Evaluating Agricultural Research and Productivity

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AGRICULTURAL PRODUCTIVITY MEASURES FOR U.S. STATES 1950-1982

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Productivity measures are of interest for two purposes. First, under certain carefully documented situations they can be used for comparative purposes. That is, one can compare productivity levels in one period with levels in another period or productivity levels in one region with productivity levels in another region. Second, productivity measures can be used to facilitate the statistical association of productivity change with determining variables (the term productivity decomposition is used here to describe this analysis). For both purposes productivity measures at a relatively detailed level are useful.

At present the USDA provides measures of total factor productivity at a ten region level for U.S. agriculture. These measures, available for the period 1939-1983, have been subject to critical review in the past, but the USDA has not responded to the criticisms offered by revising its procedures.[1] The only prior total factor productivity series computed at the State level is by Landau and Evenson for the 1949-71 period.[2] This series served as the basis for decomposition analysis in previous work by Evenson, Waggoner and Ruttan in which returns to agricultural research, extension and schooling were computed.[3]

In this paper we report a new total factor productivity series at the state level for the 1950-1982 period. Part I of the paper outlines the methodological issues inherent in productivity measurement. Part II addresses particular issues for state level productivity measurement. Part III summarizes the new state measures, compares them with the regional USDA measures, and discusses their reliability. Part IV provides concluding comments.

I. PRODUCTIVITY MEASUREMENT

There are basically two formal procedures for deriving total factor productivity (TFP) indexes. The first, and in many ways simplest, is to derive the measure from an economic accounting measure. The second is to derive the measure from a production function or from the cost function associated with the production function. The relationship can also be derived from the output supply and factor demand equations associated with the profits function. In the case of the accounting derivation no knowledge of the production "curvature," i.e., the form of the production or transformation function, is presumed. In the case of the production and cost function derivations such knowledge is presumed but an approximating index formulation (the Divisia) is often used rather than actual estimates of these functions. This Divisia index is the same index form derived for the accounting relationship.

The Accounting Derivation

Suppose that an economic sector is in long run equilibrium. Firms may be technically efficient and they may be minimizing costs and maximizing profits, but they need not be. In equilibrium, firms will not be making profits (i.e., abnormal profits). This produces the accounting relationship where

$$(1) \quad \sum_i P_i Y_i = \sum_j R_j X_j$$

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where the Y_i are outputs with prices P_i, and the X_j are inputs with prices R_j. (Note that "quasi-fixed" factors such as land or buildings are treated as having a "rental" or service price.)

Now differentiate (1) totally with respect to t

$$(2) \quad \sum_i Y_i \frac{\partial P_i}{\partial t} dt + \sum_i P_i \frac{\partial Y_i}{\partial t} dt = \sum_j X_j \frac{\partial R_j}{\partial t} dt + \sum_j R_j \frac{\partial X_j}{\partial t} dt$$

This expression is exact for infinitely small changes. For discrete or finite changes, index number problems must be dealt with.

Divide the left-hand side of (2) by $\sum_i P_i Y_i$ and the right-hand side by $\sum_j R_j X_j$ -- the two sums are equal. Then multiply the first term of (2) by P_i/P_i, the second by Y_i/Y_i, the third by R_j/R_j, and the fourth by X_j/X_j. Note that

$Y_i P_i / \sum_i P_i Y_i = S_i$, the output share of the ith output

and $X_j R_j / \sum_j R_j X_j = C_j$, the input cost share of the jth input.

Let $\hat{X}_j = \frac{1}{X_j} \frac{\partial X_i}{\partial t} dt$ be a rate of change.

This produces:

$$(3) \quad \sum_i S_i \hat{P}_i + \sum_i S_i \hat{Y}_i = \hat{p} + \hat{y} = \sum_j C_j \hat{R}_j + \sum_j C_j \hat{X}_j = \hat{r} + \hat{x}$$

where $\hat{p}$, $\hat{y}$, $\hat{r}$ and $\hat{x}$ are now rates of change of aggregated output prices, output quantities, factor prices and factor quantities respectively. The rate of change in total factor productivity $\hat{T}$ is now defined as

$$(4) \quad \hat{T} = \hat{y} - \hat{x} = \hat{r} - \hat{p}$$

The motivation for this definition is that $\hat{T}$ captures efficiency gains. The following six interpretation of these gains can be given:

(a) Suppose all inputs stay constant (i.e., $\hat{x} = 0$), $\hat{T} = \hat{Y}$ measures the increase in output (or output index) achievable at constant input levels.

(b) If all outputs are constant, $\hat{y} = 0$, $\hat{T} = \hat{x}$ then measures the reductions in input requirements at constant output levels.

(c) If both inputs and outputs change, then $\hat{T} = \hat{y} - \hat{x}$ is the increase in total factor productivity. Note that the change in the output/input ratio (or factor productivity for a single factor is

$$\frac{\partial}{\partial t} \left[\frac{\hat{Y}}{X}\right] / \left[\frac{\hat{Y}}{X}\right] dt = \hat{Y} - \hat{X} = \frac{\partial}{\partial t} \log Y - \frac{\partial}{\partial t} \log X$$

Thus the rate of productivity growth is the rate of change in the ratio of output to input or in the ratio of an output index to an input index.

(d) Suppose all output prices to be constant ($\hat{P} = 0$). This arises when all goods are traded and their prices cannot change or when we consider an individual firm in the large market. Then $T = \hat{r}$. Total factor productivity growth is then the rate of increase in factor prices or factor rewards or factor incomes made possible by efficiency gains.

(e) Suppose all input prices constant, $\hat{r} = 0$. This case would arise if all factors were traded but goods were not. Then $\hat{T} = -\hat{P}$. The rate of total factor productivity change is measured by the reduction in output prices made possible by the efficiency gains

(f) Suppose both input and output prices change

$$\hat{T} = \hat{r} - \hat{P} = \left[\frac{\hat{r}}{P}\right] .$$

Total factor productivity change is the increase in real factor incomes, deflated by the output price (or an index thereof).

Note further that to measure factor productivity we can use both sides of the equation (4) and should arrive at the same answer.

These interpretations provide a general content to the TFP index. Note that one cannot describe the TFP index as a technology change index. Public sector infrastructure investments and closing of the technology gap via extension and schooling investments also produces TFP gains.

Before turning to the productivity description specifications, however, it will be useful to discuss the production and cost function foundation for TFP measures and then to discuss index number problems.

Production Function Derivations

Suppose a single output Y, several inputs (X_1--X_n), and production technology is described by a production function:

$$(5) \quad Y = F(X_1, \ldots, X_n, t)$$

Suppose further that (5) is a linear homogeneous function describing the maximum product technically feasible for any given set of inputs. Note that several things are "held constant" in the background behind this expression. Specifically, the technology set available to farmers, the existing infrastructure (roads, markets) and transactions costs (legal system, etc.) are all treated as constant in (5). One of the purposes of productivity analysis is to infer from data only on Y and the X's the probable contributions to output that changes in these factors in the background contribute.

Differentiate (5) totally with respect to time to obtain:

$$(6) \quad \frac{\partial Y}{\partial t} dt = \sum_j F_j \frac{\partial X_j}{\partial t} dt + F_t \, dt$$

where $F_i = \partial Y/\partial X_i$, the marginal product of the ith factor of production. The first order conditions for profit maximization are:

$$F_j = P_j/P_y$$

where P_j and P_y are prices of inputs and outputs. Substituting these in for the F_j and dividing by Y to obtain:

$$(7) \quad \frac{\partial Y}{\partial t}\frac{1}{Y}\, dt = \sum_j \frac{P_j}{P_j Y}\frac{\partial X_j}{\partial t}\, dt + \frac{F_t}{Y}\, dt$$

Multiplying each term in this summation by X_i/X_i and making use of the property that $\Sigma P_j X_j = P_y Y$ (i.e., that the value of total inputs equals the value of output; this is the "no profit" condition that holds in a competitive economy) we obtain

$$(8) \quad \frac{\partial Y}{\partial t}\frac{1}{Y}\, dt = \sum_j C_j \left(\frac{\partial X_j}{\partial t}\frac{1}{X_j}\right) dt + \frac{F_t}{Y}\, dt$$

where C_j is the cost share for the jth factor.

This expression holds for small changes when the "background variables" are constant. It relates growth in output to growth in factors or inputs. When this equation does not hold, the logic of this development tells us that the background variables have not remained constant. This is the basis for the definition of total productivity change T as:

$$(9) \quad \hat{T} = \frac{F_t}{Y}\, dt = \hat{y} - \sum_j C_j \hat{X}_j = \hat{y} - \hat{x}$$

This development thus leads to the same expression as did the accounting expression. Note that scale economics were imposed to obtain this relationship. Technical errors by farmers in obtaining maximum output, profit maximizing errors and scale economics may, in practice, be included in measures of T.

Cost Function Derivation

The producer minimizing costs subject to the production function (5) solves this economic problem by choosing the cost minimizing combination of factors for any given output.

These cost minimizing quantities can be expressed as functions of prices and quantities of fixed factors. Thus when substituted into the cost relationship, the minimum cost function can be expressed as:

$$(10) \quad C^* = G(R_j, F, t)$$

This expresses minimum unit costs as a function of input prices and fixed factor quantities, F.

Now differentiate (10).

$$(11) \quad \frac{\partial C}{\partial t}dt = \sum_j G_j \frac{\partial R_j}{\partial t}\, dt + G_F \frac{\partial F}{\partial t}\, dt + G_t dt$$

The term $G_t dt$ measures the reduction in unit costs of production holding prices constant. This is a natural definition of productivity change. Transforming to proportional changes gives $T = r - c^*$, and since in competition $c^* = P$ we have the relationship derived earlier. (Note that fixed factors may or may not be given rental values. If not, this is a variable factor productivity measure.)

This relationship can be further developed in terms of factor demand functions. The Shephard-Hotelling lemma states that the first partial derivative of (10) with respect to factor prices are the factor demand curves. These factor demand curves are:

$$(12) \quad X_j = X_j\,(R, t)$$

differentiating

$$\frac{\partial X_j}{\partial t} dt = \sum_j \sum_k X_{jk} \frac{\partial R_{jk}}{\partial t} dt + X_{jj} dt$$

In proportional changes we define $\hat{T} = \sum_j C_j \hat{T}_j$ where $\hat{T}_j = \hat{X}_j dt/Y$.

Profit Function Derivation

Recent developments in profits functions or duality models now enable much richer analysis than afforded by the earlier developments. They allow for the analysis of production of more than one farm output. They also allow an estimate of research and other effects on the supply of each output produced and the demand for each input used. These can then be combined into a productivity effect. (It is also possible to estimate the impact of research on the rent to fixed factors.)

The multiple output model begins with a very general specification:

$$(13) \quad g(Y,X,F,E) = 0$$

where Y is a vector of outputs,
X is a vector of variable inputs,
F is a vector of fixed inputs, and
E is a vector of background variables characterizing technology and other factors affecting production (including research and extension outputs or inputs).

Variable profits are defined as:

$$(14) \quad \pi = PY - RX$$

where P is a vector of output prices and R a vector of variable input prices.

Maximized variable profits π^* are obtained by maximizing (14) subject to (13). The first order conditions for the Y and X vectors can be expressed as functions of P,R,F, and E. Substituting these into (14) yields the maximized profits function.

$$(15) \quad \pi^* = \pi^*(P,R,F,E)$$

Note that maximized profits are now expressed as functions of the exogenous variables only. The choice variables Y and X do not enter into (15) because they are expressed as functions of exogenous variables.

The Shephard-Hotelling lemma states that the first derivatives of (15) with respect to each output price yields the supply function for that output. (See Chapter III.) The first derivatives of (15) with respect to input prices yields the input demand functions. Thus a system of output supply and factor demand equations is derived.

$$(16) \quad \partial\pi^*/\partial P_i = Y_i = Y_i(P,R,F,E)$$

$$\partial\pi^*/\partial R_j = X_j = X_j(P,R,F,E)$$

Note that the E variables, including research variables, enter into each equation in the system (16) as well as in (15).

Differentiating (16) we obtain

$$(17) \quad \frac{\partial Y_i}{\partial t} dt = \sum_i Y_i \frac{\partial P_i}{\partial t} dt + \sum_i Y_{ij} \frac{\partial R_j}{\partial t} dt + Y_{iE} \frac{\partial E}{\partial t} dt + Y_{iF} \frac{\partial F}{\partial t} dt$$

$$\frac{\partial X_j}{\partial t} dt = \sum_j X_j \frac{\partial P_i}{\partial t} dt + \sum_j X_{ij} \frac{\partial Ri_j}{\partial t} dt + X_{jE} \frac{\partial E}{\partial t} dt + X_{jF} \frac{\partial F}{\partial t} dt$$

Treating the $\frac{\partial E}{\partial t}dt$ terms as indexing productivity change, i.e., the vector E as containing all of the relevant productivity variables, and converting to rate of change we have:

$$(18) \quad \hat{T} = \sum_i S_i\hat{T}_i - \sum_j C_j\hat{T}_j$$

where $\hat{T}_i = Y_i \frac{\partial E}{\partial t} dt/Y$ and $\hat{T}_j = X_j \frac{\partial E}{\partial t} dt/Y$

Index Numbers and Functional Forms

The basic TFP index postulated in (3), $\hat{T} = \hat{Y} - \hat{x} = \hat{r} - \hat{p}$, and other versions derived require an index number to aggregate outputs, inputs and prices. The accounting derivation suggested a natural index for T when changes are "small": $\hat{y} = \sum_i S_i Y_i$, $\hat{x} = \sum_j C_j \hat{x}_j$, etc.

Most TFP measures are "cumulated" on a base (as well as being expressed in rates of change for short periods). This cumulation does not present a problem with the Theil-Tornqvist approximation since "weights" are changed each period.

This natural index is known as a Divisia index. The Theil-Tornqvist discrete approximation to this index is

$$\hat{Y} = \ln(Y_t/Y_{t-1}) = \frac{1}{2} \sum_i (S_{it} + S_{it-1}) \ln(Y_{it}/Y_{it-1})$$

$$\hat{x} = \ln(X_t/X_{t-1}) = \frac{1}{2} \sum_j (C_{jt} + C_{jt-1}) \ln(X_{jt}/X_{jt-1}) \quad .$$

When changes are not small, any index number formula will impose implicit "curvature" on production technology. This comes about because the index number for a quantity aggregate is designed to "purge" that aggregate of price change effects. If prices do not change or if all prices change proportionately, this does not become a problem. In practice, of course, prices do change from one period to the next. If one knows the actual form of the production or transformation function, one can use an appropriate index number formula.

For example, if production technology is Cobb-Douglas, a geometric index with constant share weights over time is exact. If the technology is Leontief, i.e., fixed coefficient, the linear Laspeyres or Paasche indexes are appropriate. If the technology is linear homogeneous translog, the appropriate index is the Theil-Tornqvist index.

In practice, not only is the Theil-Tornqvist index a discrete approximation to a Divisia index and the appropriate index when technology is linear homogeneous translog (either for the production function, the cost function, or the profit function), but it is also the appropriate index for a second order differential approximation to any arbitrary non-homethetic production technology. This is because the translog function is a "flexible" function form in the sense that it is a second order approximation to any arbitrary production, cost or profit function.

Because of these properties, the Theil-Tornqvist index is superior to other indexes for TFP measurement. Index numbers cannot handle the problem of scale economies, however. Antle and Capalbo (1987) discuss this problem and show that when economies of scale exist (as in U.S. agriculture, for example) and there are changes in firm size, TFP measures will include a mixture of realized scale economies and general scale constant productivity gains. Furthermore, TFP measures derived from cost functions (where output is held constant) will diverge from TFP measure derived from profits function (where it is not).

This distinction, however, is in general not of strong practical interest. First, with appropriate data this scale component can be estimated. Second, from the perspective of productivity decomposition, the scale component requires decomposition in much the same way as the more general component.

Estimating $\hat{T}$ with Trend Variables

A substantial body of literature has attempted to estimate $\hat{T}$ or TFP growth by incorporating a time trend variable in estimated production, cost or profits function systems. While this has some appeal for purposes of comparative work, it is not generally of value to decomposition work. Where the interest is in a single average or mean time trend to be given a particular interpretation, it has merit. Obviously, time trend estimation is a poor estimate of a productivity series since it imposes smoothness. For some purposes, (see below) a short period mean estimate of TFP may be desirable. However, since such a number will have a lower ratio of errors or "noise" to its real component than will a single annual change number. Generally the best way to deal with the noise ratio problem, however, is to use cumulated TFP indexes (see below). Estimation of $\hat{T}$ with trend variables requires the same considerations that are entailed in integrated estimation and these issues are discussed below.

Integrated Estimation vs Two-Stage Decomposition

The analyst has effectively two options in decomposition work. The two-stage option is to first compute TFP measures for particular observations (this could be a farm, or a "constructed" farm based on county, district or state data for a particular year or season). The second stage is to develop a decomposition specification in which the TFP measures are statistically related to "determining" variables. These determining variables will include variables characterizing productivity enhancement investments: research (both public and private); extension (both public and private); schooling and infrastructure variables (roads, markets, electrification, etc.). They can also include "bias" and "error correction" variables. For example, one could include factor share and price variables (or perhaps "predicted" variables to control for simultaneity bias) to correct for possible errors in TFP measurement.

The integrated approach incorporates these determining variables directly into an estimated production, cost or profits function or in the derived product supply and factor demand functions. The advantage of the integrated approach is that a more direct estimate of the effects of determining variables can be made. Furthermore, these determining variables are appropriate variables to enable estimation of price effects in these estimates.

There are, however, several disadvantages to the integrated approach. Under certain circumstances, one may actually "purge" or control for price effects using TFP calculations than doing so implicitly in an estimating equation. For example, one may estimate a production function (or output supply equation) using a "pooled" time-series cross-section data set from several districts. The estimation imposes the same coefficients for farms across districts. The TFP calculation allows for the implicit coefficients to differ by district and year. Probably the greatest advantage to the two-step procedure is that it allows the pooling of "price purged" TFP measures for a range of observations over which the proposition of constant production curvature is untenable.

Consider the estimation of a profits function based system:

$$Y_i = Y_i(P,R,F,E)$$

$$X_j = X_j(P,R,F,E)$$

The ideal data for estimating E impacts would be data with no variations in P,R, and F and substantial variations in E. It is generally not possible to obtain data where F (land size and other fixed capital) does not vary, but regression techniques can estimate F impacts along with E impacts in data where only P and R do not vary. (Of course, such data cannot be used to estimate P and R impacts.) Some large cross-section farm surveys (or censuses) for a single year could be used to estimate E impacts efficiently because one may have little variation in P and R. (These data sets may have other limitations regarding the estimation of research timing effects.)

To date, most studies of this type have used secondary cross-section time-series data bases in order to achieve enough variation in the E variables to identify their impacts. They have been forced to estimate P and R impacts as well because P and R do vary in these data sets. The price response measures are of great interest in and of themselves of course (actually the measures of the E impacts are generally not highly sensitive to the functional form specifications used for the P and R variables). Secondary data on outputs and on inputs are usually available and can be used to construct average farm observations. Note that data showing how much of each input is used to produce each output is not required to estimate these systems.

Profits function residual productivity measures can be "pooled" from different regions to attain more variation in the E variables without imposing constant coefficients for the P,R, and F impacts over these regions. The analyst may wish to estimate separate systems for different regions to avoid problems with "corner" solutions. The residuals, i.e., predicted minus actual values of the dependent variable where the predicted values do not include E variables impacts (even though they may have been estimated), may then be pooled from one region and regressed on E variables specified consistently over several regions.

The analyst may also use P,R, and F (or some subset) coefficient estimates that he regards to be reliable to compute "productivity" residuals from other data to enable estimation of E variable effects. For example, a sample of farms may provide good estimates of a system where E variables are roughly constant. The P,R, and E coefficients may be well estimated. They can be used to convert secondary data from larger regions where E varies into productivity residuals suited to estimation of E impacts.

The problem of "corners" can be partially avoided by judicious pooling of residuals. Other procedures for correcting for the selectivity bias from this problem are available as well (see Huffman, 1984).

Recent work with profits function systems are beginning to exploit the fact that most agricultural research programs are unit-cost reducing in impact. That is, they usually do not change the quality of the product (in ways that are not measurable) but reduce the cost of production. Commodity specific research then has effects on supply that are similar to price effects. A ten percent reduction in the cost of producing a unit of soybeans, for example, will have the same effect on producers as a ten percent rise in the price paid for soybeans. This means that research impacts will be "symmetric" across commodities and related to price effects by a scalar. Symmetry means that the effects of soybean research that reduces costs by one percent on corn supply is the same as corn research that reduces the cost of producing corn by one percent on soybean supply.

II. PROBLEMS AND ISSUES IN USDA REGIONAL PRODUCTIVITY MEASURES AND IN STATE PRODUCTIVITY MEASUREMENT

In 1980 an AAEA Task Force reviewed the USDA productivity series in the Gardner report. Several criticisms were levied against the USDA indexes. One was the use of Laspeyres indexes instead of Divisia type indexes. In constructing a state series, we have attempted to respond to the Gardner report criticisms. The state series is thus, in our judgment, an improvement over the USDA series in several respects. There are, however, some data limitations that affect the state series to a greater degree than they affect the regional series. In this section, we note some of the most important differences between our series and the USDA's. For details and additional points, the reader is referred to Appendix I.

The USDA publishes indices of farm output, input, and total factor productivity annually in Changes in Farm Production and Efficiency. Some information about the procedures used to construct these indices is available in Agricultural Handbook No. 365 (1970); more details appear in the Gardner report cited above. The output and input indices are Laspeyre's quantity indices with base-period price weights; the base periods are changed every ten years or so and the historical series spliced together. Following the Task Force recommendation, we used instead the Tornqvist-Theil approximation to the Divisia index, obtaining an index of total factor productivity as the ratio of outputs to inputs.[4] It should be noted that the Task Force also recommended replacing Laspeyre's with Divisia indices in the construction of certain composite inputs like agricultural chemicals and fertilizers. Due to limited data we were unable to adopt this procedure at those levels of aggregation.

Our output index is composed of thirty-four categories of farm products. Most major national crops and livestock categories are represented. Products of minor importance from the national perspective are picked up in residual, miscellaneous categories. In some states these products (e.g., truck crops) may be of disproportionate importance so that our index is less well suited to the agricultural sector there. Output was measured as calendar-year production. The difference in the logarithm of current and lagged outputs was used as an approximation to relative change. The Tornqvist-Theil index used value-of-production weights. We constructed the value of production as current output times the lagged price. We then used the mean of this year's value of production and the past year's value as the index weight.

Our input index is based on eight input categories: land, labor, fertilizer, feed, seed, service flow from capital stock, machinery operation and repair, and miscellaneous. These categories closely match the production expenditure categories in the USDA's Farm Income Statistics, the principal source of data at the state level. Lack of data forced us to include agricultural chemicals with miscellaneous items. Feeder livestock does not appear as an input category; thus we omit any value added outside the farm sector. The USDA adjustments for production of commercial hatcheries is superior to our approach in this matter, but the resources we could devote to what appeared a relatively minor component were severely limited. The use of different data sources means that our procedures deviate from those of the USDA in many respects, both large and small. Our construction of input flows is described at length in Appendix I. Two of the more important differences are summarized below.

Labor: The USDA measures labor manhours by summing over.all planted acres or units of livestock on imputed labor input. The labor input is based on benchmark figures for the time an average agricultural worker takes to cultivate an acre of the crop in question or raise the sort of livestock involved. The benchmark figures are infrequently revised. The resulting figures are grossed up by 15% for general farm overhead.

Instead of tying labor input to production figures, we based our estimate on direct measures of labor employment. We used two sources. For hired labor, we used expenditures on labor published in the USDA Farm Income Statistics. We divided by the average wage for agricultural laborers working for cash wages to obtain hired manhours. We based an estimate of unpaid family and operator labor on the surveys of the Statistical Reporting Services published in Farm Labor. From the Task Force report: "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." Our approach adjusts the quarterly series for the information contained in the earlier monthly series.

Feed Grains: The USDA employs a net measure of productivity, netting out from both outputs and inputs farm-grown intermediate products. Most notably, they compute feed input as a proportional constant times quantity of liveweight production. (The constant varies by livestock type.) Of this total, a certain fraction is taken to represent value added outside the farm sector by commercial processors. The rest is considered an intermediate product and is not counted as an input. An equal quantity is subtracted from feed grain output. A couple of critical considerations led us to prefer a gross measure of productivity which retains feed grains as both inputs and outputs. First, as noted by the Task Force: "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." To these considerations we would add that the net approach seems particularly ill-suited to development of productivity indices at the state level. Understanding differences across states will be impeded rather than aided by an approach that obscures whether productivity improvements originate in the use of fertilizer and machine power to grow crops or in the development of specialized feedlots and the conversion of grain to animal weight.

In addition we utilized somewhat different procedures to measure the service flow from real estate, power and machinery. For land we constructed a service flow based on deflated cash rent series. Property taxes were retained in our land service flow measure. We utilized the state income service depreciation data for structure and used a constant 5 percent real interest rate in computing service flows for capital stock. Our machine operating expenses and repairs were not combined with service flows as in the USDA index.

III. STATE TOTAL FACTOR PRODUCTIVITY INDEXES

Table 1 reports growth rates of the TFP index by state and USDA region for several sub-periods and for the 1950-82 period. Actual state indexes are reported in Appendix 2. These indexes are compared with USDA indexes in Section IV. That comparison generally shows consistency with the USDA indexes and indicates little reason to conclude that major biases exist in the state indexes. Accordingly, some discussion of the indexes in merited.

It may first be noted that there is a fair amount of state heterogeneity within regions even though our regional aggregates are closely correlated with the USDA regional series. The fastest TFP growth region is the Delta region. Two states in this region, Mississippi and Arkansas, are also the two leading states in TFP growth. Alabama and Georgia are next, and they are in the second ranked region, the Southeast. Florida, also in the Southeast, however, has a relatively poor record of TFP growth.

The Mountain region clearly stands out as the region of lowest TFP growth but four states in the region, Montana, Idaho, Colorado and New Mexico, exhibit modest growth. New York and New Jersey in the Northeast also show low growth rates (New England States are not included).

In most regions, TFP growth was lowest in the 1970s. All regions and most states show rapid growth in the 1980-82 period. However, this is only a 3-year period and thus subject to weather influence. The Appalachian region shows particularly strong performance in this period.

These TFP growth patterns reflect many forces. The underlying rate of real technology generation varies by commodity, time period and region. The <u>structural efficiency</u> of farms, i.e., size and specialization, varies over time and by region as well. In addition, structural and institutional changes are related to technology generation. Much of the technology produced by public and private sector institutions is designed to enable productivity gains <u>through</u> structural change.

The regional pattern of gains is thus related to investments in technology enhancing activities (research, extension, and schooling) and to geographic diffusion or transfer of produced technology. Previous work on productivity change in U.S. agriculture (Evenson 1982) has utilized the geo-climate region specification depicted in Figure 1. This figure defines 16 regions and 34 sub-regions based on soil and related classifications in the 1957 <u>Yearbook of Agriculture</u>. It is thus a useful exercise to calculate growth rates for these 16 regions by proportionate weighting of state indexes. This exercise is reported in Table 2.

The rates of growth reported in Table 2 are somewhat more regular than are the state indexes. As expected, they show the Mississippi Delta to have outpaced other regions in most periods. Regions 3 and 13 rank lowest in part because of poor performances during the 1970s.

Table 3 reports comparisons of the average annual growth rate over the 1950-82 period of our state output, input and TFP series aggregated to a regional level and the USDA regional series. As can be seen, at the aggregate U.S. level, our state series has effectively the same TFP growth rate as the USDA series. The state output and input series both grow faster than the USDA series largely because of the treatment of feed fed on farms as both an output and an input in the state series. There are, however, some differences at the regional level in the two series.

Table 4 reports a comparison by region of the state Divisia TFP index growth (aggregated to regions), the state TFP index computed using a Laspeyres formula and the USDA index. Average growth rates by period of 3 years moving averages are reported as well as an estimated

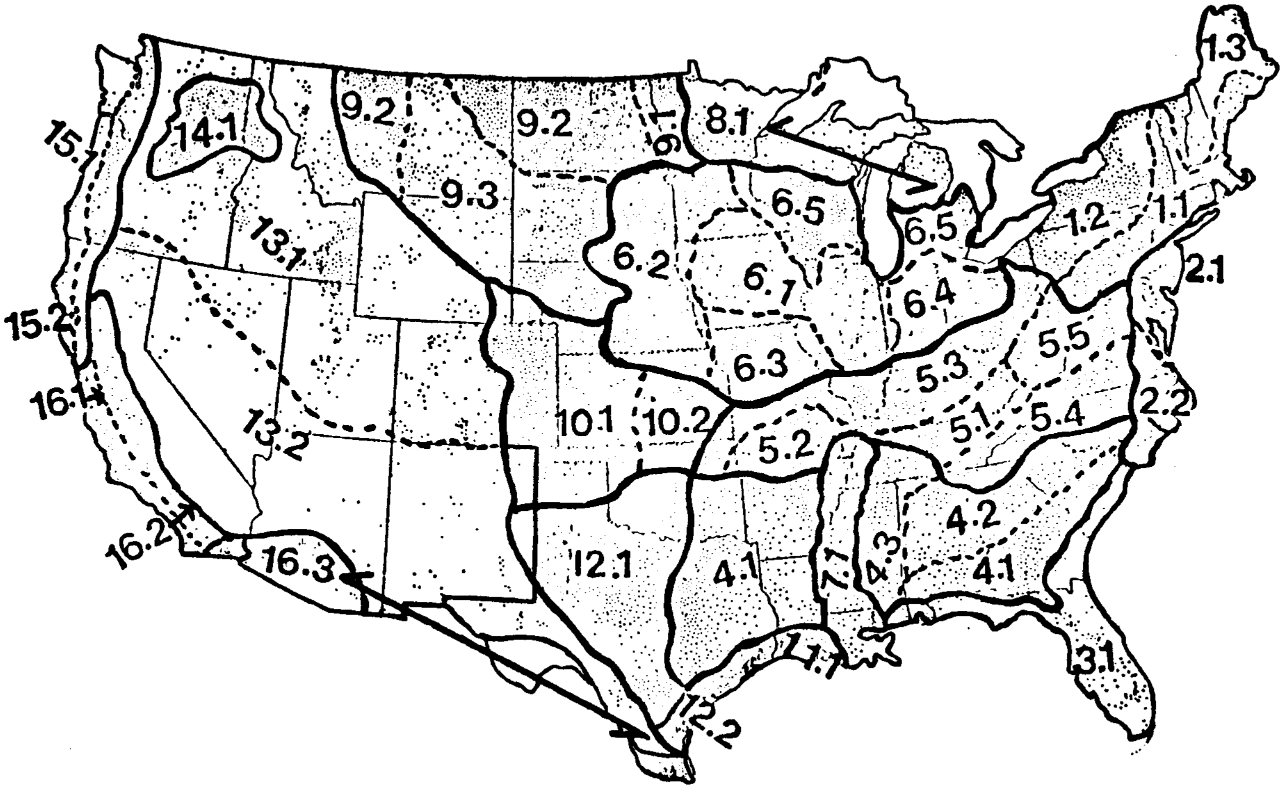
TABLE 1: Total Factor Productivity Growth by State for the 1950's, 60's, 70's, 80's and Entire Period

Northeast Region	1950-59	1960-69	1970-79	1980-82	1950-82
New York	.010	.017	-.004	.022	.009
New Jersey	.025	.022	-.033	.056	.009
Pennsylvania	.021	.027	.013	.034	.021
Delaware	.034	.031	.009	.028	.025
Maryland	.016	.030	.002	.040	.018
Regional Total	.021	.025	-.003	.036	.016
Lake States Region					
Michigan	.016	.022	.027	.047	.024
Minnesota	.024	.011	.025	.021	.020
Wisconsin	.020	.004	.024	.009	.015
Regional Total	.020	.012	.025	.026	.020
Corn Belt Region					
Ohio	.016	.011	.023	.034	.018
Indiana	.016	.023	.005	.060	.019
Illinois	.023	.011	.012	.020	.015
Iowa	.020	.006	.010	.010	.012
Missouri	.025	.004	.027	.018	.019
Regional Total	.020	.011	.015	.028	.017
Northern Plains Region					
North Dakota	.016	.038	.011	.069	.026
South Dakota	.016	.029	.010	.028	.019
Nebraska	.032	.022	.014	.010	.021
Kansas	.036	.029	.007	.011	.023
Regional Total	.025	.029	.010	.030	.022
Appalachian Region					
Virginia	.023	.028	.011	.023	.021
West Virginia	.024	.017	.023	-.003	.019
Kentucky	.011	.027	.011	.110	.025
North Carolina	.037	.034	.013	.042	.029
Tennessee	.021	.014	.018	.068	.022
Regional Total	.023	.024	.015	.048	.023
South Eastern Region					
South Carolina	.029	.036	.015	.041	.028
Georgia	.046	.039	.007	.034	.031
Florida	-.004	.015	.007	.021	.007
Alabama	.044	.026	.023	.039	.032
Regional Total	.029	.029	.013	.034	.025

TABLE 1 (continued)

	1950-59	1960-69	1970-79	1980-82	1950-82
Delta Region					
Mississippi	.049	.034	.032	.023	.037
Arkansas	.047	.026	.023	.029	.032
Louisiana	.009	.035	.026	.030	.024
Regional Total	.035	.032	.026	.027	.031
Southern Plains					
Oklahoma	.029	.015	.020	.032	.022
Texas	.019	.009	.017	.003	.014
Regional Total	.024	.012	.018	.018	.018
Mountain Region					
Montana	.023	.024	-.015	.079	.017
Idaho	.007	.029	.004	.030	.015
Wyoming	.024	.005	-.009	.024	.008
Colorado	.019	.012	.012	.018	.015
New Mexico	.016	.001	.002	.055	.011
Arizona	-.013	.012	.002	.012	.0002
Utah	.0002	.011	-.014	.059	.004
Nevada	-.020	.011	.001	.028	.0003
Regional Total	.007	.013	-.003	.038	.009
Pacific Region					
Washington	.025	.028	.017	.047	.025
Oregon	.025	.023	.016	.019	.021
California	.021	.022	.018	.004	.019
Regional Total	.023	.024	.017	.023	.022

FIGURE 1: U.S. Agricultural Geo-Climate Regions and Sub-Regions. (1 dot = 25,000 Acres Cropland, 1964)



1. Northeast Dry Region
2. Middle Atlantic Coastal Plain
3. Florida and Coastal Plain
4. Southern Uplands
5. East-Central Uplands
6. Midland Feed Region
7. Mississippi Delta
8. Northern Lake States
9. Northern Great Plains
10. Winter Wheat and
11. Coastal Prairies
12. Southern Plains
11. Coastal Prairies
12. Southern Plains
13. Grazing-Irrigation Region
14. Pacific Northwest Wheat Region
15. North Pacific Valleys
16. Dry Western Mild Winter Region

TABLE 2: Total Factor Productivity Growth by Geo-Climate Region for the 1950's, 60's, 70's, 80's, and for Entire Period

	Total Factor Productivity Growth				
Geo-Climate Region	1950-59	1960-69	1970-79	1980-82	1950-82
1. Northeast Dairy Region	.016	.022	-.0001	.031	.014
2. Middle Atlantic Coastal Region	.026	.028	.0003	.037	.020
3. Florida and Coastal Flatwoods	.004	.020	.008	.025	.012
4. Southern Uplands	.033	.026	.018	.028	.026
5. East-Central Uplands	.023	.019	.015	.045	.021
6. Midland Feed Region	.022	.015	.017	.024	.018
7. Mississippi Delta	.034	.031	.027	.030	.031
8. Northern Lake States	.020	.012	.025	.025	.020
9. Northern Great Plains	.020	.028	.009	.053	.022
10. Winter Wheat and Grazing Region	.030	.021	.009	.014	.020
11. Coastal Prairies	.015	.020	.020	.014	.018
12. Southern Plains	.022	.010	.017	.013	.016
13. Grazing - Irrigated Region	.012	.016	.002	.033	.012
14. Pacific Northwest Wheat Region	.021	.027	.014	.038	.022
15. North Pacific Valleys	.024	.024	.017	.022	.021
16. Dry Western Mild-Winter Region	.014	.018	.014	.006	.015

TABLE 3: Growth Rates 1950-81: TFP, Output, Inputs

Region	Northeast		Lake		Corn Belt		North Plains		Appalachian		Southeast	
	State	USDA	State	USDA	State	USDA	State	USDA	State	USDA	State	USDA
TFP	1.55	1.76	1.99	1.99	1.57	1.71	2.09	2.08	2.48	1.68	2.17	2.10
Output	.91	.66	1.97	1.90	1.97	2.05	2.82	2.38	1.90	1.07	2.95	2.08
Inputs	-.63	-1.10	-.02	-.09	.40	.34	.73	.30	-.58	-.61	.78	-.02

Region	Delta		South Plains		Mountain		Pacific		U.S.	
	State	USDA	State	USDA	State	USDA	State	USDA	State	USDA
TFP	3.12	2.37	1.89	1.78	1.19	1.84	2.04	2.03	1.97	1.92
Output	3.08	2.06	2.38	1.51	2.13	2.09	3.02	2.42	2.38	1.98
Inputs	-.04	-.31	.49	-.27	1.04	.25	.98	.39	.41	.06

TABLE 4: Compound Annual Growth Rates of TFP in Percent

REGION	Northeast			Lake States			Corn Belt		
PERIOD	STDV	STLSP	USDA	STDV	STLSP	USDA	STDV	STLSP	USDA
1950-60	1.97	2.31	2.62	2.24	2.05	2.42	2.04	1.81	2.22
1960-70	1.83	1.73	1.82	1.60	1.37	1.67	1.38	1.26	0.99
1970-81	0.91	0.73	0.92	2.12	1.73	1.88	1.32	1.00	1.91
1950-65	2.09	2.30	2.24	2.14	1.91	2.09	1.81	1.59	1.88
1965-81	1.04	0.87	1.31	1.85	1.54	1.89	1.34	1.12	1.55
1950-81	1.55	1.56	1.76	1.99	1.72	1.99	1.57	1.34	1.71
TREND 1950-81	1.48	1.45	1.66	1.92	1.66	1.90	1.42	1.25	1.62

REGION	Northern Plains			Appalachian			Southeast		
PERIOD	STDV	STLSP	USDA	STDV	STLSP	USDA	STDV	STLSP	USDA
1950-60	2.79	2.94	2.36	2.45	2.41	1.76	2.88	2.89	2.54
1960-70	2.42	2.19	2.30	2.57	2.43	1.64	2.61	2.86	1.71
1970-81	1.61	0.62	1.62	2.43	2.26	1.64	1.13	1.30	2.04
1950-65	2.58	2.52	2.30	2.57	2.45	1.69	3.01	2.96	2.25
1965-81	1.64	1.27	1.87	2.40	2.28	1.67	1.39	1.72	1.95
1950-81	2.09	1.88	2.08	2.48	2.36	1.68	2.17	2.32	2.10
TREND 1950-81	2.14	1.87	2.10	2.35	2.25	1.69	2.19	2.37	1.95

REGION	Delta			Southern Plains			Mountain		
PERIOD	STDV	STLSP	USDA	STDV	STLSP	USDA	STDV	STLSP	USDA
1950-60	4.30	4.15	3.30	3.54	2.96	2.70	0.92	.097	1.86
1960-70	3.04	3.15	2.17	0.57	0.63	0.04	1.70	1.34	2.03
1970-81	2.10	1.32	1.71	1.59	1.24	2.51	0.96	0.67	1.67
1950-65	4.20	4.08	3.25	2.74	2.30	2.14	1.12	0.97	1.90
1965-81	2.10	1.65	1.56	1.09	0.93	1.44	1.25	0.99	1.79
1950-81	3.12	2.82	2.37	1.89	1.60	1.78	1.19	0.98	1.84
TREND 1950-81	2.97	2.80	2.23	1.89	1.71	1.76	1.18	0.93	1.60

REGION	Pacific			U.S.		
PERIOD	STDV	STLSP	USDA	STDV	STLSP	USDA
1950-60	1.62	1.81	1.60	2.36	2.29	2.24
1960-70	2.45	2.21	1.77	1.98	1.90	1.61
1970-81	2.05	2.13	2.66	1.61	1.34	1.91
1950-65	1.59	1.61	1.76	2.26	2.14	2.08
1965-81	2.47	2.47	2.28	1.70	1.53	1.77
1950-81	2.04	2.05	2.03	1.97	1.83	1.92
TREND 1950-81	2.24	2.17	1.86	1.95	1.82	1.84

trend for the 1950-81 period.

These comparisons show that the state Divisia index is generally closer to the USDA Laspeyres index than the state Laspeyres index. This appears to indicate that the practice of shifting weights in the USDA index once each decade allows the USDA index to approximate a Divisia index. The state index when computed on a Laspeyres basis, i.e., with one set of weights (1950) diverges significantly from the Divisia index. It is lower in every period.

TABLE 5: Annual Compound Rates of Change of Labor Input: Divisia and USDA Series for 10 Regions and the U.S. 1950-81

Regions	N.E.	LAKE	CORN BELT	N. PLAINS	APPA.	S. EAST	DELTA	S. PLAINS	MOUNT.	PACIF.	U.S.
					(Percent)						
Div.	-3.2	-2.9	-3.3	-2.3	-4.6	-3.6	-5.4	-3.5	-1.7	-1.2	-3.2
USDA	-5.0	-4.5	-4.6	-3.2	-4.8	-4.2	-5.7	-4.5	-3.4	-2.0	-4.1
Diff.	-1.8	-1.6	-1.3	-0.9	-0.2	-0.6	-0.3	-1.0	-1.7	-0.8	-0.9

Regional comparisons show that all indexes generally rank the regions similarly with region 7 (Delta) ranking first, region 5 (Southeast) second and region 9 (Mountain) last.

The regions of closest agreement are the Lake States, the Northern Plains, and Southeast, the Southern Plains, and the Pacific. Inside these regions, our state results often show a wide range of TFP growth rates, indicating the regional level indexes will be misleading for some uses. For regions where we found that TFP increased significantly faster than the national average - Appalachian and Delta regions - our results show a faster rate of increase that the USDA.

One possible explanation for these differences is our use of a Divisia index where the USDA uses Laspeyres indexes. We calculated Laspeyres indexes using our series on quantities and prices with the USDA procedure of taking a base of the average of 3 years which is updated every 10 years. Where our results are close to the USDA, these Laspeyres indexes are usually further from the USDA figure. Where our indexes show a slower rate of TFP increase than the USDA, these Laspeyres indexes either equal our Divisia result (i.e., in the Northeast) or show an even greater difference from the USDA figure (i.e., in the Corn Belt and Mountain states). Where our results indicate faster rates of TFP increases, the Laspeyres indexes are slightly closer to the USDA figure for the Appalachian states and split the difference for the Delta states. In sum, of the five cases where our results differ markedly from the USDA, only in one case can the use of Divisia instead of Laspeyres indexes account for a significant share of the difference.

A second possible source of the differences for the 5 regions is the treatment of feed grains. We used a gross output, gross input procedure counting all grain produced as output and all grain feed as input. The USDA attempts to use a net output, net input procedure with feed grains, counting as an input only the value added by commercial processors of feed concentrates. Thus our procedures produces a faster rate of output and input increase than the USDA. (See Table 3.) One would expect the USDA procedure to distort the rate of TFP increase for feed surplus and feed deficit regions. We recalculated our indexes using as an approximation to the USDA approach. We used 10% of purchased feed to replace our series of all purchased and farm-fed feed. This changed our TFP series generally in the direction of diminishing the difference with the USDA series, but the change was less than 10% of the difference between our indexes and the USDA. Thus the different treatment of feed by itself does not account for the differences between our regional results and the USDA.

We also investigated a third possible source of the differences in regional results, the labor input series. The USDA uses manhours per acre of head of livestock times the number of acres planted or head of livestock raised. The manhours per unit are based on benchmarks which are grossed up 15% for general farm overhead labor. Our procedure uses the SRS surveys of actual farm labor usage with adjustments to allow for the switch from monthly to quarterly surveys. Table 5 gives the compound annual rates of change in labor input for the 10 regions and the U.S. used by the USDA and our series. Both series show a sharp fall in labor input over the 1950-81 period (calculated from 3 year moving averages). However, the USDA series shows a much faster rate of decrease in labor input for every region and the country as a whole. The national differences in the compound rates of decrease is 0.9% per year. For the regions where we found faster TFP growth (the Appalachian and Delta regions) the difference in rates of labor input change is only 0.2 or 0.3 percent while for the regions where we found slower TFP increase (Northeast, Corn Belt, and Mountain states) the difference in labor input growth rates runs from 1.3 - 1.8% per year. Thus it would appear the difference in the labor input series could account for much of the discrepancy in cases where we found slower regional TFP growth than the USDA, but not where we found faster regional TFP growth.

IV. CONCLUDING COMMENTS

Productivity measurement is a useful exercise. A number of insights into national and regional issues can be obtained from carefully measured and computed productivity indexes. In this paper we report total factor productivity indexes at the state level and compare them with USDA indexes. We follow some procedures generally regarded to be superior to those used by the USDA (Gardner report). Our indexes have some limitations because of the state data base.

We believe them to be useful in two broad senses. First, on the whole, these indexes tend to support and verify the reported USDA indexes. We do not find major differences in aggregate growth rates between state and USDA indexes. The USDA shifting of weights each ten years produces a result not far from the Divisia result. Our results do not, however, support the failure of the USDA to change its procedures along the lines suggested by the 1980 AAEA Task Force report. Clearly the USDA has been remiss in not responding to that report.

The second use for the state indexes is in further decomposition analysis. In this regard, they are much richer than more aggregated indexes because they enable the analyst to take advantage of state and geo-climate regional differences in investments and other factors to analyze determinants of productivity change. Appropriate statistical procedures will enable this analysis even in the presence of errors of measurement. In the long-run, we believe that this second use will be the more important.

FOOTNOTES

[1] See the AAEA Task Force Report on Measuring Agricultural Productivity (The Gardner Report), ESCS Technical Bulletin No. 1614, February 1980.

[2] Landau and Evenson (1973) report a state series. This unpublished work in summarized in Evenson 1982.

[3] The Evenson, Waggoner, Ruttan 1979 paper summarizes statistical productivity decomposition studies for early periods as well as for the 1949-71 period.

[4] See the discussion of index numbers and functional forms.

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APPENDIX I

CONSTRUCTION OF THE 1949-1982 STATE-LEVEL DATA SET FOR U.S. AGRICULTURE

INTRODUCTION

This appendix describes the construction of the 1949-1982 state-level data set. We have commented on some of the deficiencies of the approaches we used; other will certainly be obvious to the reader.

I. INPUTS

Labor

The labor variable is an estimate of the manhours of labor input to agricultural production. It includes both hired labor and unpaid operator and family labor.

Hired Labor

Our source for hired labor was the expenditure on labor (EXPLABOR) published in the production expenditures series in State Farm Income and Balance Sheet Statistics (formerly State Farm Income Statistics and Farm Income Situation, State Estimates). This figure includes cash wages, non-cash perquisites, and payroll taxes. To convert dollar expenditures to labor manhours we used the hourly wage paid to employees working for cash wages only (WAGE) published in Farm Labor.[1] Typically, workers who receive some combination of room and board and other non-cash perquisites receive a lower cash wage. We assumed that the differential in cash wage rates equaled the cash value of such perquisites. Consequently it was appropriate to retain the value of perquisites in the expenditure figure, prior to dividing EXPLABOR by WAGE to obtain an estimate of manhours of hired labor. However, retaining payroll taxes in the total wage bill would lead to an overstatement of manhours, since such taxes were not included in WAGE; thus we sought to remove them prior to dividing expenditures by the wage rate. From the Social Security Bulletin we obtained the percentage of wages that employers were required by law to contribute to social security (SOC). We reduced total expenditures on hired labor by this percentage (EXPLAB2 = EXPLABOR(1-SOC) to obtain the portion of the wage bill that went to workers. We then divided EXPLAB2 by WAGE to obtain an estimate of manhours (HRD2).

This procedure creates two sources of measurement error. First, we have overstated social security contributions by including non-cash perquisites in the wage base and by assuming that all farm workers were covered by social security over the entire sample period. However, our second measurement error is to neglect other payroll taxes besides social security contributions, thus understating the sum diverted to the federal government. The two errors work in off-setting directions, but the extension of social security, workman's compensation, and other state-secured benefits to more and more farmworkers over time suggests that in early years we are apt to be overcorrecting EXPLABOR for the payroll tax component, even if the errors are nearly off-setting in a later part of the period.

Unpaid Operator and Family Labor

State-level estimates of unpaid operator and other family labor used on farms have been published by the USDA for 1965-1980 in Farm Labor. These estimates are based on a mail survey conducted monthly prior to 1974 and quarterly from 1974 to 1980. After a one-year hiatus the survey was resumed in 1982 on a much more limited basis; conducted once a year, in mid-summer. The respondents were asked to report, for the week prior to the receipt of the survey, the number of persons employed on the farm in each of the following categories--operator, other unpaid family, and hired--as well as the average number of hours worked by a person in each category. Published results were not the raw sample figures, but projections of state-wide totals for workers and hours based on sample information. At the time the survey was converted from monthly to quarterly, the sampling technique was put on a probability frame basis. Presumably the procedure for converting sample responses to state-wide estimates was put on a sounder footing by using the probability frame.

To make use of this data we had to solve a number of problems: (1) converting estimates for 12 (or 4) weeks of the year to estimates of annual operator and family labor input; (2) smoothing discontinuities in the series created by the change in sampling procedure in 1974; (3) extrapolating data to the missing years, 1949-1964 and 1981-82.

Problem (1). For 1965-1973 we computed total family (including operator) hours per month as the number of family workers times the average hours worked by a family worker times 4.3 (grossing up the observation for a single week to a 'monthly' total). Thus we assumed the week observed was characteristic of the 4.3 weeks around it. We obtained an annual figure (FAM) by summing the twelve 'monthly' totals. For 1974-1980 we had only one observation per quarter to work with. The assumption that a single week is characteristic of the entire quarter in which it appears is more problematic than the assumption that it is representative of its month. It seems likely that such an assumption would create cross-sectional biases stemming from the fact that all states were sampled during the same calendar week rather than at the same point in their crop year. Thus an early-April observation is likely to show more agricultural activity and a higher labor input in southern states than in northern states because planting gets underway earlier there, and should not be taken as an indication that labor input is higher in the south by the same proportion throughout the spring. To avoid creating such a bias, we took a set of intermediate steps to derive annual estimates from the four quarterly observations. For example, we took the ratio of all January observations on workers and hours to the sum of the January, February, and March observations for the 1965-1973 period. Then for 1974-1980, when only the January observation was available, we multiplied it by this ratio, hoping by this procedure to capture the extent to which the January observation was representative of the winter quarter in each state. We proceeded in a like way for the April, July, and October observations, multiplied the results by factors of 4.3 and 13 (to convert to quarters) and added the four quarters to obtain the annual total (FAM).

Problem (2). The change in sampling methods in 1974 did indeed introduce discontinuities in the reported series. For 1974 the USDA reported estimates based on both the old and new sampling methods, and in nearly every state there was a sizeable drop in unpaid manhours calculated from the new figures. We spliced together the two parts of the series by lowering the earlier period numbers by the amount of the discontinuity at 1974 (SHIFT), on the assumption that the sampling procedure during the latter period was better. However, rather than taking the actual difference between the two 1974 figures, we used the difference between the 1974-fitted values for each sub-period of manhours regressed on time. We used fitted instead of actual values because the latter might be unduly influenced by large, one-time measurement error, while the difference between fitted values presumably better reflected the extent to which the observations in the latter period were systematically lower than those in the earlier period. The regressions were run on each state separately.

Problem (3). To extrapolate the series to 1981 and 1982 we used the intercept and slope terms from the regression of the 1974-1980 observations on time to predict values for 1981 and 1982. To extrapolate the series backwards to pre-1965, a different approach was taken due to the availability of some additional data for those years which enabled us to put the extrapolations on a surer basis. During 1949-1964 farm labor surveys were taken on the same monthly schedule as in the 1965-1973 period; however, respondents were asked only for the number of workers of each type, not the average hours worked. Still, this provided a basis for extrapolating the manhours series backwards. We averaged the number of hours worked by a family member per week over the whole year, for the period 1965-1967. We assumed that this average also characterized the years 1949-1964.[2] Our extrapolation was therefore simply to take the annual average number of family workers (MFW) times the 1965-1967 average hours per week (MFH) times 52. Like the estimates of manhours for 1965-1973, this figure was lowered by the difference between 1974 fitted values to splice together the two parts of the sample.

The estimate of unpaid family and operator labor arrived at by these procedures (FAM2) was added to the estimate of hired labor (HRD2) to give an estimate of total manhours (LABORN).

Seed

Expenditure on seed is published yearly in State Farm Income Statistics (EXPSEED). Prices of individual seed varieties are published in Agricultural Prices. The only available index of seed prices is a national index also published in Agricultural Prices. Because of the varying composition of output across states, we decided it would not be appropriate to use the national index at the state level. This left us with two problems: (1) determining an appropriate price index; (2) determining the quantity of seed used at the state level. We consider these problems in reverse order.

The Quantity of Seed Used

We constructed the quantity of seed used (SEED) as the product of acreage planted times seeding rates for the following crops: winter wheat, spring wheat, durham wheat, corn, oats, barley, sorghum, rice, potatoes, soybeans, dry edible beans, cotton, peanuts, and hay. Seeding rates for each state for 1956 and 1982 were taken from Agricultural Statistics for all crops and hay. We assumed any changes in rates were evenly distributed over time and so estimated seeding rates for the years between 1956 and 1982 as simple linear interpolations. The estimated annual changes were extrapolated backwards to the years 1949-1955. The estimate of seed use is associated with the year in which the crop was harvested; thus, winter wheat seed use for 1981 is the quantity of seed planted in 1980 for the crop harvested in early summer of 1981.

No seeding rate is published for hay. Since the value of hay seed sold in many states is on the order of 10% of EXPSEED, we decided it was too large an item to ignore and arrived at a pseudo-seeding rate as follows. We took national production of alfalfa seed, less exports, as alfalfa seed available for domestic use. We then assumed that this seed was planted in the following year. The ratio of this figure to all alfalfa acres harvested nationwide gave us a national alfalfa "seeding rate." We used harvested acreage because planted acreage was unavailable. Thus the ratio obtained is not strictly speaking a seeding rate, but a "disappearance per harvested acre," or pseudo-seeding rate. To obtain estimates of hay seed used on the state level, we multiplied the national pseudo-seeding rate times harvested hay acreage (of all varieties) in each state. Thus we were ignoring differences in seeding rates over different hay varieties and different regions. We also implicitly assumed a constant ratio of harvested to planted hay acreage across states.

We converted all units to millions of pounds and summed to obtain total seed use. Aside from difficulties already noted, this procedure was subject to error arising from the omission of some crops: tree and bulb crops, rye, sunflowers, flax. This biases SEED downward.

Seed Price

Rather than constructing an index of seed prices as a quantity-weighted average of prices of individual varieties, we took the more expedient course of defining the price of seed as the total value of seed used (VSEED) divided by SEED. VSEED is not the same as EXPSEED since some seed is taken out of stocks from previous years' production. Estimates of wheat, rice, soybeans, peanuts, dried beans, and potatoes used as seed on the farms where they were grown have been published by the USDA in its Field Crops Production, Disposition, and Value series. Estimates of corn, sorghum, oats, and barley used either for feed or seed have been published in the same source. However, due to missing observations and the costs of data collection, we did not use this data exactly as we found it.

We assumed all feed grains used on the farm where grown were used as feed. Thus the value of seed for corn, sorghum, oats and barley is assumed to be wholly included in EXPSEED. To the extent this is untrue, VSEED is biased downward.

We used published figures when available for wheat and soybeans used as seed, and extrapolated to years of missing observations. (See the discussion under FEED for details of the extrapolation procedure.)

Like wheat and soybeans, farm use of peanuts, beans, potatoes, and rice for seed were published through 1974. Due to the costs of data collection, we used the published figures for 1949, 1954, 1959, 1964, 1969, and 1974 only. We took the ratio of these quantities to total seed used in the following year and assumed that any changes in these ratios occurred evenly over time. That is, we computed the ratio of farm use for seed/total seed required for 1950, 1955, 1960, 1965, 1970, and 1975 and made a linear interpolation of this ratio over the intervening years. For 1949 we used the 1950 ratio; for all years after 1975, the 1975 ratio. We then applied this ratio in each year to total seed required for the crop in question, giving us an estimate of the total amount of seed that was not purchased. We then evaluated non-purchased seed at the season average price for the year in which it was applied as an input. Moreover, we corrected EXPSEED, which is expressed on a calendar-year basis, for the value of winter wheat seed, subtracting seed used in the current year for next year's crop, and adding seed used in the previous year for the current crop. The corrected measure is denoted as EXPSEEDC. We then obtained VSEED as

$$\text{VSEED} = \text{EXPSEEDC} + \text{VPESEED} + \text{VPOSEED} + \text{VRISEED} + \text{VWHSEED} + \text{VSYSEED}$$

where VPESEED through VSYSEED are the values of non-purchased seed, determined as indicated above. Then PSEED = VSEED/SEED.

As noted above, both VSEED and SEED are probably understated. To some extent these errors are offsetting when it comes to estimating PSEED.

Land and Rent

Land input was measured as land in farms (LAND). This is the sum of all types of land. The data source for all years except 1981 and 1982 was Farm Real Estate Market Developments. For the latter two years the source was Agricultural Statistics, 1982.

The service flow from land was assumed to be a constant proportion of the quantity of land in farms. (The proportional constant washes out of the calculation of the relative change in service flow from one year to the next; hence it is immaterial what its value is taken to be.) To obtain a value for this service flow, we used data on rents. Series on rents are not complete, however. For the entire period of interest, 1949-1982, the USDA compiled a series of the cash rent in dollars per acre paid on farms rented for cash. The series covered all states east of the Mississippi, plus Minnesota and North and South Dakota. In addition, Nebraska was covered through 1966, Kansas through 1975, and Texas through 1966. The series was discontinued for New York, West Virginia, Florida, Louisiana, and Oklahoma beginning with 1982. The series was based on a mail-survey of crop reporters in which respondents were asked to report the going rental value for farmland in their locality. They need not themselves have been party to a rental agreement.

For western states, separate series were complied on the rent paid on dryland, irrigated land, and grazing land. This series began in 1960. Not all western states were covered in every category. In addition to rent paid, respondents were asked for the value of land rented, permitting calculation of a third series, ratio of rent to value. This was true of the eastern as well as all three western series.

Data on all series from 1960-1979 was published in "A Comparison of Cash Rents and Land Values for Selected U.S. Farming Regions," John P. Doll and Richard Widdows, NED Staff Report No. AGES820415, April, 1982. Unpublished data for other years was furnished by the Economic Research Service. Different problems arose for eastern and western data. We consider them separately.

The East

To use the cash rent series as a measure of the service flow from land, statewide, we had to make two assumptions:

(1) The rented farms which survey respondents took note of were representative of the locality with respect to the quality of land and the composition of farms (cropland versus

pasture).

(2) The rent was a return to land per se and contained little or no rent for service structures or dwellings.

For West Virginia, Florida, Oklahoma, Louisiana, and New York, missing values in the USDA series were replaced with extrapolations based on the rate of change of neighboring states. Kansas observations after 1966 were missing and were imputed using changes in the ratio of rent to value in Missouri (see below).

The West

The problems were:

1. There were no data before 1960.
2. There were separate series for cash rent for dryland, grazing land, and irrigated land, but no single cash rent series.
3. There were missing values for some states in some years.
4. The grazing land rents were unstable, with large jumps between some years, probably due to smallness of the sample.
5. Differences between rents in neighboring states seemed implausible. They were probably not indicators of the average difference in quality, but rather reflected the unrepresentativeness of the samples in one or more states.

We took the following steps:

1. Missing values were interpolated as simple averages of neighboring values.
2. Grazing land rents which deviated by more than 100% from observations in the nearest two years were dropped and replaced by the closer of the surrounding values.
3. Regional grazing land rents were computed as simple averages of the rents for the states in that region. The regions were the Pacific Northwest (Washington, Oregon, Idaho), Mountain States (Montana, Wyoming, Colorado, Utah), Southwest (Arizona, New Mexico). A revised state rent was then computed as 1/3 the rent for that state plus 2/3 the rent for the region in which the state was located. This smoothed differences across states, addressing problem 5 above. No smoothing was applied to grazing rents in California, Texas, or Nebraska.
4. From the Agricultural Censuses the number of acres planted to crops and the number of acres used for range or pasture were obtained. From cropland the number of acres irrigated was separated. Straight-line interpolation was used to obtain values for intercensal years. The share of each type of land use in total land was computed.
5. Average cash rent on farm land was obtained as the sum of the cash rents on grazing land, dryland, and irrigated land, weighted by the shares computed in the preceding step.
6. For the years before 1960, cash rent was extrapolated based on the average ratio of rent to per-acre land value during 1960-1965, for each state.
7. For the years 1980-1982, a similar extrapolation was based on the ratio of rents to land value from 1975-1979. The rents used for this step and the preceding step were the average rents computed in step 5. The land value was the average value of an acre, as reported in Farm Real Estate Market Developments.

In addition, due to the peculiarities in the treatment of some states, the following measures were taken:

1. All Nevada observations were missing. Cash rents for Nevada were computed as the average of rents to value per acre for New Mexico and Utah, times the value of an acre of farmland for Nevada, in all years.
2. Nebraska was handled as an eastern state from 1949-1966, and a western state thereafter.
3. Observations for Texas were missing from 1949-1966, and were computed as the Oklahoma ratio of rent to value, times Texas value per acre, times the average ratio of the Oklahoma rent/value to the Texas rent/value for 1967-1969.
4. Kansas observations after 1966 were missing and were computed as Missouri ratio of rent to value times Kansas value per acre, times the average ratio of the Missouri rent/value to

the Kansas rent/value for 1963-1966.

Capital

There are two capital categories. The first is based on expenditures on operation and repair of machinery and buildings, which may be thought of as a variable expense. The second is a measure of the quasi-fixed factor, capital, consisting of machinery and service structures. The input to production from this quasi-fixed factor is its service flow.

1. Repair and operation of machinery and buildings.

Expenditures on this item (EXPCAP) are reported in the State Income series. Repair of operators' dwellings is excluded. We divided this dollar figure by an index of the 'price' of operation and repair to convert it to real terms. This price was based on two indices prepared by the USDA at the national level and published in Agricultural Prices: the index of the price of farm and motor supplies (IFM), and the index of the price of building and fencing supplies (IBF). IFM was not available prior to 1965. In earlier years the same groups of inputs were handled in two separate series: the price of machinery supplies (IMS), and the price of farm supplies (IFS). To splice together the earlier indices with IFM, and to weight the various components in an overall index of the cost of operating and repairing capital items, we used the weight given to each index in the 1958 composite index of prices paid by farmers for commodities and services, interest, taxes, and wage rates. These weights were:

IMS	3.5%
IFS	2.8%
IBF	2.9%

Adding the first two gave us

IFM	6.3%

for the 1965-82 period. We extrapolated IFM to the pre-1965 period by computing the percentage change in IMS and IFS relative to their 1965 values, weighting the two as follows -- % change in IMS x (35/63) + % change in IFS x (28/63)--and multiplying the result by IFM for 1965. We then computed an index of the costs of operation and repair of capital items (PCAPOP) for the whole period as IFM x (63/92) + IBF x (29/92).

Operation and repair in real terms was computed as expenditures (EXPCAP)/(PCAPOP) = CAPOP.

2. The stock of capital was based on unpublished USDA figures giving depreciation of various capital items annually at the state level. They are depreciation on service structures (SERDEP), trucks (TKDFP), tractors (TRDEP), automobiles (AUDEP), and other equipment (EQDEP). All depreciation is calculated at current replacement cost. Only the share of truck and automobile depreciation corresponding to farm (as opposed to household) use is included.

The USDA arrives at state depreciation figures by allocating national depreciation across states according to various criteria. The national depreciation figures themselves are computed on a straight-line basis from national estimates of the value of the capital in each category. We took the straight-line depreciation percentages and divided them into the state depreciation figures to obtain estimates at the state level of the stock of capital in each category. That is, we computed

value of automobiles (VAU) = AUDEP/.22
value of trucks (VTK) = TKDEP/.21
value of tractors (VTR) = TRDFP/.12
value of other equipment (VEQ) = EQDEP/.14

where .22, .21, .12, and .14 are the USDA's depreciation rates on automobiles, trucks, tractors, and other equipment, respectively.

The depreciation rate on service structures has not been constant over time. We computed the national rate (SDRATE) as the national service structure depreciation divided by the national value of service structures, published in the Farm Balance Sheet statistical series. We then used this estimate to obtain the value of service structures at the state level as VSER = SERDEP/SDRATE.

We estimated the nominal service flow from these capital items as depreciation plus a fixed percentage (.04) of their current value at replacement cost. 4% was used as a proxy for farmers' view of the long-term interest rate to which the marginal product of capital should correspond. That is, defining

FARMDEP = AUDEP + TKDEP + TRDEP + EQDEP + SERDEP
VMACH = VAU + VTK + VTR + VEQ

we obtained the value of the service flow from capital as

VCAPSER = FARMDEP + .04 (VMACH + VSER).

We converted this to real terms using the USDA national indices on prices paid for automobiles and trucks (IAU), tractors (ITR), farm equipment (IMA) and building and fencing supplies (IBF). IAU was not available for the years before 1965. In the earlier period, trucks, automobiles and tractors were treated together in IMV, an index of the prices of motor vehicles. Examination of the separate series in the post-65 period showed they moved quite similarly until the last few years. We assumed therefore that they moved similarly in the earlier period as well and used the single series IMV to deflate VTR, VTK, and VAU pre-1965. Two different series were published for farm machinery items not covered in the motor vehicle indices. One of these was discontinued in the 1960's, replaced by what is now called the index of prices paid for other machinery and implements. Despite a change in some of the items covered in the two series, we took them to be measures of the same things. This approach seems reasonable since the two had very similar values during the overlapping years in which both were published:

	old series	new series	
1965	426	424	(1914=100)
1966	442	437	

The real service flow from the capital stock was then computed as

= (AUDEP + .04 VAU)/IAU
+ (TRDEP + .04 VTR)/ITR
+ (TKDEP + .04 VTK)/ITK
+ (EQDEP + .04 VEQ)/IMA
+ (SERDEP + .04 VSER)/IBF.

In this calculation, as in previous steps, all indices were converted to 1977=100 to ensure consistency.

Feed

There are three classes of feed inputs: (1) purchased, commercially-prepared feeds; (2) harvested grain, soybeans, and hay; (3) forage and silage. The second class can be subdivided into grain, etc. that is (2a) purchased from another farm and (2b) fed to animals on the farm where it was grown. For brevity, we refer to the latter as "farmfed" output.

Discussion of our procedures is facilitated by regrouping these classes into two: purchased feed inputs and non-purchased feed inputs.

Purchased Feed

Production Expenditures published in the State Farm Income series include expenditures on feed (EXPFEED). These expenditures were for items in classes (1) and (2a) above.

To convert this measure of value to a measure of quantity, we divided by the price of 16% protein dairy feed (PFEED) observed in June for each state as reported in Agricultural Prices. Occasionally this variable was not available for some states, in which cases we used observations from a neighboring state. We then obtained FEED = EXPFEED/PFEED.

Non-Purchased Feed

Class (2b): Harvested grain, soybeans and hay fed to animals on the farms where grown (farmfed).

1. Data on hay production were unavailable. USDA estimates of hay sales in each state (HAS) were available. We assumed all sales were intrastate. HAS was divided by the state price of hay and counted as an output, while HAS on the input side is included in EXPFEED. Farmfed hay was counted neither as an output nor as an input. (See remarks below on silage and forage.)

2. From 1949-1980 the USDA published estimates on wheat, soybeans, and the four feed grains used on the farms where grown (in our notation WHUSED, SYUSED, COUSED, BAUSED, OAUSED, and SOUSED, respectively). From 1949-1974 the figures for wheat and soybeans were further broken down into use for feed (WHFEED, SYFEED) and use for seed (WHSEED, SYSEED). This left us with the problem of filling in missing values.

(i) We assumed all feed grains used on farms were fed to animals.

(ii) We extrapolated the xxUSED series to 1981 and 1982 by computing the average ratio of xxUSED to xx production over 1978-1980 and applying this ratio to 1981 and 1982 production.

(iii) For soybeans and wheat, we made a second extrapolation extending the breakdown of total use into seed and feed to the post-1974 period.

For soybeans, we computed the ratio of SYSEED to SYUSED for 1969-1974, and applied this ratio of SYUSED in the years after 1974. We then computed SYFEED = SYUSED-SYSEED.

We attempted the same procedure for wheat. This gave implausible results, however, as the quantity of wheat used for feed is unstable, rising sharply when wheat prices fall near the price of corn, corrected for the difference in nutrient value. We therefore based our approach on the assumption that WHSEED is more likely to be a stable fraction of the total amount of seed required to plant the year's wheat crop, than the proportions of WHSEED and WHFEED in WHUSED are apt to be stable. Thus, we computed the ratio of WHSEED to total seed input for the current crop (WHSD) for 1969-73 and applied this ratio to WHSD for 1974-82 to extrapolate the WHSEED series. We then computed WHFEED for these years as the residual, WHUSED-WHSEED.

(iv) The next set of assumption concerned the timing of feeding. We assumed that 1/4 of the farmfed corn, sorghum, and soybeans were fed in the year of harvest (roughly October through December), and the remainder fed the following year. We made no attempt to measure stocks that might have been held over to later years.

For wheat, oats and barley, which are harvested in mid-year, we made a analogous assumption: half the farmfed grain was assigned to current year use and half to the following year.

(v) Farmfed grains and soybeans were valued at the season average price received by farmers for the crop being fed. Thus, 1978-crop corn fed to animals in 1978 was valued at the season average price for the 1978 crop, as was 1978-crop corn fed in 1979.

(vi) Lacking reliable series on the quantity and value of silage and forage, we ignored these input items. However, we also omitted them from the output side. Aside from the (minor) effect on the weights attaching to measured inputs and outputs, their omission from both sides will not affect measurement of total factor productivity. The same applies to unsold hay output.

Final estimates of feed quantities and prices were obtained by summing appropriately lagged or averaged WHFEED, SYFEED, COFEED, BAFEED, OAFEED, SOFEED. This quantity plus FEED = TOTFEED. Valuing the quantities as indicated under (v), we obtained their total value (in $ million) as VTOTFEED and divided by TOTFEED to obtain PTOTFEED.

All quantities were converted to millions of tons prior to summing.

Fertilizer

From Production Expenditures in the State Farm Income series we obtained calendar year expenditures on fertilizer (EXPFERT). There is considerable diversity among states in the breakdown of these expenditures among types of fertilizer. In consequence, there are differences in the appropriately weighted price to be used to convert dollar expenditures into a measure of the quantity of fertilizer. We assumed that this diversity is not nearly so great within production regions as across regions, however, and therefore proceeded to obtain an appropriate regional price as follows.

The USDA's Production and Efficiency Statistics published annual estimates of fertilizer use in ten major production regions (e.g., the Corn Belt, the Southeast) by major component--that is, how many million tons of nitrogen, potassium, and phosphate were used. We added these figures and divided the total into the regional subtotal of EXPFERT, obtaining a regional price per ton of chemical ingredient (PFERT). This is in effect a quantity-weighted index of fertilizer prices where the weights reflect the regional mix of nitrogen, potassium and phosphate in a 'representative' ton of fertilizer, as well as cost differences arising from the use of cheaper sources of nitrogen (e.g., anhydrous ammonia) in some regions compared to others.

Miscellaneous Inputs

Production Expenditures in State Farm Income include a catch-all item for miscellaneous inputs (EXPMISC). We divided EXPMISC by IPR, an index of prices paid for all production items, computed at the national level and published in Agricultural Prices, to obtain a measure of the quantity of miscellaneous inputs, MISC.

II. OUTPUTS

Price and quantity data for the following outputs are reported at the state level. Price is the season average price received by producers.

Cotton (CN)
Tobacco (TO)
Sugar cane (SC)
Sugar beets (SB)
Dry edible beans (DB)
Milk (MI)
Broilers (BR)
Turkeys (TU)
Eggs (EG)
Corn (CO)
Sorghum (SO)
Oats (OA)
Barley (BA)
Wheat (WH)
Rice (RI)
Apples (AP)
Grapes (GR)
Oranges (OR)
Grapefruit (GF)
Hay sold (HAS)
Cattle & calves (CC)

Hogs & pigs (HO)
Sheep & lambs (SL)
Soybeans (SY)
Peanuts (PE)
Cottonseed (CS)
Lettuce (LE)
Onions (ON)
Tomatoes (TM)
Potatoes (PO)
Other crops (OCR)
Other livestock products (OLP)
Other fruits (OFR)
Other vegetables (OVE)

Quantities

For most output categories, quantity is production as reported by the USDA. For crops, production is the harvest of that year.

Where inventories carried over from one year to the next are negligible relative to annual production, we constructed a measure of production as calendar year receipts from sales divided by the season average price. This was true of milk, eggs, broilers, and turkeys. We followed this procedure as well for oranges and grapefruits, and for the residual "other" categories. (See the discussion under prices.)

Since we used meat animal production as our measure of output, we dropped feeder livestock from the category of inputs. Production is in terms of pounds added=the weight of slaughtered animals less change in inventory (including net inshipment of feeder livestock). Since we are using a net rather than gross measure of output, it is appropriate to drop such inventory changes on the input side.

Prices

Prices are not reported for states where the output in question was not produced.

We sought a measure of expected price for the value weights in the output index. We used 1-year lagged prices as a proxy for expected prices for crops with well-defined growing seasons and meat animals with long gestation and feeding periods. We used current prices for outputs produced continuously through the year (dairy and poultry products) and for outputs whose main current production decisions concern harvest and marketing. The latter include tree and vine crops: apples, grapes, oranges and grapefruits. In the long run, of course, their output depends on farmers' expectations of the long-run "normal" price, but we did not attempt to approximate this.

The USDA has not always published a single season average price at the state level for crops where several varieties are grown. For tomatoes, onions, potatoes, and tobacco our price is a quantity-weighted average of the prices of the individual varieties when no such price was published.

Neither quantity nor price data per se were available for the "other" categories. We used dollar receipts data, divided by price indices, to obtain quantities of "other" outputs. The price indices used were

ILP = index of price of all livestock products
ICR = index of the price of all crops
IVE = index of the price of vegetables
IFR = index of price of fruits.

They are nationally-weighted price indices.

FOOTNOTES (Appendix I)

[1] No Wage data are available for 1981. We interpolated the 1981 wage as the simple average of the 1980 and 1982 values.

[2] This is probably false. The farmer's working day likely grew shorter over this period. However, the years for which we have data on both the number of workers and the average number of hours show that by far the biggest source of reduction in manhours has been the fall in the number of workers, not the number of hours. Inasmuch as we have a measure of the number of workers for 1949-1964, we have by far the most important component of variation in labor input over this period.

APPENDIX II

State TFP Indexes, 1949-82

by Region

NORTHEAST

YEAR	DELAWARE	MARYLAND	NEW JERSEY	NEW YORK	PENNSYLVANIA
1949	100.000	100.000	100.000	100.000	100.000
1950	115.646	103.596	114.101	104.719	102.506
1951	104.303	99.647	115.794	97.393	101.752
1952	95.902	97.653	104.505	100.645	102.291
1953	106.070	105.187	121.572	106.159	109.420
1954	106.364	102.356	110.825	101.854	112.358
1955	111.346	99.228	99.548	104.689	111.195
1956	131.935	113.403	125.799	108.821	118.530
1957	123.221	100.588	115.765	108.833	113.639
1958	137.457	118.791	126.901	110.647	125.320
1959	140.306	116.861	128.799	110.732	123.443
1960	145.780	125.092	136.193	113.681	130.566
1961	148.188	128.125	142.803	118.212	135.499
1962	144.588	123.964	146.025	118.587	134.764
1963	143.166	122.214	132.888	116.483	134.797
1964	145.815	149.905	137.410	122.629	141.044
1965	169.694	158.301	160.616	130.095	149.303
1966	151.055	135.964	158.320	128.692	144.548
1967	182.554	155.050	170.964	132.387	160.706
1968	169.930	150.694	165.462	128.917	152.743
1969	191.501	157.391	160.524	130.764	161.152
1970	181.220	155.382	170.100	132.887	158.887
1971	183.310	150.090	148.126	130.244	160.842
1972	180.397	150.249	135.738	121.557	153.942
1973	170.776	144.988	139.335	118.389	148.154
1974	174.631	143.727	157.504	117.326	151.523
1975	173.631	146.989	136.869	118.502	149.315
1976	196.309	158.768	140.514	118.482	171.065
1977	196.641	154.189	128.885	123.046	174.867
1978	221.179	172.632	124.125	129.018	182.545
1979	209.061	160.967	115.600	125.125	182.971
1980	183.133	153.441	122.859	130.713	177.018
1981	212.691	181.260	134.000	131.866	202.658
1982	227.499	181.726	136.629	133.646	202.920

LAKE STATES

YEAR	MICHIGAN	MINNESOTA	WISCONSIN
1949	100.000	100.000	100.000
1950	98.896	98.550	102.276
1951	97.657	99.171	100.556
1952	98.798	103.069	104.008
1953	104.213	104.335	107.791
1954	100.194	108.814	106.506
1955	104.197	113.984	109.964
1956	108.593	121.279	113.093
1957	106.234	120.363	114.656
1958	114.860	142.336	115.381
1959	117.513	127.098	121.620
1960	115.605	128.829	119.130
1961	123.688	132.360	127.700
1962	126.960	124.127	126.502
1963	128.448	137.490	130.142
1964	134.563	128.826	137.529
1965	138.026	133.839	143.348
1966	140.809	140.996	141.387
1967	144.677	142.669	146.106
1968	142.355	146.949	147.552
1969	146.406	141.912	125.988
1970	145.297	147.788	148.286
1971	152.032	158.293	152.565
1972	162.810	153.089	148.616
1973	154.277	165.967	145.079
1974	158.570	147.599	149.676
1975	180.370	152.000	150.362
1976	176.157	145.176	152.618
1977	190.939	185.635	167.437
1978	193.441	185.162	165.721
1979	191.249	182.112	160.542
1980	199.586	181.016	162.939
1981	206.487	195.410	166.919
1982	220.296	194.048	164.785

CORN BELT

YEAR	ILLINOIS	INDIANA	IOWA	MISSOURI	OHIO
1949	100.000	100.000	100.000	100.000	100.000
1950	97.045	99.007	101.280	101.901	97.773
1951	101.457	103.609	93.352	94.238	95.854
1952	103.125	100.408	109.813	101.585	101.892
1953	103.888	105.164	101.224	101.721	106.869
1954	102.818	108.018	108.777	100.674	109.699
1955	113.691	108.224	109.371	117.902	109.464
1956	124.978	114.882	109.690	121.614	111.160
1957	114.378	108.487	119.121	108.922	104.551
1958	123.606	111.827	117.744	118.806	112.529
1959	125.350	117.200	122.691	128.094	116.782
1960	124.136	122.131	116.804	123.305	120.537
1961	128.599	121.665	117.732	122.795	122.194
1962	127.593	127.092	115.052	120.929	126.945
1963	134.518	131.059	123.286	128.682	127.988
1964	129.521	122.957	124.010	124.100	126.772
1965	141.605	141.313	125.227	135.332	140.034
1966	128.347	128.931	128.892	129.550	138.026
1967	146.428	140.908	134.545	135.809	139.625
1968	135.820	142.835	130.909	144.831	150.639
1969	139.331	147.935	130.186	133.492	130.522
1970	125.457	139.783	128.708	136.953	147.659
1971	149.644	158.453	140.814	155.739	161.582
1972	142.587	146.086	135.465	147.744	150.477
1973	141.335	145.628	137.138	148.950	134.528
1974	121.080	122.768	121.966	135.194	136.541
1975	157.405	150.800	132.455	150.988	159.896
1976	142.064	159.524	128.522	146.790	164.746
1977	147.277	151.639	135.016	175.339	158.866
1978	148.828	157.757	147.489	166.763	156.908
1979	156.352	156.284	144.533	174.515	164.595
1980	142.922	157.537	146.604	157.879	164.803
1981	166.713	164.404	161.219	188.716	150.446
1982	165.870	187.240	148.923	184.415	182.320

NORTHERN PLAINS

YEAR	KANSAS	NORTH DAKOTA	NEBRASKA	SOUTH DAKOTA
1949	100.000	100.000	100.000	100.000
1950	110.581	112.302	113.150	103.629
1951	96.943	114.335	101.711	110.318
1952	129.440	98.332	117.279	105.512
1953	100.240	103.952	107.603	116.334
1954	111.448	99.110	108.842	115.112
1955	97.823	127.902	105.325	115.762
1956	102.386	131.468	103.150	109.680
1957	108.080	131.661	136.840	135.063
1958	158.750	144.651	141.924	135.632
1959	143.930	117.545	137.467	117.572
1960	161.826	130.969	140.724	141.375
1961	157.796	104.510	130.176	133.995
1962	150.096	152.377	134.139	136.065
1963	148.826	143.796	137.264	144.674
1964	154.234	150.130	142.511	142.769
1965	162.402	169.534	144.082	152.381
1966	162.146	161.246	162.045	154.229
1967	170.677	161.475	161.487	164.379
1968	180.542	173.997	159.697	166.014
1969	191.850	172.626	170.712	156.541
1970	188.272	153.833	164.086	151.558
1971	208.044	202.285	173.294	167.481
1972	206.725	182.166	170.430	167.532
1973	202.067	189.347	166.525	171.069
1974	182.458	172.682	156.609	165.267
1975	193.290	192.283	179.791	161.574
1976	190.774	196.651	171.812	136.848
1977	202.209	189.637	187.243	177.797
1978	188.608	211.172	189.608	173.474
1979	205.294	193.558	196.252	172.240
1980	187.452	186.567	181.079	169.319
1981	203.696	242.347	212.711	190.398
1982	212.337	237.860	202.229	187.422

APPALACHIAN

YEAR	KENTUCKY	NORTH CAROLINA	TENNESSEE	VIRGINIA	WEST VIRGINIA
1949	100.000	100.000	100.000	100.000	100.000
1950	93.208	106.598	96.082	107.883	96.574
1951	100.765	125.826	99.096	109.981	101.064
1952	97.989	123.475	100.955	109.210	102.496
1953	102.732	120.884	109.881	111.618	108.170
1954	109.655	124.292	101.265	114.590	121.229
1955	101.952	132.888	113.657	111.803	111.862
1956	114.276	150.396	106.794	130.133	122.741
1957	105.234	129.386	103.619	115.078	118.167
1958	104.964	144.016	111.356	127.737	123.286
1959	111.460	144.074	123.006	126.269	126.492
1960	111.156	154.265	119.033	132.204	127.183
1961	117.765	156.828	123.831	135.420	126.800
1962	127.324	167.574	125.000	140.110	127.535
1963	136.175	171.523	131.775	134.726	130.621
1964	125.742	184.261	134.175	149.615	141.042
1965	129.898	172.211	140.381	155.339	143.756
1966	130.907	178.315	128.730	145.858	132.938
1967	134.184	199.558	134.205	161.639	143.969
1968	120.528	186.810	137.199	158.555	144.336
1969	145.449	202.708	141.340	167.601	149.563
1970	141.400	212.057	139.645	169.570	145.278
1971	147.742	205.758	144.640	163.097	143.478
1972	151.387	214.000	141.618	166.396	143.247
1973	141.137	222.259	140.465	172.274	137.906
1974	159.125	218.072	137.760	175.164	146.915
1975	156.345	238.256	160.316	174.728	158.085
1976	174.645	240.215	163.613	180.187	162.036
1977	166.075	222.353	167.232	180.800	149.547
1978	161.339	266.123	166.594	195.253	180.434
1979	161.558	231.831	169.806	187.435	188.015
1980	182.643	263.952	166.470	176.858	181.169
1981	219.104	269.043	202.940	211.290	185.904
1982	224.540	263.155	208.319	200.781	186.321

SOUTHEAST

YEAR	ALABAMA	FLORIDA	GEORGIA	SOUTH CAROLINA
1949	100.000	100.000	100.000	100.000
1950	97.444	101.784	104.262	93.665
1951	109.241	98.191	119.684	130.950
1952	106.120	100.535	109.042	120.814
1953	130.729	97.351	128.638	130.431
1954	108.647	87.117	110.996	110.496
1955	149.133	98.588	140.697	132.441
1956	141.435	97.740	151.630	134.487
1957	135.623	94.495	139.405	123.953
1958	143.265	90.097	147.887	124.675
1959	155.801	95.812	158.889	133.247
1960	163.477	99.111	168.549	138.557
1961	160.652	104.369	176.596	142.962
1962	162.540	105.737	174.213	154.130
1963	182.411	104.864	192.237	157.832
1964	185.024	104.854	195.673	167.318
1965	198.327	104.807	207.861	177.643
1966	185.504	110.072	211.334	169.685
1967	189.659	117.313	240.774	193.212
1968	195.364	107.172	222.099	164.882
1969	202.806	111.564	233.935	190.825
1970	206.562	106.536	230.847	184.011
1971	220.947	112.868	252.417	199.289
1972	216.385	113.088	239.340	187.460
1973	213.357	104.860	227.327	190.600
1974	217.709	109.868	237.030	203.960
1975	244.650	125.756	239.723	215.620
1976	250.884	132.418	252.476	219.884
1977	240.408	123.100	215.455	198.605
1978	256.384	121.219	248.452	219.029
1979	256.392	119.575	250.708	220.680
1980	235.667	123.230	223.667	198.325
1981	294.399	125.256	265.167	246.125
1982	288.564	127.505	277.340	249.313

DELTA

YEAR	ARKANSAS	LOUISIANA	MISSISSIPPI
1949	100.000	100.000	100.000
1950	91.440	90.910	101.869
1951	93.835	100.927	110.182
1952	101.667	106.589	126.039
1953	112.360	115.069	145.103
1954	116.602	110.003	125.607
1955	133.730	114.349	158.538
1956	135.345	114.145	144.425
1957	123.238	101.740	131.012
1958	127.119	100.763	134.761
1959	160.287	109.831	163.632
1960	154.106	115.088	165.485
1961	159.953	117.875	175.799
1962	165.623	118.134	176.170
1963	169.303	133.452	205.894
1964	185.040	131.079	213.408
1965	190.918	134.326	221.676
1966	184.874	141.869	207.881
1967	184.665	153.161	216.509
1968	202.303	165.271	233.611
1969	207.824	156.635	229.337
1970	201.743	169.338	242.314
1971	206.040	163.962	243.093
1972	208.288	167.995	254.355
1973	207.143	151.471	242.562
1974	201.331	155.922	229.967
1975	236.113	175.477	246.794
1976	233.797	191.857	261.526
1977	251.663	202.553	292.938
1978	254.004	192.755	283.909
1979	260.374	198.939	317.305
1980	223.654	167.348	260.191
1981	283.306	199.212	313.727
1982	283.957	217.464	340.134

SOUTHERN PLAINS

YEAR	OKLAHOMA	TEXAS
1949	100.000	100.000
1950	88.090	86.172
1951	92.021	87.849
1952	103.464	91.110
1953	105.140	96.417
1954	105.593	100.986
1955	97.471	103.561
1956	106.094	100.955
1957	99.699	108.907
1958	136.122	119.713
1959	133.420	121.279
1960	154.913	127.646
1961	146.830	130.824
1962	126.144	124.301
1963	131.837	126.184
1964	146.450	130.879
1965	164.761	140.549
1966	149.385	131.222
1967	146.941	132.042
1968	155.707	139.485
1969	154.953	132.645
1970	155.382	139.625
1971	143.986	131.829
1972	154.003	138.953
1973	163.442	145.570
1974	162.157	138.395
1975	171.615	152.873
1976	170.633	157.616
1977	187.861	174.837
1978	165.554	150.546
1979	188.600	156.799
1980	187.170	138.978
1981	192.768	167.576
1982	207.798	158.308

MOUNTAIN

YEAR	ARIZONA	COLORADO	IDAHO	MONTANA	NEVADA	NEW MEXICO	UTAH	WYOMING
1949	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
1950	94.539	91.586	107.144	119.800	110.961	88.316	101.771	109.278
1951	107.853	91.484	93.310	118.579	109.883	93.883	105.864	111.671
1952	109.714	99.785	96.890	116.055	99.542	90.281	101.072	114.379
1953	108.627	98.686	104.648	134.526	109.941	95.923	107.110	114.040
1954	100.948	86.269	104.247	124.854	106.640	98.549	101.807	112.712
1955	89.951	84.921	107.168	146.497	103.875	92.648	104.158	111.335
1956	91.821	87.845	103.669	127.105	98.075	97.815	108.845	115.904
1957	93.179	108.845	110.459	128.708	97.110	99.930	109.049	127.845
1958	88.853	122.796	110.020	137.950	81.421	112.865	97.863	127.110
1959	87.886	120.688	107.255	125.445	81.995	117.120	100.248	126.767
1960	96.241	121.377	104.829	127.997	80.312	115.488	100.047	121.646
1961	96.506	119.331	113.653	112.076	74.672	119.985	99.925	118.210
1962	95.829	112.098	107.936	128.039	77.198	116.474	103.749	116.352
1963	95.065	112.379	116.062	137.587	79.634	116.978	101.077	128.879
1964	94.793	119.782	109.327	145.837	88.913	111.727	100.307	130.128
1965	99.772	119.335	125.481	150.441	89.628	117.941	99.986	131.778
1966	93.674	122.484	125.703	151.340	89.989	119.373	105.229	134.142
1967	93.572	125.373	134.665	148.674	82.318	120.572	114.527	140.208
1968	98.377	127.362	136.061	160.147	88.517	114.035	111.552	138.313
1969	98.838	136.628	142.882	158.807	91.975	118.006	111.659	133.216
1970	97.999	139.838	146.099	153.708	92.956	126.018	114.779	132.900
1971	94.876	137.983	148.543	158.095	101.709	118.311	109.640	139.389
1972	99.837	138.877	141.823	152.564	101.325	122.700	109.064	136.346
1973	94.445	144.343	135.785	145.311	104.570	125.313	112.100	128.360
1974	114.557	139.705	140.987	149.931	99.824	119.936	112.386	137.321
1975	101.399	150.598	146.767	171.590	100.300	123.021	105.523	131.530
1976	114.735	149.812	145.631	177.610	97.681	136.212	115.183	143.409
1977	109.714	151.379	139.919	155.724	97.722	132.875	114.452	138.510
1978	109.361	157.137	152.539	168.193	99.031	124.759	113.011	138.861
1979	97.276	154.522	148.808	136.629	92.910	120.431	96.705	121.200
1980	107.699	161.724	162.904	150.533	99.975	139.920	103.414	133.641
1981	112.397	164.022	168.012	177.063	103.696	135.480	118.374	139.846
1982	100.733	162.881	162.926	172.967	101.163	141.875	115.360	130.273

PACIFIC

YEAR	CALIFORNIA	OREGON	WASHINGTON
1949	100.000	100.000	100.000
1950	101.010	101.775	112.522
1951	110.423	102.213	98.198
1952	109.052	105.731	104.006
1953	106.482	113.900	113.716
1954	104.114	113.589	115.529
1955	113.500	118.086	109.411
1956	120.775	121.923	107.658
1957	115.265	123.073	126.143
1958	115.092	120.769	121.514
1959	123.499	128.129	127.772
1960	122.887	120.341	121.571
1961	117.366	120.564	120.638
1962	124.631	123.114	125.985
1963	116.557	123.277	133.373
1964	126.372	127.693	133.072
1965	123.698	140.789	143.678
1966	135.465	144.530	157.033
1967	139.423	152.107	164.067
1968	151.971	146.552	156.328
1969	153.516	160.913	169.591
1970	151.007	159.548	165.224
1971	154.294	160.083	172.740
1972	163.584	168.352	180.244
1973	162.684	157.880	181.712
1974	176.653	177.417	186.435
1975	193.793	178.511	216.482
1976	182.479	192.307	212.860
1977	192.230	181.263	202.547
1978	174.198	183.979	223.306
1979	183.904	188.507	201.415
1980	188.756	203.863	227.577
1981	188.051	209.258	235.365
1982	186.219	199.482	231.836