Productivity and Economic Growth in U.S. Agriculture

Eldon Ball, Sun Ling Wang, and Richard Nehring
Economic Research Service
U.S. Department of Agriculture

Abstract: It is widely reported that productivity growth is the main contributor to economic growth in U.S. agriculture. This article provides estimates of economic growth over the postwar period and decomposes that growth into the contributions of input growth and productivity growth. The analysis is based on recently revised production accounts, now spanning the 1948-2013 period. Our findings are fully consistent with those reported in the literature. Productivity growth dominates input growth as a source of economic growth in the sector.

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1. Introduction

The rise in agricultural productivity has long been chronicled as the single most important source of economic growth in the U.S. farm sector. Though their methods differ in important ways, the major sectoral productivity studies by Kendrick and Grossman (1980), Jorgenson, Gollop, and Fraumeni (1987), and Jorgenson and Gollop (1992) share this common conclusion. In a more recent study, Jorgenson, Ho, and Stiroh (2005) find that productivity growth over the 1977-2000 period accounted for nearly 80% of output growth in agriculture. This compares with only 9% for the economy as a whole. Moreover, the rate of productivity growth over this period in agriculture (1.9%) was nearly 10 times the corresponding economy-wide rate (0.21%).

The U.S. Department of Agriculture (USDA) has been monitoring the industry’s productivity performance for decades. In fact, the USDA in 1960 was the first agency to introduce multifactor productivity measurement into the Federal statistical program. Today, having incorporated recommendations made by an American Agricultural Economics Association taskforce (USDA, 1980) and by a second more recent panel (see Shumway et al., 2014), the department’s Economic Research Service (ERS) bases its official productivity statistics on a sophisticated system of production accounts. The USDA model of productivity growth is based on the translog transformation frontier. It relates the growth rates of multiple outputs to the cost-share weighted growth rates of labor, capital (including land and inventories), and intermediate inputs.

The applied USDA model is quite detailed. The changing demographic character of the

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1 These comparisons are based on median rates of growth for forty-four sectors of the economy.
2 The more recent review was motivated by the Office of Management and Budget’s (OMB, 2011) mandates for ensuring data quality and valid procedures for developing Federal statistical information.
agricultural labor force is used to construct a quality-adjusted index of labor input. Similarly, much asset-specific detail underlies the measure of capital input. The index of capital input is formed by aggregating over the various capital assets using cost-share weights based on asset-specific rental prices. The contributions of feed and seed, chemicals, energy, and purchased services to output growth are captured in the index of intermediate inputs. An important innovation is the use of hedonic price indexes in constructing measures of fertilizers and pesticides consumption, as well as certain purchased services. The result is a USDA time series of total factor productivity (TFP) indexes now spanning the 1948-2013 period.

The primary objective of this paper is to report trends in output growth over the 1948-2013 period and to identify the contributions of input growth and productivity growth to economic growth in the sector. The analysis is based on the model of sectoral production developed in Jorgenson, Gollop, and Fraumeni (1987) and on the updated production accounts as described in this paper. The important role of productivity growth in agriculture becomes immediately apparent.

We also examine the importance of changing input quality as a source of economic growth. The observation, first made by Griliches (1964) some fifty years ago, that improved labor quality of the agricultural labor force is an important determinant of the sector’s economic growth is confirmed in this analysis.

The paper’s major conclusion is that productivity growth has been the principal source of economic growth in agriculture over the postwar period, accounting for more than 90% of the growth in output. In addition, changes in input quality have made significant contributions to input growth and, therefore, economic growth. The net effect of quality change in all three inputs (i.e., labor, capital, and intermediate inputs) has resulted in a 0.12% per year contribution to
economic growth. In fact, quality change was the sole reason for any positive contribution arising through growth in aggregate input.

**Production Accounts**

The USDA’s Economic Research Service (ERS) has constructed aggregate accounts for the farm sector consistent with a gross output model of production (see Ball, 1985; Ball et al., 1997).\(^3\) Output is defined as gross production leaving the farm, as opposed to real value added.\(^4\) Inputs are not limited to labor and capital but include intermediate inputs as well. The model views all of agriculture within its geographic boundary as if it were a single farm. Output includes all off-farm delivers but excludes intermediate goods produced and consumed within the farm.\(^5\)

The ERS defined the farm sector in exactly the same way as in the National Income and Product Accounts (NIPA). This means that minor goods and services (i.e., secondary outputs) for agriculture that are primary to other industries were included in the primary industry’s output. For example, machine services performed by farmers, a secondary output, were excluded from agriculture and included in agricultural services.

However, current USDA output accounts take the existence of certain (inseparable) secondary activities into account when measuring the productive activity of the sector. These activities are defined as activities whose costs cannot be separately observed from those of the

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\(^3\) We have also developed production accounts for the forty-eight contiguous states. However, efforts to maintain the state accounts were suspended when in 2002 the Farm Labor Survey administered by USDA’s National Agricultural Statistics Service (NASS) was discontinued. The adoption of new data sources (Current Population Survey and, more recently American Community Survey) has allowed us to extend our estimates of labor input (and, hence, productivity) at the aggregate level through 2013, but we have been limited in our ability to develop spatially reliable estimates of labor input.

\(^4\) The existence of the value added function requires that intermediate inputs be separable from primary inputs (capital and labor). This places restrictions on marginal rates of substitution that are not likely to be realistic. Moreover, even if the value added function exists, the exclusion of intermediate inputs assigns all measured technical progress to capital and labor inputs, ruling out increased efficiency in use of purchased inputs.

\(^5\) Intermediate goods produced and consumed within the farm are self-cancelling transactions and, therefore, do not
primary agricultural activity (see United Nations Revised System of National Accounts, 1993; Eurostat, 2000). Examples include machine services for hire, custom feeding of livestock, farm forestry, and recreational activities. The output of the sector thus results from two kinds of activities: agricultural activities, whether primary or secondary, and non-agricultural (or secondary) activities of farms.

To avoid ambiguity, it should be pointed out that the accounts do not include all secondary activities. Those that can be observed separately from the agricultural activity are excluded. Moreover, they include the agricultural activities of sectors whose primary activity is non-agricultural.

Output: The development of a measure of output begins with disaggregated data on prices and quantities of agricultural goods. For each category of output, the quantity includes the quantities sold off the farm (including unredeemed Commodity Credit Corporation loans), additions to inventory, and quantities consumed in farm households as part of final demand. The corresponding price reflects the value of that output to the producer; that is, subsidies are added and indirect taxes are subtracted from market values. We also include the output of goods and services of certain non-agricultural (or secondary) activities when these activities cannot be distinguished from the primary agricultural activity. Translog indexes of farm output are formed by aggregating over agricultural goods output and the output of goods and services of inseparable secondary activities.

Intermediate Input: Intermediate input consists of goods used in production during the calendar

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6 Prices received by farmers, as reported in USDA’s Agricultural Prices, include an allowance for net Commodity Credit Corporation loans and purchases by the government under the marketing loan program valued at the average loan rate. However, direct payments under the Federal commodity programs are not reflected in the data.
year, whether from beginning inventories or purchased from outside the farm sector.\textsuperscript{7}

Measures of intermediate inputs are formed as translog indexes over a set of goods and services. Price and quantity data corresponding to purchases of feed and seed are available from the USDA and directly enter the calculation of intermediate goods.\textsuperscript{8} Data on current dollar consumption of petroleum fuels, natural gas, and electricity in agriculture are also available.\textsuperscript{9} Prices for individual petroleum fuels are taken from annual issues of Agricultural Prices. The Monthly Energy Review (Energy Information Administration, U.S. Department of Energy) is the source for natural gas and electricity prices. The corresponding quantity measure for each energy source is formed implicitly as the ratio of expenditures and price.

Fertilizers and pesticides are important intermediate inputs, but their data require adjustment since these inputs have undergone significant changes in input quality over the study period. Since input price and quantity series used in a study of productivity must be denominated in constant-efficiency units, price indexes for fertilizers and pesticides are constructed using hedonic regression techniques. A price index for fertilizers is formed by regressing the prices of single nutrient and multi-grade fertilizer materials on the proportion of nutrients contained in the materials. Prices of pesticides are regressed on differences in physical characteristics such as toxicity, persistence in the environment, and leaching potential (see Fernandez et al., 2014). The corresponding quantity indexes for fertilizers and pesticides are formed implicitly by taking the ratio of the value of each aggregate to the corresponding hedonic price index.

Finally, price and implicit quantity indexes are constructed for purchased services, such

\textsuperscript{7} We assume that intermediate goods produced and consumed within the farm are from beginning stocks. Therefore, the measure of output is equated with gross production.

\textsuperscript{8} Purchases of livestock are recorded as additions to the stock of “goods in progress” and not as intermediate input.

\textsuperscript{9} Expenditures for motor fuels are net of excise tax rebates.
as contract labor services, purchased machine services, and maintenance and repairs.\textsuperscript{10} The available data consist of nominal expenditures for the various services. To decompose expenditures for contract labor services into price and quantity components, we estimate a hedonic wage function where hourly earnings are expressed as a function of demographic characteristics including sex, age, education, and experience, as well as legal status and type of employment (hired versus contract laborers).\textsuperscript{11} Purchased machine services substitute for own capital input. Therefore, we construct the implicit quantity of purchased machine services as the ratio of expenditures to an index of rental prices of agricultural machinery (i.e., farm tractors; agricultural machinery excluding tractors). Translog indexes of intermediate input are constructed by weighting the growth rates of each category of intermediate input described above by their value share in the overall value of intermediate inputs.

\textit{Labor Input:} Current USDA labor accounts for the farm sector incorporate the demographic cross-classifications of the agricultural labor force developed by Jorgenson, Gollop, and Fraumeni (1987) (see Ball et al., 1997). Matrices of hours worked and compensation per hour are developed for laborers cross-classified by sex, age, education, and employment class (employee versus self-employed and unpaid family workers).

This is accomplished using the RAS procedure popularized by Jorgenson, Gollop, and Fraumeni (pp.72-76) by combining the farm sector matrices initially produced in that study with demographic information taken from the decennial Census of Population (Bureau of the Census, U.S. Department of Commerce).\textsuperscript{12} The result is a set of annual hours worked and hourly

\textsuperscript{10} Premiums less subsidies for publically-provided disaster insurance are included in the cost of purchased services, while indemnity payments are included in the value of output (see Shumway et al., 2014).

\textsuperscript{11} See Wang et al. (2013) for further discussion.

\textsuperscript{12} The American Community Survey (ACS), introduced in 2005, is now part of the Decennial Census Program and
compensation matrices with cells cross-classified by sex, employment class, age, and education, and with each matrix controlled to the USDA hours and compensation totals, respectively.

Translog indexes of labor input are constructed for the 1948-2013 period using the demographically cross-classified hours and compensation data. Under the translog approach, labor hours having higher marginal productivity (wages) are given higher weights in forming the index of labor input than are hours having lower marginal productivities. Doing so explicitly adjusts the time series of labor input for changes in quality of labor hours as originally defined by Jorgenson and Griliches (1967). As a result, the price and quantity series for labor input are measured in constant-quality units.\textsuperscript{13}

\textit{Capital Input:} The measurement of productivity requires time series measures of capital input and capital rental prices for the aggregate farm sector. Construction of these series begins with estimating the capital stock and rental price for each component of capital input. For depreciable assets, the perpetual inventory method is used to develop capital stocks from data on investment. For land and inventories, capital stocks are measured as implicit quantities derived from balance sheet data. Implicit rental prices for each asset type are based on the correspondence between the purchase price of the asset and the discounted value of future service flows derived from that asset.

\textit{Depreciable Assets:} The perpetual inventory method cumulates investment data measured in constant prices into a measure of capital stock. Data on investment in current prices are obtained

\textsuperscript{13} See Jorgenson and Gollop (1992) for a discussion of the theoretical basis for adjusting labor input for compositional shifts in the labor force.
from the ERS Resource and Rural Economy Division. The Bureau of Labor Statistics Producer Price Indexes for passenger cars, motor trucks, wheel-type farm tractors, and agricultural machinery excluding tractors are employed as investment deflators. For structures, the implicit price deflator is taken from the U.S. national income and product accounts.

Under the perpetual inventory method, the capital stock at the end of each period, say $K_t$, is measured as the sum of past investments, each weighted by its relative efficiency, say $d_\tau$:

$$K_t = \sum_{\tau=0}^{\infty} d_{\tau} I_{t-\tau}.$$  

In equation (1), we normalize initial efficiency $d_0$ at unity and assume that relative efficiency declines so that:

$$d_0 = 1, \quad d_\tau - d_{\tau-1} \leq 0, \tau = 0,1,\ldots, T.$$  

We also assume that every capital good is eventually retired or scrapped so that relative efficiency declines to zero:

$$\lim_{\tau \to \infty} d_\tau = 0.$$  

The decline in efficiency of capital goods gives rise to needs for replacement investment to maintain the productive capacity of the capital stock. The proportion of a given investment to be replaced at age $\tau$, say $m_\tau$, is equal to the decline in efficiency from age $\tau-1$ to age $\tau$:

$$m_\tau = -(d_\tau - d_{\tau-1}), \tau = 1,\ldots, T.$$  

These proportions represent mortality rates for capital goods of different ages.

Replacement requirements, say $R_t$, are a weighted sum of past investments:

$$R_t = \sum_{\tau=1}^{\infty} m_\tau I_{t-\tau},$$

\[14\] The series on investment in farm structures includes capital outlay on housing provided employees. Accordingly,
where the weights are the mortality rates.

Taking the first difference of expression (1) and substituting (4) and (5), we can write:

\[ K_t - K_{t-1} = I_t - \sum_{\tau=1}^{\infty} (d_\tau - d_{\tau-1})I_{t-\tau} \]

\[ = I_t - \sum_{\tau=1}^{\infty} m_\tau I_{t-\tau} \]

\[ = I_t - R_t. \]

The change in capital stock in any period is equal to the acquisition of investment goods less replacement requirements.

To estimate replacement, we must introduce an explicit description of the decline in efficiency. This function, \( d \), may be expressed in terms of two parameters, the service life of the asset, say \( L \), and a curvature or decay parameter, say \( \beta \). Initially, we will hold the value of \( L \) constant and evaluate the efficiency function for various values of \( \beta \). One possible form for the efficiency function is given by:

\[ d_\tau = \frac{(L - \tau)}{(L - \beta \tau)}, 0 \leq \tau \leq L \]

\[ d_\tau = 0, \tau \geq L. \]

This function is a form of a rectangular hyperbola that provides a general model incorporating several types of depreciation as special cases.

The value of \( \beta \) is restricted only to values less than or equal to one. Values greater than one yield results outside the bounds established by the restrictions on \( d \). For values of \( \beta \) greater than zero, the function \( d \) approaches zero at an increasing rate. For values less than zero, \( d \) approaches zero at a decreasing rate.

Little empirical evidence is available to suggest a precise value for \( \beta \). However, two studies (Penson, Hughes, and Nelson, 1977; Romain, Penson, and Lambert, 1987) provide

housing service flows are viewed as a component of output.
evidence that efficiency decay occurs more rapidly in the later years of service, corresponding to a value of $\beta$ in the zero-one interval. For purposes of this study, it is assumed that the efficiency of a structure declines slowly over most of its service life until a point is reached where the cost of repairs exceeds the increased service flows derived from the repairs, at which point the structure is allowed to deteriorate rapidly ($\beta=0.75$). The decay parameter for durable equipment ($\beta=0.50$) assumes that the decline in efficiency is more uniformly distributed over the asset's service life.

Consider now the efficiency function that holds $\beta$ constant and allows $L$ to vary. The concept of variable lives is related to the concept of investment used in this study where investment is composed of different types of capital goods. Each of the different types of capital goods is a homogeneous group of assets in which the actual service life $L$ is a random variable reflecting quality differences, maintenance schedules, or simply chance variation. For each type of capital good there exists some mean service life $\bar{L}$ around which there is a distribution of the actual service lives of the assets in the group. In order to determine the actual capital available for production, the actual service lives and the relative frequency of assets with these service lives must be determined. It is assumed that this distribution may be accurately depicted by the standard normal distribution.

One property of the normal distribution is related to the infinite nature of the distribution. Without adjustment, the distribution would yield cases where assets were discarded prior to their purchase or assets with unrealistically long service lives. In order to eliminate these extremes, some adjustment is warranted. This adjustment involves truncation of the normal at some point before and after $\bar{L}$. The values of the normal are then adjusted upward within the allowed range of service lives.
In this study, we truncate the distribution at points two standard deviations before and after the mean. This dispersion parameter was chosen to conform to the observation that assets are occasionally found that are considerably older than the mean service life and that a few assets are accidentally damaged when new. Once the frequency of a service life \( L \) is known, the decay function for that particular service life is calculated using the assumed value of \( \beta \). This step is repeated for all possible service lives. An aggregate efficiency function is then constructed as a weighted sum of the individual efficiency functions using as weights the frequency of occurrence. This function not only reflects changes in efficiency but also the discard distribution around the mean service life of the asset.

**Land:** To obtain a constant-quality stock of land, we compile data on acres of land in farms and average value (excluding buildings) per acre for each county in each state using information gleaned from the Census of Agriculture. Data for years intermediate to the censuses are obtained by interpolation.

The Census definition of land in farms includes all grazing land (including reservation grazing land, land in grazing associations, and land leased for grazing) except public lands leased for grazing on a per-head basis. From total land in farms, we exclude the land area in roads and house lots and miscellaneous areas such as marches, open swamps, and bare rock areas.

The Census of Agriculture reports data on the value of farm real estate (i.e., land and

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15 Mean service lives correspond to 85% of the U.S. Department of the Treasury’s *Bulletin F* lives.
16 Interpolation involves fitting a cubic spline curve to the observed values. A cubic spline is a segmented function consisting of third-degree (cubic) polynomial functions joined together so that the entire curve and its first and second derivatives are continuous.
17 Service flows from public lands are estimated from grazing fees paid (Bureau of Land Management and Forest Service) and are included in intermediate input.
18 Land enrolled in the Conservation Reserve Program (CRP) is a component of capital stock, while conservation
structures); it does not provide data on land values separately. Historically, the value of farm real estate was partitioned into its components using information from the Agricultural Economics and Land Ownership Survey (AELOS). However, AELOS was last conducted in 1999. More recently, we have relied on the annual Agricultural Resource Management Survey (ARMS) to derive estimates of the value of land from data on the value of farm real estate.

**Inventories:** Beginning inventories of crops and livestock are treated as capital inputs. The number of animals on farms is available from annual surveys, as are the stocks of grains and oilseeds (National Agricultural Statistics Service, USDA). December average prices, available from *Agricultural Prices*, are used to value commodities held in inventory.

**Capital Rental Prices:** An important innovation in measuring capital input is the rental price of capital originated by Jorgenson (1963, 1973). However, this rental price is based on the particular assumption that the pattern of capacity depreciation is characterized by a decaying geometric series. The remaining task in this section is to generalize the representation of the rental price to allow for any pattern of capacity depreciation.

To accomplish this task, we draw on the literature on investment demand (see Arrow, 1964; Coen, 1975; Penson, Hughes, and Nelson, 1977; Romain, Penson, and Lambert, 1987). Assume that firms buy and sell assets so as to maximize the present value of the firm. Let \( w_K \) denote the price the firm must pay for a new unit of capital, \( p \) the price the firm receives for each unit of output, and \( r \) the real discount rate. An increase in the capital stock \( K \) by one unit will increase output in each period by \( \partial y / \partial K \), the marginal product of capital. Gross revenue in each

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19 Net additions to inventory during the calendar year are included in the measure of output.
20 The estimates are of stocks in all positions. To obtain estimates of producer-owned stocks, we subtract quantities of commodities held by commercial (i.e., non-farm) entities, as well as commodities used as collateral for
period will rise by $p(\partial y / \partial K)$, but net revenue will rise by only $p(\partial y / \partial K) - w(\partial R_c / \partial K)$, where $\partial R_c / \partial K$ is the increase in replacement in period $t$ required to maintain the capital stock at the new level. Firms should add to the capital stock if the present value of the net revenue generated by an additional unit of capital exceeds the purchase price of the asset. This can be stated algebraically as:

$$\sum_{t=1}^{\infty} \left( p \frac{\partial y}{\partial K} - w_K \frac{\partial R_c}{\partial K} \right) (1 + r)^t > w_K.$$  

(8)

To maximize net present value, firms will continue to add to capital stock until this equation holds as an equality. This requires that:

$$p \frac{\partial y}{\partial K} = r w_K + r \sum_{t=1}^{\infty} w_K \frac{\partial R_c}{\partial K} (1 + r)^t = c.$$  

(9)

The expression for $c$ is the implicit rental price of capital corresponding to the mortality distribution $m$. The rental price consists of two components. The first term, $r w_K$, represents the opportunity cost associated with the initial investment. The second term, $r \sum_{t=1}^{\infty} w_K \frac{\partial R_c}{\partial K} (1 + r)^t$, is the present value of the cost of all future replacements required to maintain the productive capacity of the capital stock, multiplied by the discount rate $r$.

Expression (9) can be simplified as follows. Let $F$ denote the present value of the stream of capacity depreciation on one unit of capital according to the mortality distribution $m$:

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Commodity Credit Corporation loans.

21 If $r > 0$, then $\sum_{t=1}^{\infty} (1 + r)^{-t} = \frac{1}{1 - \frac{1}{1 + r}} = \frac{1}{r}$. Substituting this result in (8) and rearranging terms yields expression (9).
\[ F = \sum_{t=1}^{\infty} m_t \left( 1 + r \right)^t. \]

It can be shown that:

\[ \sum_{t=1}^{\infty} \frac{\hat{R}}{\partial K} (1 + r)^t = \sum_{t=1}^{\infty} F^t \]

\[ = \frac{F}{(1 - F)} \]

so that

\[ c = \frac{r \omega K}{(1 - F)^{22}}. \]

The real rate of return \( r \) in equation (12) is calculated as the nominal yield on investment grade corporate bonds, less the rate of asset price inflation (i.e., capital gain).\(^{23}\) An \textit{ex ante} real rate is obtained by expressing inflation as an ARIMA process.\(^{24}\) Implicit rental prices are then calculated for each asset type using the expected real rate of return.\(^{25}\)

\(^{22}\) For the special case where \( d_{r} = \delta (1 - \delta)^{r-1} \), which was assumed by Jorgenson (1963, 1973),

\[ F = \sum_{r=1}^{\infty} \delta (1 - \delta)^{r-1} (1 + r)^{-r} = \delta / (r + \delta) \]

and

\[ c = \omega_K (r + \delta), \]

which is the expression for the rental price commonly found in the literature.\(^{23}\) The nominal rate is taken to be the average yield on Moody’s AAA bonds over all maturities (Federal Reserve Board).\(^{24}\) Price inflation is expressed as an AR(1) process. We use this specification after examining the correlation coefficients for autocorrelation, partial and inverse autocorrelation, and performing the unit root and while noise tests.\(^{24}\) A more common approach to measuring the user cost of capital is to use an \textit{ex post} rate of return (see Jorgenson and Griliches, 1967; Christensen and Jorgenson, 1969; Jorgenson, Gollop and Fraumeni, 1987). This unknown rate of return can be found by using the condition that the sum of returns across all assets equals observed total profit (alternatively, gross operating surplus). However, many have expressed concern with the \textit{ex post} approach (see Schreyer, Bignon, and Dupont, 2003; Schreyer, 2004). They note that investment decisions must be made in advance of having all the relevant information. Firms employ some notion of the required rate of return when deciding how much to invest, and this required rate may differ from the realized rate. Moreover, they must base their decisions on expected, not actual, capital gains and losses. Using the \textit{ex post} measure would imply either that all expectations are realized or that the quantities of capital can be instantaneously adjusted to the desired level after all uncertainties have been resolved. Neither assumption appears plausible a priori. It is for this reason that we adopt the \textit{ex ante} approach when measuring user costs.
Translog quantity indexes of capital input are formed by aggregating over the various capital assets using cost-share weights based on asset-specific rental prices. Rental prices for capital input are formed implicitly as the ratio of the total value of capital service flows to the translog quantity index. As is the case for labor input, the resulting measure of capital input is adjusted for changes in asset quality.

3. Productivity Growth

Input growth typically has been the dominant source of economic growth for the aggregate economy and for each of its producing sectors. Jorgenson, Gollop, and Fraumeni (1987) find this to be the case for the aggregate economy for every sub-period over the period 1948-79. Denison (1979) draws a similar conclusion for all but one sub-period, covering the longer period 1929-76. In their sectoral analysis, Jorgenson, Gollop, and Fraumeni find that output growth relies most heavily on input growth in forty-two of forty-seven private business sectors over the 1948-79 period, and in a more aggregated study (Jorgenson and Gollop, 1992) that extends through 1985, in 8 of 9 sectors. Finally, Jorgenson, Ho, and Stiroh (2005) provide estimates of the sources of output growth for forty-four sectors of the U.S. economy for the period 1977-2000. Input growth dominates in thirty-six of the forty-four sectors.

Agriculture turns out to be one of the few exceptions. Productivity growth dominates input growth. This is confirmed in the top panel of table 1 which reports the source decomposition of output growth in the farm sector over the full 1948-2013 period and twelve peak-to-peak sub-periods. Applying the translog model, output growth equals the sum of

\[ \text{output growth} = \sum_{\text{sub-periods}} \text{source decomposition} \]

\[ = \text{productivity growth} + \text{input growth} \]

\[ = \text{productive efficiency growth} + \text{capital input growth} + \text{labor input growth} \]

\[ \text{productive efficiency growth} \quad \text{capital input growth} \quad \text{labor input growth} \]

The sub-periods are not chosen arbitrarily but are measured from cyclical peak to peak in aggregate economic activity. Since the data reported for each sub-period are average annual growth rates, the unequal lengths of the sub-periods do not affect the comparisons across sub-periods. This convention and these sub-periods have been adopted by the major productivity studies. See, for example, Jorgenson, Gollop, and Fraumeni (1987)….
contributions of labor, capital, and materials input and productivity growth. The contribution of each input equals the product of the input’s growth rate and its respective share in total cost.

The singularly important role of productivity growth in agriculture is made all the more remarkable by the dramatic contraction in labor input in the sector, a pattern that persists through every subperiod. Over the full 1948-2013, labor input declined at an average annual rate of 2.2%, a rate unmatched by any of the fifty non-farm sectors evaluated by Jorgenson, Gollop, and Fraumeni (1987). When weighted by its 0.22 share in production costs, the contraction in labor input contributes an average -0.49 percentage points per year to output growth.

Capital input (including land and inventories) in the sector exhibits a different history. Its contribution to output growth alternates between positive and negative over the 1948-2013 period. On average, however, capital, like labor, contracts over the full period. Its negative growth contributes an annual -0.06 percentage points to output growth.

The negative contributions of both labor and capital are particularly striking given the positive contributions offered through improvements in both labor and capital quality, the recomposition of labor hours and capital stocks to higher marginal productivity components. As revealed in table 1, farms have shifted to higher-quality labor. This primarily is due to a more highly educated farm labor force.27 Increased labor quality made a positive contribution to output in 11 of 12 sub-periods, averaging 0.12 percentage points per year. Quality improvements in capital added another 0.02 percentage points, yet neither improved labor nor capital quality was

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27 As discussed earlier, labor hours are cross-classified by sex, age, education, and employment class. Analysis of the changing composition of hours over the 1948-2011 period reveals that, among the four sources, education was the only dimension making a positive contribution to labor quality. As overall labor hours declined, demographic shifts in the sex, age, and class of employment composition of hours worked left higher proportions of hours worked in cells representing lower marginal productivity sex, age, and class cohorts. In contrast, the decline in hours worked was coincident with an increase in the proportion of more highly educated workers. This was sufficient to offset the negative effects of changes in sex, age, and class composition of hours and result in the persistent pattern of improving labor quality.
sufficient to offset the contractions in the corresponding input. Increased labor quality offsets less than 20% of the decline in raw labor hours; improvements in capital quality offset about 25% of the decline in capital stocks.

Material input’s contribution, as reported in table 1, was positive in 10 of the 12 sub-periods and averaged a substantial positive rate equal to 0.60% per year. Though large, this positive contribution just offsets the negative contributions through labor and capital. The net contribution of all three inputs was 0.05 percentage points per year, leaving responsibility for positive growth in farm sector output essentially to productivity growth in all but the 1973-79 and 2000-07 sub-periods.

Examining table 1 makes clear that the 1973-79 period was an outlier. Output, labor, and capital growth rates did not deviate much from trend. Material input, however, exhibited significant positive growth at a rate far in excess of the incremental growth in output, accounting single handedly for the measured decline in the rate of productivity growth. This anomaly appears to be due to rapid growth in export demand during the period which resulted in the increased consumption of intermediate goods as well as a significant withdrawal of goods from inventory. Both led to a reduction in productivity growth. First, while additional intermediate inputs generated additional output, the incremental growth in materials input exceeded the incremental growth in output. Second, one-for-one transfers of final goods from inventory to market embed zero productivity growth.

The early 2000s saw the emergence of biofuels as a source of demand for grains and oilseeds. Corn used in ethanol production in 2007 accounted for roughly one-quarter of total demand. In response, many producers abandoned usual crop rotations, opting instead for continuous planting of corn. The land area planted to corn increased some 15 million acres (or
roughly 20%) between 2006 and 2007, resulting in the cultivation of more marginal lands. Consumption of agricultural chemicals increased more than 10%, yet yields per acre were largely unchanged.

In spite of these anomalous sub-periods, productivity growth was truly extraordinary over the 1948-2013 period. As indicated in table 1, it averaged 1.47 per year. Cumulated over the full sixty-five year period, this average annual rate (compounded annually) implies that farm sector productivity in 20131 was 160% above it 1948 level. Given the cumulative 3.3% increase in total input between 1948 and 2013, productivity growth caused agricultural output to grow significantly in every subperiod so that by 2013 farm output was 170% above its level in 1948.

4. Summary and Conclusions

It is widely argued that increased productivity is the main contributor to economic growth in U.S. agriculture. This paper reports estimates of growth of the sector over the postwar period and decomposes that growth into the contributions of input growth and growth in productivity. The reported results are fully consistent with earlier findings suggesting that productivity growth is, indeed, responsible for positive growth in farm sector output.

We report estimates of productivity growth for the 1948-2013 period and twelve peak-to-peak sub-periods. Over the complete 1948-2013 period, productivity growth averaged 1.47% per year. Positive in all twelve sub-periods, the rate of growth fell below 1% in only three sub-periods and exceeded 2% in five of the twelve sub-periods.

Growth in intermediate inputs averaged 1.26% per year. Energy use increased less than 1% per year, but the rate of growth of chemicals input exceeded 2.5% annually. Purchased
services (e.g., contract labor services; purchased machine services) increased an average annual rate of 1.16% per year.

Labor input in agriculture contracted at an average annual rate of 2.2% per year over the 65-year period. Moreover, this pattern persisted through all twelve sub-periods.

Capital input increased dramatically during the immediate postwar period. Service flows from durable equipment increased at a 9% annual rate from 1948 to 1953, reflecting the rapid mechanization of agriculture. But the average growth rate over the full 1948-2013 period was slightly less than 1% per year. Land input declined at a 0.46% average annual rate. Overall, capital input declined 0.18% per year.

In spite of the declines in capital and labor inputs and the relatively modest increase in intermediate inputs, growth in farm-sector output averaged 1.52% per year. These results leave little doubt that productivity growth was the principal factor responsible for economic growth in postwar agriculture.
References


Table 1. Sources of Growth: U.S. Farm Sector (Average Annual Growth Rates, percent)

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Output growth

Sources of growth

Labor

Capital

Material

Total Factor Productivity

Source decomposition

Labor

Hours

Quality

Capital

Stocks

Quality

Material

Quantity

Quality