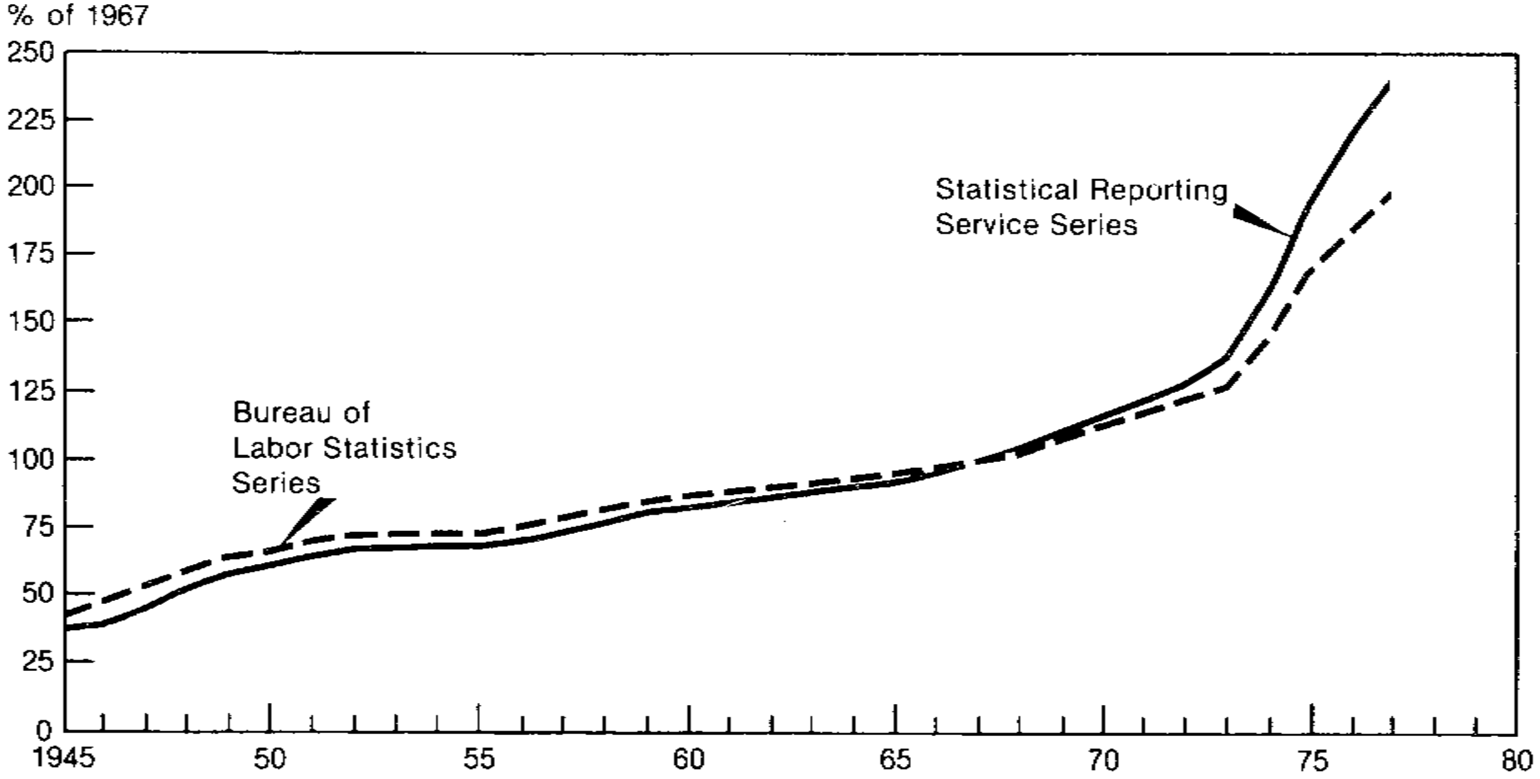
The effects of more appropriate accounting for output and input associated with the cattle breeding herd (both dairy and beef) are currently being explored in the income and finance program area of NED. Measured aggregate output is found to increase by an average of about 1.5 percent over the 1965-1977 period when breeding herd capital accumulation is accounted for. On the other hand, including breeding herd capital consumption (depreciation in value plus death loss) results in similar magnitudes of adjustment on the input side. The overall result is that the multifactor productivity index for 1977 is increased by 1 index point, from 118 to 119, when the more appropriate measurement is used. Thus, the measured rate of productivity growth between 1967 and 1977 is increased by roughly 4 percent (from 18 to 19 percentage points).

Overall, the task force was unable to determine if the USDA multifactor productivity index has tended to overstate or understate the rate of productivity growth in agriculture. There is ample opportunity for bias in either direction in both the level and rate of change in the aggregate input index. It seems likely that bias and error have increased in recent years as we get further from the 1967-69 benchmark used in constructing the input measures. Certainly a measured slowdown (or increase) in the multifactor productivity index's growth rate in, say, 1970-76 as compared to 1950-1970, cannot confidently be taken as an indicator of anything important.

However, while not obviously imbued with cheery optimism, the task force is not as skeptical as Kenneth Robinson's 1957 position that, "Changes in output are due to a complex combination of changes in scale, substitution (based on changes in price relationship), and the development of entirely new inputs and methods of combining inputs (new production surfaces). One cannot, in retrospect, sort out how much of this change was due to any of these factors." (*41*) Since these words were written, much progress has been made in sorting out these factors. This progress was dependent on the output and input statistics that have been developed in the past 20 years, and on the ingenious analytical methods that have been applied to them by researchers in production economics. We believe that there is reason to expect substantial further progress.

Figure 3

Farm Machinery Price Paid Index



RECOMMENDATIONS

This section serves as a guide to improvements in the measurement of agricultural productivity.

Improved Productivity Measurement

The task force has two types of recommendations to offer: specific proposals to deal with problems that have been identified in this report, and general ideas for improving the institutional mechanism for generating productivity statistics. The specific proposals follow closely the preceding discussion, being intended to improve measurement in the problem areas. Some such recommendations have been scattered through the report. In this section, these proposals are collected, and further attention is given to the alternatives available for dealing with data problems.

While the task force gave some thought to budgetary and manpower restraints as they affect the feasibility of improvements in the USDA statistics, we do not attempt to recommend levels of resource commitment. In formulating its recommendations, however, the task force tried to avoid asking for the impossible, and even the outrageously expensive. Because many of the problems do not have obvious or easy remedies (undoubtedly the reason why they persist in being problems), it is as important to suggest general strategies for treating the issues as to suggest particular changes. Indeed, while the general recommendations of the task force are necessarily more tentative, they may be more important in the long run.

The recommendations are couched in the framework of suggestions for productivity measurement in USDA. This approach is taken not to be especially critical of USDA's statistics, but on the contrary, because we believe the USDA productivity measurement effort is the best base from which to move forward in a practical context.

Institutional Framework for USDA Productivity Measurement

The problem areas in measuring U.S. agricultural productivity are pervasive and fundamental, so much so that the effort to generate productivity measures is more properly regarded as a research program rather than a project in the mechanical gathering and presentation of statistics. While the task force has many suggestions to offer, the main general criticism of past performance is that productivity measurement has been, and is, being handled as a number-generating exercise to the neglect of efforts to improve and assess alternatives to currently used methods.

Here we echo a recent comprehensive survey of Federal statistics, which came to the following conclusion (among others):

> The committee finds federal statistical activities deficient in resources devoted to analysis as distinct from collection of the data. Too many dollars are annually spent on the collection and processing of data which are then published in routine tabulations without evaluation or without the documentation which would permit others to perform the evaluation, and with little attention to the meaning of changes in the figures, the relationships of the figures to related series, the importance of differences apparent in the data, or the problems of measurement inherent in the subject under study[4].

The overconcentration on bare numbers is most apparent in the annual publication of input, output, and productivity indexes in *Changes in Farm Production and Efficiency* (*12*). The 1977 publication contains 67 tables of statistics, mostly index numbers, with virtually no documentation of sources or methods. Following 25 tables of production and land use figures, one can read 24 tables of data on "total hours used for farmwork" without a hint that the latter are not independent estimates but are essentially derived from the former via requirements coefficients.

In reality, the substance of the data in *Changes in Farm Production and Efficiency* is more like the results of a research report by ESCS economists than an ESCS data collecting effort (*12*). Yet it is published in a form more nearly resembling the ESCS *Crop Production* or similar series (*56*). It is recommended that the publication containing the USDA productivity statistics be changed to contain a ratio of text to figures closer to the *Wheat Situation* than to *Crop Production* (*62*).

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[4] The Joint Ad Hoc Committee on Government Statistics, "The Professional Associations and Federal Statistics," report to sponsoring associations, April 1978, p. 6.

A change of title might also be in order to describe more accurately what is in the publication, such as "Statistics of Agricultural Production, Resource Use, and Productivity." And the text should focus on discussing the sources, methods, and alternatives to the figures presented, in addition to interpreting the behavior of the measured series, as is done in the 1977 publication's five pages of text. One way to make the space for this would be to limit printing of regional data to the multifactor productivity index and to publish national data only for the output categories. Such a change would have reduced the number of tables in the 1977 publication from 67 to 11. The expanded text would periodically, perhaps every 5 years, describe the construction of the statistics in greater detail. Each year could present some experimenting with alternative approaches to particular measurement problems and tests of the sensitivity of measured productivity to the alternatives.

Some change in emphasis could be accomplished with a staff no larger than currently is utilized (though it would be preferable to see more people devoted to the area). Some of the exploration and measurement alternatives being asked for are the kinds of things the staff already does. We are asking that the deliberations and alternative results obtained in the kind of work already done be written up for the report.

The idea of productivity measurement as a research program also suggests that there is room for use of a decentralized data system for productivity measurement. Especially for regional- or commodity-specific productivity measures, university or private analysts could be encouraged to contribute experimental measurement efforts in the ESCS publication. Specific results could be occasionally included on such issues as using the output and input data in accounting for sources of growth. Thus, the ESCS publication would function, in part, as an instrument for disseminating research on agricultural productivity measurement along with the best data currently available to the purpose.

As part of the dissemination function we recommend that the effort currently underway be continued to put USDA's detailed input and output statistics on magnetic tape in a form readily available to users. This step should do much to facilitate experimentation and improvement in productivity measurement in the decentralized data system without needless repetition.

Methods of Productivity Measurement

The task force considered recommendations on two types of issues: first, conceptual issues involving the proper specification of outputs, inputs, and economic agents, in order to obtain the most meaningful quantitative indicator of productivity; and second, specific proposals for putting into practice the conceptually appropriate measurement.

Conceptual Issues

The problem of conceptual obsolescence, which has been emphasized by the AAEA's Economic Statistics Committee, affects the measurement of productivity primarily in deciding exactly which activities, firms, and individuals are to be included. It is natural to consider activities on farms by farmers. The set of economic activities conducted in establishments officially designated as farms and the relationship between the activities on farms and the activities by people who live on farms have changed so much over time as to call in question the usefulness of the concept of a "farm" as a basis for aggregate, intemporal comparisons. Fortunately, the task force believes that the basic conceptual framework for productivity measurement exists and is readily applicable to agriculture, namely, the economic theory of production built upon the basic technological relationship of the production function.

In keeping with this framework, we wish to commend the USDA productivity measures for two respects in which they remain ahead of productivity measures for most nonagricultural sectors: first, the concentration on multifactor opposed to partial productivity indexes; and second, the use of a gross as opposed to a net or value-added measure of output. Both of these conceptual issues, particularly the latter, raise difficult choices. In both cases, however, the task force came out in favor of the choice made in the USDA measurement.

The main conceptual change that we recommend is to move further toward a total factor productivity measure. This change involves taking into account qualitative aspects of inputs wherever possible. For example, hired, operator, and family labor should be handled separately to the extent that the data allow. There should be a general effort to improve the measurement of service flows from new inputs and production techniques. The task force formed opinions on particular kinds of improvements that seem most promising, but the development of close-to-total productivity measure remains essentially a research issue. Developments here are part of the research function that we recommend for a more important part of the ESCS productivity measurement effort. We are not ready to support including specific new or nonconventional inputs in USDA's official productivity statistics.

A second important conceptual change follows from the conceptual instability that exists in the notion of a "farm." We should concentrate on the product, rather than attempting to define the productivity of particular social entities or business establishments. Our underlying concern is how the function of producing raw agricultural products is being performed. Concerns as to which firms perform this function and the labels attached to these firms are of low priority. Another reason for this recommendation is that the conceptual basis for a productivity index, flowing from production functions, retains much more of its integrity if the stage of production at which inputs and outputs are measured remains as uniform as possible over time. Finally, cross-sectional comparisons of productivity, such as international comparisons, must be based upon comparable definitions if the analyses are to have meaning; this is easier to attain on a product basis.

The recommendation of this general approach leaves unanswered the issue of where one draws the line between agricultural production and food processing and marketing. The task force concluded that the first point of assembly upon completion of production should uniformly be used to determine agricultural output. First point of assembly is commonly identical with the "point of the first sale" with quoted country prices—the country livestock market, the grain elevator, the creamery, and the plant of the fruit or vegetable processor. This is, of course, advantageous in terms of reflecting industry practice and sampling prices. However, first point of assembly may come after the point of first sale; for example, there are products, usually fruits and vegetables, for which procurement and processing firms provide or assist in some production processes such as spraying and harvesting. On the other hand, the point of first sale may extend beyond the country assembly point and thus includes more than production plus local delivery; for example, some eggs are sized, candled, boxed, cartoned, and distributed to retail stores by integrated poultry firms. When first point of assembly and point of first sale do not coincide, adjustment of transaction prices to reflect the value of the output at the boundary of the agricultural sector is necessary.

The distinction between the input and the agricultural production sectors should continue to reflect two factors. First, agricultural functions should be closely related to a dependence on biological processes. For example, while the mechanized egg-producing plant and tractor assembly plant have much in common, the former is more intimately tied to biological processes than the latter. Second, tradition will continue to play a role in the partitioning of functions. However, the tradition should cease of using the farmgate, that is, an establishment rather than a product basis, as the boundary between the two sectors. In other words, the set of functions included in agriculture should remain as stable as possible over time, rather than varying as establishments take on or cast off functions.

A more specific set of conceptual issues involves what outputs and inputs should be incorporated in a measure of agricultural productivity. Some of these issues turn on balancing the desire for a near total accounting for inputs against a deterioration of data quality and continuity. In other cases, the choice depends on the use to which the productivity measure is to be put.

Treatment of Set-Aside Land

Land diverted from its optimal commercial use in response to government programs is not an input into a production function in the ordinary sense. Therefore, if one is interested in using the land input in growth accounting via production functions, then set-asides or other diverted land should be excluded. Otherwise, it may be argued that a performance measure for agriculture as a sector is made more meaningful by the inclusion of diverted acreage. The preferable approach depends on which purpose the productivity measure is to fill. (Some task force members argued that if diverted acreage is to be counted as an input then diversion payments should be counted as output. The argument is that if one counts politically imposed costs on the input side, then one should count political benefits on the output side. The counterargument is that net political benefits are zero since taxpayers pay whatever producers receive.)

A practical problem also comes to bear, however, in that diverted acreage under many programs does contribute to output. It has been permitted to grow certain crops on land idled under some programs, and more important, the farmers' options for choosing land to divert and comply with program provisions have left leeway for substantial "slippage." The result is that subtracting all land officially labelled as diverted for program purposes would understate the land input and, hence, overstate productivity.

The task force recommends that USDA for the present continue its current practice of including diverted or set-aside acreage in the land input. However, an estimate of diverted acreage should be included as a separate input item so that users can make adjustments to estimate a land input index excluding such acreage.

Treatment of Underemployed Labor and Excess Capacity in Machinery or Other Capital Equipment

While it would be tempting to try to adjust for these factors for some purposes, the task force recommends that no attempt be made to accomplish these adjustments in USDA's official productivity statistics. There is the practical problem that we are very far from having appropriate data to the purpose, apart from the conceptual problems in identifying excess labor or capital and asserting that the excess is valueless in production. It is important, however, that time devoted by part-time farmers to work outside of agriculture not be counted as an agricultural input.

Improved Accounting for Natural Resource Inputs

The main issues here involve water, depletion of land, and environmental inputs.

On water resources, the task force recommends that service flows from irrigation be given more explicit attention. While attempts are currently made to include costs of operating and owning irrigation equipment, these should be broken out as a separate input category and combined with service charges on the value of water itself. The quantity index of land currently includes the effects of irrigation, because a higher base-period price weight is placed on irrigated land. A better approach would be to break out the added base-period value of irrigated land as a separate input item, which would increase (decrease) over time as land moved under (out of) irrigation.

On the depletion or depreciation of land, while this could conceivably be similarly fashioned after the depreciation of buildings or other capital items, the task force does not recommend attempting this measurement because the economic and statistical basis for it does not exist and is not on the horizon. We do recommend that expenditures on conservation and reclamation activities be counted on the input side. However, as durable capital items they should not be counted as input expense items in the year incurred (the current procedure) but should instead be depreciated. This is not a subject on which immediate adjustments can satisfactorily be made, but there should be continuing efforts to explore ways to improve our measurement capabilities.

The conceptual issue in environmental resources is more complicated. It is necessary to account for changes in the output side through recognizing that use of waterways and the atmosphere for waste disposal is a real input to agricultural production, and that compliance with environmental regulations is a real resource cost. The agricultural sector produces not only raw food and fiber but also various kinds of good and bad joint products. The proper means of productivity measurement in this area is a most important one to investigate and is even more a research problem than the other natural resource issues. The task force recommends that such research be undertaken. However, in this as in other research areas, we do not recommend that progress in productivity measurements be seen as primarily a function of USDA. Here the land-grant universities or other participants in the private, decentralized data system have an apparent comparative advantage.

Nonconventional Inputs

The main issues here involve management and overhead costs, public infrastructure, and research.

On management and overhead costs, agricultural production increasingly makes use of services that were perhaps negligibly important in the past but may not continue to be so. These should be counted in input service flows. Examples include legal expenses, tax and other accounting services, and general managerial skills. Estimates of legal fees and tax consulting expenses are currently made in ESCS but not used in productivity accounting. The task force recommends that they be counted as inputs, and that similar expenses also be included as the data permit. The issues are more exactly ones of quality of labor input with respect to managerial skills.

Public infrastructure and research are undoubtedly important nonconventional inputs, but current knowledge and data are insufficient to incorporate them into the official input statistics. The current USDA input indexes already include one element intended to measure public services, the value of property taxes paid. While the task force did not find the argument convincing that property taxes measure public inputs into agricultural production, we do accept the idea that property taxes at least partially measure service flows from land. Therefore, we recommend that USDA retain property taxes in its input accounting, but that they be shifted from the other inputs category to the land input index.

Agricultural research and other public inputs, like the natural resource issues, should be treated for the present as matters for research on productivity measurement. The knowledge base is too insecure to attempt an immediate index to measure these nonconventional inputs.

Productivity Measurement for Specific Commodities

The task force recommends that ESCS not devote major resources to calculations of multifactor productivity indexes for individual commodities. New resources would be better spent in refining the measures of outputs and inputs underlying the currently available multifactor productivity indexes, and pursuing needed analyses of these refined data. Exceptions to this recommendation may be warranted where a commodity is produced independently of other commodities, in terms of an absence of both output interactions and shared inputs. Some task force members saw merit in separate productivity indexes for the broad categories of crops and livestock.

The task force also recommends continuation of two specialized but useful classes of productivity indexes now calculated and published. First, partial productivity measures such as crop yield per acre and pounds of meat per pound of feed are useful measures whose marginal cost is very low, given other needs for the separate measures of inputs and outputs. These measures accomplish the objective of providing a commodity-specific description of change. In addition, the unrefined nature of these series is well understood. Many factors, among them weather and fertilizer, are potentially the cause of observed changes. Second, the regional index of multifactor productivity should be continued. Disaggregation on a geographic basis does not suffer from the same interdependency problems as does disaggregation on a commodity basis. Typical combinations of enterprises in a region are left intact rather than arbitrarily disentangled. Many questions which are originally stated in terms of specific commodities are best answered in terms of regional data. For example, a comparison of productivity change among Corn Belt, Delta States, and Northern Plains systems of agriculture may very well be more meaningful in economic and policy terms than an attempted comparison of productivity change among corn, cotton, and wheat commodities.

Measuring Quality Change and New Inputs

No area of improvement in productivity statistics is more important than the measurement of quality change in inputs for the purposes of improved growth accounting. Given the input categories in use for past data, the most practical way of handling new inputs is to account for them as being effectively qualititative changes in old inputs (see the prior discussion of chemicals). However, quality measurement is not yet well enough nailed down, even for areas which have been most extensively studied such as labor, to yield a quality-adjusted input index in which one can have confidence. Nonetheless, the task force believes that even when accurate measurement is not possible, a conceptually more appropriate measure is often preferable to a more accurately measured but less relevant statistic. Therefore, we recommend that USDA move to publish such quality adjusted input measures as can be made available, with the help of research work done outside USDA to the extent necessary. At the same time, the unadjusted quantity indexes should continue to be published and for the time being, continue to be used in generating the official productivity statistics.

Specific Recommendations on Techniques of Measurement

The conceptual recommendations address the problem of defining an appropriate productivity measure and the corresponding input and output specifications. The task force also considered some of the detailed steps that would help in bringing the existing statistics more nearly into conformity with a conceptually appropriate productivity measure. They are as follows:

1. With respect to weighting of input categories, the task force endorses the idea put forward in Jorgenson and Griliches and in Christensen that index-number problems resulting from Laspeyres factor price weights would be reduced by use of annual factor share weights used in a discrete time approximation to a Divisia index of inputs (*26, 5*). This approach should be tried out and, if it proves operationally feasible, adopted.

2. The labor input index should be based on direct sampling instead of the requirements approach. The requirements approach by its nature cannot detect changes in productivity trends independently of assumed production coefficients. The sample surveys of both USDA's ESCS and the Census Bureau's Current Population Survey do give independent estimates of labor use which may then be compared to output. Unfortunately, both of these surveys have problems, but we regard either as a lesser evil compared to the requirements series currently used. If the SRS data were moved to a monthly survey instead of the current quarterly sampling, it would be our choice as a basis for the national labor input.

3. The labor input data should be handled separately for hired, operator, and family labor, each weighted to construct an aggregate by their relative wage rates. (In both 2 and 3, our recommendations follow the current practice of Agriculture Canada).

4. Immediate adjustment should be made in the procedures for converting land stock to a service flow. First, the inflation premium in long-term interest rates is becoming large enough to cause an overstatement of service flows when the mortgage interest rate is used to convert stocks to flows. The task force recommends that the estimated ratio of base-period cash rental value to stock value be used as the basis for stock/flow conversion (currently used for the equity portion of land owned). Second, whatever conversion factor is used, it should be the same for land owned as equity and mortgaged land, since the real flow of services is not a function of the financial arrangements. Third, reflecting the discussion of property taxes above, base-period property taxes, as a fraction of land value, should be added to the conversion factor.

5. With respect to service flows from public lands, Federal grazing fees should be replaced by a shadow-rent estimate based on the rental value of comparable private lands.

6. Some of the weakest basic input data relate to the stocks of machinery and equipment. While this situation cannot be corrected immediately and without substantial cost, we believe the improvement of data on stocks of capital equipment, including quality aspects, should be a high priority item in developing future Agriculture Census and other surveys.

7. The task force recommends that procedures for depreciating structures and capital equipment be changed to reflect better the economic value of services at each point of an item's lifetime.

8. Where possible, BLS price indexes for machinery should be used instead of SRS indexes. Alternatively, USDA could undertake its own quality adjustment of the SRS price indexes.

CONCLUSIONS

The Task Force on Productivity Measurement was unable to go as far as it would have liked toward providing a practical recipe for attaining ideal measurement of U.S. agricultural productivity. There are simply too many open questions at both the theoretical and practical levels to be confident about the final appropriateness of some recommendations. The task force was struck at several discussion points by the aptness of Swanson's emphasis that the appropriate measurement of productivity cannot be specified independently of the use one has in mind for such statistics (*51*). Morever, in several areas where no analytical subtlety is required, but only commitment of resources to carry out better data measurement, the task force was hindered from strong recommendations by uncertainty as to the marginal value of the improvements compared with the (in some cases, very large) marginal costs of the necessary surveys and data processing. In short, productivity measurement was very much a research question at both the theoretical and practical levels.

There is an apocryphal saying around Washington, D.C., that "an index is worth a thousand reports." Given that policymakers seem more pressed for time than report-writers, one may see good reasons for the appeal of an index. Nonetheless, the desire for a simple numerical answer may be dangerous. While the task force found many areas in which it seems that improved productivity measurement is possible, the most serious current mistakes are believed to arise not from limitations of the statistics but from the limitations of the users of these statistics. Thus, the task force believes the earlier sections of our report on the meaning and use of productivity measures are as important as the recommendations on improved measurement. In the end, there is no substitute for an informed use of productivity statistics, especially if one wishes to use them as ammunition in political argument.

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Appendix table 1—1967 base period quantity-price aggregates for components of the farm input index, in 1967-69 dollars, by regions and United States

Component	Northeast	Lake States	Corn Belt	Northern Plains	Appalachian	Southeast	Delta States	Southern Plains	Mountain	Pacific	United States
	Thousand dollars										
Farm labor	694,201	914,760	1,388,400	742,759	868,150	687,060	444,000	641,700	477,020	1,138,941	7,996,991
Hired labor	159,319	209,937	318,638	170,463	199,240	157,680	101,898	147,270	109,476	261,387	1,835,308
Operator labor	409,509	539,617	819,017	438,154	512,122	405,297	261,916	378,539	281,394	671,861	4,717,426
Unpaid family labor	125,373	165,206	250,745	134,142	156,788	124,083	80,186	115,891	86,150	205,693	1,444,257
Farm real estate	298,979	673,430	2,176,335	1,112,781	797,402	537,561	603,683	1,002,375	732,643	986,281	8,921,470
Real estate service charges on equity	116,386	372,051	1,518,189	833,215	582,655	372,124	449,208	756,128	496,787	669,101	6,165,844
Interest on real estate mortgages	75,067	161,169	341,571	157,581	101,774	97,627	98,789	164,279	159,206	210,296	1,567,359
Depreciation on service buildings	38,610	48,489	99,767	34,811	38,546	21,371	17,849	21,549	18,769	29,250	369,011
Accidental damage to service buildings	10,682	14,465	31,211	12,235	10,806	6,447	5,156	7,194	6,216	9,189	113,601
Repairs on service buildings	58,149	77,229	184,563	67,306	62,984	39,550	32,665	52,180	41,548	65,018	681,192
Grazing fees, total	85	27	1,034	7,633	637	442	16	1,045	10,117	3,427	24,463
Mechanical power and machinery	707,758	1,211,500	2,590,350	1,462,097	902,106	604,979	581,814	993,644	814,867	822,774	10,691,889
Automobile depreciation, farm share	31,229	51,381	93,695	40,294	60,168	30,102	22,305	33,147	19,472	21,056	402,849
Interest on automobile inventory	8,815	15,252	27,192	11,853	17,182	9,186	7,048	9,897	5,791	6,365	118,581
Automobile repairs, parts, and tires	8,161	15,444	28,758	16,169	11,917	6,096	5,433	9,531	8,600	8,118	118,227
Automobile licenses, farm share	2,049	2,879	5,302	2,606	1,909	991	885	1,600	1,116	1,540	20,877
Automobile insurance, farm share	7,651	10,749	19,793	9,729	7,126	3,699	3,303	5,974	4,169	5,749	77,942
Tractor depreciation	77,925	136,200	238,499	117,566	101,422	51,579	48,410	76,510	52,035	50,862	951,008
Interest on tractor inventory	36,976	67,992	116,386	58,154	48,709	26,455	25,705	38,425	26,032	25,845	470,679
Tractor repairs, parts, and tires	42,485	82,362	144,313	71,711	57,070	30,940	35,630	68,699	34,486	46,265	613,961
Truck depreciation	41,212	57,203	111,948	75,912	73,113	44,053	38,416	65,539	48,251	45,031	600,678
Interest on truck inventory	10,683	15,592	29,838	20,516	19,164	12,342	11,149	17,964	13,182	12,498	162,928
Truck repairs, parts, and tires	26,800	24,611	48,275	33,944	31,955	20,254	19,053	36,979	34,690	28,316	304,877
Truck licenses	9,347	7,252	14,071	8,206	7,351	4,895	3,536	6,744	5,803	7,612	74,817
Truck insurance	16,720	12,969	25,168	14,678	13,148	8,756	6,326	12,062	10,380	13,615	133,822
Depreciation on other farm machinery	132,965	248,424	691,591	342,807	128,565	98,254	119,351	157,719	174,434	121,174	2,215,284
Interest on inventory of other farm machines	54,245	134,507	226,461	171,246	51,459	35,664	29,201	77,776	80,048	59,648	920,255
Other farm machines: repairs, parts, and tires	31,526	58,902	163,977	81,280	30,483	23,296	28,298	37,395	41,358	28,730	525,245
Fuel and oil [including gasoline]	108,951	161,456	362,013	226,820	151,532	115,605	111,327	180,539	130,351	126,965	1,675,559
Electricity, farm share	18,711	24,450	37,733	13,228	16,177	11,554	8,191	15,200	20,322	81,011	246,577
Blacksmithing and hardware	2,939	5,540	11,240	15,596	5,549	4,886	3,953	15,302	22,665	6,288	93,958
Harness and saddling	691	662	1,647	1,095	2,366	1,111	1,312	1,407	1,694	684	12,669
Small hand tools	4,562	7,009	13,880	5,776	8,204	4,206	3,370	4,843	3,690	4,308	59,848
Custom work	33,115	70,664	178,570	122,911	57,537	61,055	49,612	120,392	76,298	121,094	891,248
Agricultural chemicals	195,036	228,028	741,053	199,730	249,802	302,441	154,679	180,855	120,112	265,942	2,637,678
Nitrogen fertilizer	36,368	38,769	187,006	69,525	56,399	78,536	33,378	57,279	40,711	94,224	692,195
Superphosphate fertilizer	65,553	76,595	237,258	65,735	70,112	66,257	21,756	48,724	33,387	42,636	728,013
Potassium fertilizer	28,960	37,704	110,270	5,279	46,303	53,417	14,627	7,756	1,288	7,775	313,379
Limestone	17,553	7,803	42,990	2,263	17,608	15,430	10,167	3,618	76	2,872	120,380
Pesticides	46,602	67,157	163,529	56,928	59,380	88,801	74,751	63,478	44,650	118,435	783,711

Continued——

Appendix table 1—1967 base period quantity-price aggregates for components of the farm input index, in 1967-69 dollars, by regions and United States—Continued

Component	North-east	Lake States	Corn Belt	Northern Plains	Appala-chian	South-east	Delta States	Southern Plains	Moun-tain	Pacific	United States
						Thousand dollars					
Feed, seed, and livestock purchases	313,674	309,277	705,365	249,555	156,243	193,607	143,398	174,272	161,585	275,911	2,682,887
Total seed input	32,106	21,011	94,121	23,706	21,019	18,583	16,711	16,228	11,148	31,785	297,418
Total feed input	191,809	165,811	445,284	152,437	73,740	97,635	68,327	101,334	106,484	191,291	1,594,152
Milk hauling	35,554	66,446	55,867	9,164	13,880	6,835	6,925	16,261	4,237	16,089	231,258
Livestock marketing	8,297	26,736	76,439	55,954	13,388	10,816	8,985	21,546	34,467	9,415	266,043
Baby chickens purchased, broiler type	30,247	2,356	4,788	320	21,042	39,977	29,554	9,873	772	8,428	147,357
Baby chickens purchased, layer type	14,052	8,995	19,545	6,760	8,772	18,111	10,247	5,920	2,336	12,407	107,145
Baby turkeys purchased, heavy breeds	1,440	5,552	8,800	1,057	3,272	1,575	2,543	3,033	2,116	6,274	35,662
Baby turkeys, light breeds	169	1,370	521	157	1,130	75	106	77	25	222	3,852
Taxes and interest	252,193	429,073	1,071,600	627,807	201,865	174,411	128,218	353,979	344,477	488,838	4,072,461
Taxes: real estate	118,991	178,259	474,076	233,197	62,945	67,063	39,463	130,922	110,384	285,063	1,700,363
Taxes: personal property	6,887	33,135	128,241	80,765	16,179	12,825	9,485	32,234	37,426	50,756	407,933
Capital charge on inventory of:											
Cattle and calves	74,788	121,180	192,734	184,259	66,798	50,664	48,344	130,764	126,312	88,479	1,084,322
Hogs and pigs	2,121	11,587	66,820	12,746	8,095	5,491	1,628	1,963	1,134	898	112,483
Sheep and lambs	410	1,323	3,407	3,846	806	23	57	4,851	13,292	3,874	31,889
All chickens	6,200	2,412	4,718	1,303	2,771	5,809	3,018	1,653	584	4,712	33,180
All turkeys	117	478	338	57	298	95	61	252	74	794	2,564
Corn	1,981	17,454	66,951	18,105	4,147	2,374	627	325	551	218	112,733
Oats	591	3,796	2,842	3,066	129	80	45	201	290	95	11,135
Barley	156	397	27	1,988	107	10	0	83	2,006	698	5,472
Grain sorghum	0	0	207	6,806	42	16	33	1,004	428	176	8,712
Hay	7,014	9,297	12,511	10,092	5,233	1,550	1,614	3,305	8,662	3,741	63,019
Forage	2,337	4,406	4,369	4,768	1,716	579	437	1,001	1,164	430	21,207
Wheat	316	1,020	1,047	13,975	157	17	34	639	5,659	1,300	24,164
Soybean	76	4,439	16,523	1,684	1,063	997	2,402	52	0	0	27,236
Interest on operating capital	19,930	24,615	63,100	31,754	20,296	20,521	15,937	25,289	21,123	33,993	276,558
Interest added by non-real estate debt	10,278	15,275	33,689	19,396	11,083	6,297	5,033	19,441	15,388	13,611	149,491
Miscellaneous	131,543	123,476	175,025	86,649	86,996	75,876	89,040	124,637	120,102	202,348	1,215,692
Insurance: fire and wind	15,614	22,324	42,844	12,414	17,194	10,038	10,180	8,706	6,839	11,294	157,447
Insurance: crop-hail (net)	438	4,197	2,694	8,874	8,355	1,889	19	3,284	4,502	1,801	36,053
Insurance: Federal crop (net)	-50	2,382	2,088	-1,029	787	-2,043	-176	-2,507	-358	1,030	124
Containers	37,258	9,581	5,877	1,224	5,997	8,947	1,278	1,315	11,312	47,317	130,106
Binding materials	9,743	14,439	16,870	11,744	5,919	2,128	2,741	5,590	12,336	8,759	90,269
Dairy supplies	17,065	19,825	12,185	3,761	5,699	2,884	1,707	2,590	3,133	9,376	78,225
Irrigation operating and maintenance charges	0	0	0	3,997	0	212	6,776	14,734	43,237	67,912	136,868
Veterinary	37,516	33,012	55,882	27,971	26,105	35,724	26,978	20,411	15,319	20,932	299,850
Telephone (farm share)	13,959	17,716	35,338	17,693	13,504	7,224	5,215	11,056	10,462	11,069	143,236
Ginning charges	0	0	1,247	0	3,436	8,873	34,322	59,458	13,320	22,858	143,514
Total inputs	2,593,384	3,889,544	8,848,128	4,481,378	3,262,564	2,575,935	2,144,832	3,471,462	2,770,806	4,181,035	38,219,068

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