Farm Labor, Human Capital, and Agricultural Productivity in the United States

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Abstract

During the 20th century, U.S. agricultural employment fell in absolute numbers and as a share of total U.S. employment—the latter from 33 percent in 1910 to about 2 percent in 2017. According to USDA, Economic Research Service agricultural productivity data, total farm output almost tripled, and total labor use declined by nearly 80 percent in the last seven decades, implying that farm output per worker, a single factor productivity measure, grew. This report discusses the contribution of farm labor in U.S. agricultural growth and assesses the changing composition of the U.S. farm labor force with special attention to the changes in educational attainment among farm operators and other workers. The authors found that between 1948 and 2017, the decline in total labor hours worked accounted for -0.57 percentage points per year in annual output growth. These negative effects were partially offset by increasing labor quality, such as increased educational attainment. In the growth accounting framework, increased educational attainment accounts for about 8 percentage points of annual agricultural output growth. The average annual rates of labor productivity growth and total factor productivity growth would have been overstated by 13 percent and 8 percent, respectively, if labor quality changes were not accounted for in the measurement.

Keywords: U.S. agriculture, farm labor, human capital, labor quality, agricultural productivity, labor productivity, educational attainment, total factor productivity (TFP), USDA Economic Research Service, ERS

Acknowledgements

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What Is the Issue?

Agricultural output in the United States nearly tripled between 1948 and 2017 even as the amount of labor used declined by nearly 76 percent. These opposing trends reflect continuing high labor productivity growth in agriculture. Total factor productivity (TFP) accounts developed and tracked by the USDA, Economic Research Service (ERS) show farmers adopted new technologies in production practices and increased their use in farm equipment, farm structures, seeds, livestock, chemical fertilizers and pesticides, and purchased services to replace self-employed and hired labor while maintaining or promoting output.

The composition of the farm labor force also changed. In 1948, self-employed and unpaid family labor accounted for more than two-thirds of the farm workforce (which includes hired labor, self-employed, and unpaid family labor). With a faster declining pace than the hired labor, the total hour share of self-employed and unpaid family workers declined from 70 percent in 1948 to 52 percent in 2017. Moreover, the farm workforce attributes changed. In particular, the hired workforce and farm operators showed an increase in educational attainment. It is unclear how labor quality improvement through higher education affected productivity estimates and output growth in different time periods in the U.S. farm sector. This report draws on multiple data sources to assess how the farm workforce changed over the last 70 years. It evaluates the impact of changes in farm labor characteristics, especially educational attainment, on U.S. agricultural productivity estimates and output growth in different periods.

What Did the Study Find?

Agricultural employment and hours worked fell during the 20th century. Total farm labor hours declined by 83 percent between 1948 and 2017, with self-employed and unpaid worker hours declining by 88 percent and hired labor hours declining by 73 percent. The farm sector share of total U.S. employment, 32.6 percent in 1910, fell to 12.2 percent in 1950 and to 1.6 percent in 2017. However, the decline in labor hours in the farm sector slowed in the last decade.

U.S. agricultural output grew consistently even as labor input fell over time. Between 1948 and 2017, U.S. agricultural output grew by nearly 187 percent at an average annual growth rate of 1.53 percent. While other inputs such
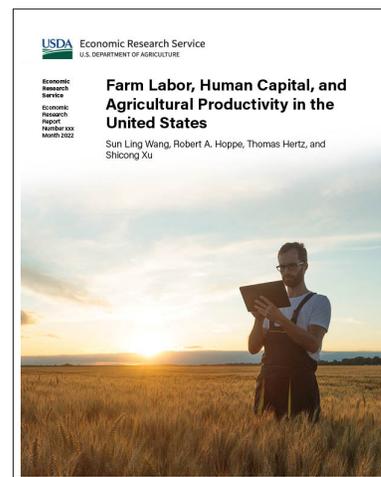
ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

as chemical use or purchased services may have been substituting for labor, total input use (an implicit quantity measure based on the deflated total input cost drawn from ERS data) was flat over that time period. This left total factor productivity—an indicator of technical change—measured as total output per unit of aggregate input as the major driver of agricultural growth post-World War II.

The educational attainment of farmworkers and operators has grown. In 1950, nearly three-quarters of the total hours worked in the farm sector were by people with less than 9 years of schooling. By 2017, only 17 percent of hours worked were by people with less than 9 years of schooling. In contrast, people with at least some college contributed 4 percent of farm labor hours in 1950 but 40 percent by 2017.

Labor productivity has grown dramatically in the U.S. farm sector since 1948. Agricultural output per worker grew by 16 times between 1948 and 2017, while output per hour grew even faster, by 17 times. According to ERS estimates, after adjusting for the changes in labor quality (human capital), labor productivity grew by about 12 times. The differences indicate that increased educational attainment contributed about 8 percent to annual agricultural output growth on average, with higher contributions (up to 25 percent) occurring in the late 1940s and 1950s.

Education's contribution to output growth slowed in recent decades. Increasing educational attainment continued to improve labor quality, reaching its peak during the 1960s, contributing more than two-thirds of labor quality improvement and nearly 0.3 percentage points to annual agricultural output growth rate, on average. In recent years, while education still dominated other factors in improving labor quality, its impact declined to about 0.1 percentage points in the last decade as the overall trend growth of educational attainment slowed in the U.S. employment pool.

How Was the Study Conducted?

This study draws data from the USDA, Economic Research Service (ERS) U.S. agricultural productivity statistics (USAP), USDA, National Agricultural Statistics Service (NASS), ERS Agricultural Resource Management Survey (ARMS), the Employment and Training Administration National Agricultural Worker Survey (NAWS), and the Bureau of Census Current Population Survey (CPS). The authors constructed various estimates of labor productivity based on alternative labor input measures—including employment, total hours worked, and quality-adjusted labor input.

Farm Labor, Human Capital, and Agricultural Productivity in the United States

Introduction

Jorgenson et al. (2014) wrote, "the great preponderance of economic growth in the U.S. since 1947 involves the replication of existing technologies through investment in equipment and software and expansion of the labor force." While economic growth overall has depended greatly on the expanded use of inputs through capital investment and increased employment of labor, the farm sector is one exception to this broad pattern with substantial contraction in farm labor employment. The use of labor input in the U.S. farm sector declined post-World War II while output grew. The total value of U.S. agricultural production, adjusted for inflation, nearly tripled between 1948 and 2017, even as the labor input declined by more than three-quarters (USDA, ERS, 2020).

In the U.S. farm sector, most farms are family businesses. Hence, self-employed and unpaid family labor (distinct from hired farm labor and managers who are paid a specific wage or salary from the farm business) form an important part of the farm workforce. However, both labor components have contracted over time, with hired workers declining by 65 percent from 2.3 million[1] to 0.8 million and self-employed and unpaid family workers[2] declining by 87 percent from 7.4 million to 0.9 million between 1948 and 2017. This increased production by fewer workers means that labor productivity in farming—a single-factor productivity estimate measured as total production per unit of labor—grew considerably.

Labor productivity can be increased by investment in human capital, agricultural research and development (R&D), and by more intensive use of other inputs. Human capital is the stock of knowledge and skills the labor force possesses or investments in people—including education, training, and health—that increase productivity (Goldin, 2016). While it is widely agreed that R&D is the major driver of productivity growth and its return is high (Griliches, 1998; Huffman and Evenson, 2006; Alston et al., 2010; Wang et al., 2013; Plastina and Lence, 2019), it is also noticeable that human capital plays a vital role in promoting economic (aggregate output) growth.

Ruttan (2002) showed that differences in human capital accounted for approximately one-fourth of the differences in labor productivity between developed and less developed countries. Human capital is said to contribute to economic growth either directly as a factor of production (Lucas, 2015) or as a means of spreading knowledge with productivity catch-up among regions or countries (Engelbrecht and Hans-Jiirgen, 1997). Acemoglu and Autor (2011) said that allowing for interactions between human capital and technologies suggest an even more crucial role for human capital in economic growth.

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[1] The total employment of hired workers in the farm sector is from the Bureau of Economic Analysis (BEA)'s National Income and Product Accounts (NIPA).

[2] The total employment of self-employed and unpaid family workers is from the Current Population Survey (CPS) prepared by the U.S. Bureau of Labor Statistics (BLS). While some sources may show different numbers of this category, CPS is the only source allowing tracing the data of "self-employed and unpaid family workers" back to 1948. For data consistency, the USDA, Economic Research Service employed this data source in its productivity estimates since USDA's National Agricultural Statistics Service discontinued the self-employed and unpaid worker survey in its Farm Labor Survey. Labor quality adjustment reported in later sections is conducted using the total employment and hours worked as control totals to adjust for the matrix of cross-classified labor attributes distribution.

Total factor productivity (TFP), measured as total production per unit of total inputs, is the remaining (residual) part of output growth that cannot be explained by the overall input growth. It is often referred to as an indicator of technical change. In this report, "technical change" represents a general expression of technology advancement; "total factor productivity- TFP" is a productivity measurement;[3] and "economic growth" is a synonym of output growth. Kendrick (1956) and Solow (1957) asserted that the changing quality (human capital) of the labor force might be an important component of the source of that residual since the conventional labor measure does not consider labor quality changes. Education was widely considered as the essential form of human capital (Becker, 1993) given its importance in the adoption and diffusion of technology (Nelson and Phelps, 1966) and as a relevant factor to labor productivity. Hulten and Ramey (2015) suggested that education affects growth through multiple channels.

In the literature, researchers explained the contributions of human capital to TFP/economic growth using mostly the education variable and sometimes other demographic characteristics. Schultz (1961) linked the role of education to the residual by estimating the contribution of total human capital in the U.S. economic growth and showed that human capital accounted for one-fifth of total output growth. Using data for 1948–73, Denison (1979) found that rising educational attainment contributed 0.52 percentage points to national income growth, accounting for 14.6 percent of total economic growth during that period. More recently, Jorgenson et al. (2018) reported that education contributed to U.S. human capital and economic growth significantly post-World War II.

From the farm sector perspective, Griliches (1964), in his seminal work, showed that increased education significantly contributed to U.S. farm production and played a role similar to labor quantity in determining output. More recently, the literature showed that higher formal schooling is also associated with a more rapid adoption of new technologies on the farm (Huffman, 1999; Schimmelpfennig and Ebel, 2016). O'Donoghue and Heanue (2018) found that education had a positive relationship to technical efficiency in most Irish agricultural sectors in terms of improved yields, while evidence of improved allocative efficiency is generally weak, except for the commercial dairy sector. Rada and Schimmelpfennig (2018) found that India's technical efficiency improvements in agricultural development were largely because of education and infrastructure investments. Higher educational attainment can also promote an agricultural productivity catch-up effect across regions (for U.S. examples, see McCunn and Huffman, 2000; Poudel et al., 2011; Liu et al., 2011; see Wang et al., 2019, for the China case).

However, it is unclear how farm labor and educational attainment embodied in each farmworker changed and affected agricultural output growth over a long period of time since 1948 in the United States. Furthermore, recent literature did not show if education still played an equivalent role to labor quantity in the U.S. farm sector. Understanding the driving forces of labor productivity and sources of agricultural growth can shed light on the agricultural policy that helps to promote farmers' welfare and increases farm income.

Most studies are based on econometric approaches that related human capital/education to productivity/efficiency/farm income when human capital is a separate variable from labor input. Griliches (1964), Denison (1979), and Jorgensen et al. (2018), on the other hand, measured quality-adjusted labor input that accounted for human capital changes based on an index number approach. Under the growth accounting framework (Solow, 1957), researchers broke down output growth into the shares associated with changes in levels of each input. It allowed researchers to separate the contribution of human capital from that of total factor productivity estimates. This study relied on the similar index number approach to identify the role of human capital, or so-called labor quality—a composition of educational attainment, gender, age, and employment type—in agricultural growth. This report uses the term "human capital" and "labor quality" interchangeably. Note that the growth accounting framework relied on assumptions about the functional form of the production

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[3] While agricultural productivity is driven mainly by innovations in on-farm tasks and research aimed at improvements in farm production, measured agricultural productivity—total factor productivity—can also be affected by random events like weather.

function to enable it to establish the marginal products of each input. These marginal products may be interpreted as causal effects, but that interpretation depends strongly on the correctness of the assumed functional form. The power of the growth accounting framework lies not so much in its ability to establish causality but in providing a straightforward and widely accepted framework for comparing the relative contributions of changes in each input to output growth over time.

This report built upon existing literature to:

- provide an overview of the structural changes in U.S. farm workforce since 1948;

- show how educational attainment and other demographic characteristics of the U.S. farm workforce changed;

- examine how labor productivity changed over time;

- discuss how labor productivity, farm income, input densities, and total factor productivity are connected using an index number approach; and

- address how human capital (labor quality), particularly increased educational attainment, contributed to U.S. agricultural growth.

The authors drew data from sources besides those used in the USDA, Economic Research Service (ERS) productivity accounts to provide a broader picture of the farm workforce and human capital, mainly because each survey or dataset was limited on the content or the period it covered (see box, "Major Data Sources," for descriptions). Besides, in some data sources, the agriculture sector includes farms, forestry, fishery, and hunting sectors, whereas ERS productivity accounts only focus on the farm sector. The authors distinguish those terms—agriculture versus farm sectors—as much as needed to be consistent with the data sources cited. However, the term "agricultural growth" is used even when discussions are based on ERS U.S. productivity data as the farm sector is the primary sector in the agriculture category under either Bureau of Economic Analysis (BEA) or Bureau of Labor Statistics (BLS) classification. According to the Bureau of Economic Analysis' National Income and Product Accounts (NIPA), in 2017, the farm sector accounted for nearly 90 percent of agricultural gross output (including farm, forestry, fishing, and hunting sectors in NIPA) and 80 percent of value-added Gross Domestic Product (GDP).

Major Data Sources

The data used and the findings presented in this report mostly focus on the farm sector unless otherwise stated. Major primary data sources include USDA, Agricultural Resource Management Survey (ARMS); U.S. Department of Labor, National Agricultural Workers Survey (NAWS) and U.S. Department of Labor, Current Employment Statistics (CES) which is based on the Current Population Survey (CPS), a joint project of the U.S. Bureau of the Census and U.S. Bureau of Labor Statistics; and USDA, ERS U.S. agricultural productivity statistics (USAP).

Farm Cost and Returns Survey/Agricultural Resource Management Survey

The Agricultural Resource Management Survey (ARMS) is an annual survey conducted jointly by the USDA, National Agricultural Statistics Service (NASS) and USDA, Economic Research Service (ERS). It is based on a representative sample of 30,000 to 40,000 farms in the contiguous 48 States and conducted annually since 1996. The Farm Cost and Returns Survey (FCRS), the predecessor to ARMS, provides data consistent with ARMS from 1991 through 1995. ARMS contains data on farm operators' education over time and the ability to link it to farm household income and farm size.

U.S. Agricultural Productivity

The USDA, ERS constructs agricultural production accounts for the U.S. farm sector. This dataset provides estimates of prices and quantities for aggregate agricultural output and 10 component outputs, aggregate input and 12 component inputs, and Total Factor Productivity (TFP) at the national level for 1948–2017 (USDA, ERS, 2020). Following Jorgenson et al. (1987), the demographic characteristics of farmworkers are from the decennial Census of Population, and in more recent years, the American Community Survey microdata (ACS), both managed by the U.S. Bureau of the Census. Data on compensation, total employment, and total hours worked for hired workers are from NIPA. Data on employment and total hours worked for self-employed and unpaid family workers are from the Current Population Survey (CPS). (See USDA, ERS, 2020; Ball et al., 2016; Shumway et al., 2017, and the appendix for more details regarding methods and data sources).

National Agricultural Workers Survey

The National Agricultural Workers Survey (NAWS) is an employment-based random-sample survey of U.S. crop workers (livestock and dairy workers are not covered, nor are seasonal workers on H-2A visas). It is funded and overseen by the U.S. Department of Labor, Employment and Training Administration. NAWS collects demographic, employment, wage, migration, housing, social service, and health data in face-to-face interviews. This annual survey started in 1989 and is the source of estimates of the legal immigration status of the Nation's crop farmworkers. While annual sample sizes are not large (about 2,400 workers per year), it provides insights on the connection between individual farmworkers and educational attainment, legal status, and other characteristics, although not an overview of the entire farm workforce.

Current Population Survey, Employment, and Earnings Data

The Current Population Survey (CPS) is a monthly survey of households conducted by the U.S. Bureau of the Census for the Bureau of Labor Statistics (BLS). It provides a comprehensive body of data on the labor force, employment, unemployment, persons not in the labor force, hours of work, earnings, and other demographic and labor force characteristics, starting in 1947. Each employed person is counted once, regardless of the number of jobs held. Workers with more than one job are assigned to the industry in which they worked the most hours. From 2000 onward, estimates of agricultural employment are for agricultural and related industries. When the North American Industry Classification System (NAICS) was introduced, veterinary and landscaping services were removed from agricultural employment while forestry, logging, fishing, hunting, and trapping were added (U.S. Dept. of Labor, 2003, p. 20). This resulted in a net decrease of about 800,000 agricultural employees between 1999 and 2000 and reduced the agricultural share of total employment from 2.5 percent to 1.8 percent. To compare agricultural and nonagricultural employment over a long period, the authors drew data from BLS Current Employment Statistics (CES) Employment and Earnings data.

For more about the differences between ACS and CPS, visit the Bureau of the Census website.

How the U.S. farm workforce is changing

An overview

The share of agricultural employment (including farms, forestry, logging, fishing, hunting, and trapping industries) in total U.S. employment fell from 13 percent in 1948 to 4 percent in 1971 and 2 percent by 2017, according to BLS, CES data. This mostly reflected the decline of agricultural employment and a tripling of nonagricultural employment[4] (figure 1). The total farm employment—the combined number of hired workers and self-employed and family workers—also fell by 81 percent between 1948 and 2017 (USDA, ERS, 2020). However, the precipitous decline in farm labor employment seems to have slowed in the last decade.

Figure 1
Agricultural employment fell during the 20th century
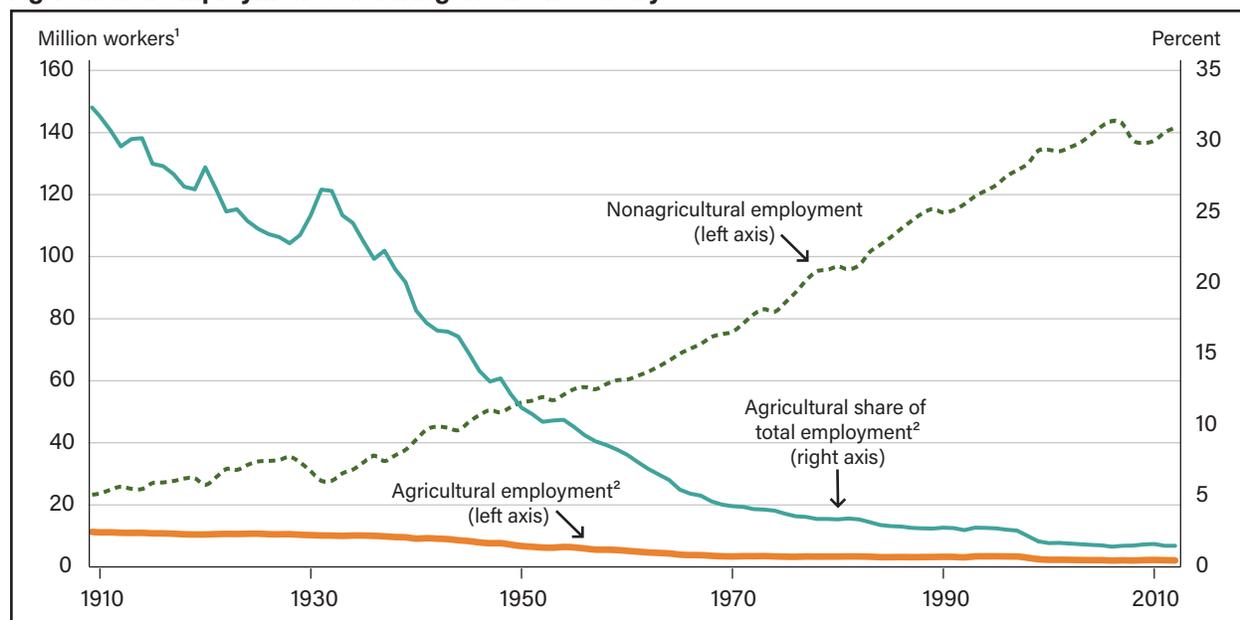
[1]Persons at least 14 years old before 1947; persons at least 16 years old in 1947 and later years.
[2]The breaks in the lines (agricultural employment and agricultural share of total employment) indicate a definition change. From 2000 onward, estimates of agricultural employment are for "agricultural and related industries." Veterinary and landscaping services were removed from agricultural employment while forestry, logging, fishing, hunting, and trapping were added (U.S. Department of Labor, 2003). This resulted in a net decrease of about 800,000 agricultural employees between 1999 and 2000 and reduced the agricultural share of total employment from 2.5 percent to 1.8 percent.

Sources: USDA, Economic Research Service, compiled from Bureau of Labor Statistics data (U.S. Executive Office of the President, 2014:378-379; U.S. Department of Commerce, Bureau of the Census, 1975:126; and Employment and Earnings.

The decline in farm labor[5] partly occurred as workers sought higher wages and other income opportunities in the nonfarm sector, especially in the immediate post-World War II period. In 1948, the salary of a full-time equivalent employee (FTE) in the farm sector was about 55 percent of that in U.S. domestic industries and about 57 percent in 2017, according to BEA, NIPA data. The transformation of farm structure with fewer farms and larger farm size over the years (Daly, 1981; Hoppe and Banker, 2010; MacDonald et al., 2013) also

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[4] There was a change in the BLS CES data definition. From 2000 onward, estimates of agricultural employment are for agricultural and related industries. Veterinary and landscaping services were removed from agricultural employment while forestry, logging, fishing, hunting, and trapping industries were added (U.S. Dept. of Labor, 2003, p.20). This change caused a net decrease of about 800,000 agricultural employees between 1999 and 2000. It reduced the agricultural share of total employment from 2.5 percent to 1.8 percent, which accounted for a minor portion of the discrepancy in the data series.

[5] Farm labor includes self-employed and unpaid family workers, as well as hired laborers.

resulted in the reduction of farm employment. The advancement of labor-saving technologies—such as bigger and faster tractors and combines and automated feeding equipment—also affected the demand for farm-workers. Operators of larger farms were more likely to adopt new technologies and rely more on machinery and purchased services[6] (Wang et al., 2015; MacDonald et al., 2018). Nevertheless, the declining trends of total hours worked for hired workers and the self-employed unpaid workers seem to have slowed in the past decade.

Farm worker types vary over the years and across regions

Along with the decline in farm employment, total hours worked for self-employed and unpaid family workers and hired workers reduced at different rates, with hours worked by self-employed and unpaid family workers declining much faster (figure 2). Between 1948 and 2017, hired workers' hours declined by 73 percent, from 5.9 billion hours to 1.6 billion, while hours worked by self-employed and unpaid hours declined by 86 percent, from 13.5 billion hours to nearly 1.7 billion, according to ERS, USAP data. In 1948, the farm sector used more than twice as many self-employed and unpaid labor hours as hired labor hours. By 2017, directly hired labor hours and self-employed and unpaid hours account for about the same total labor hours.

Figure 2
Self-employed/unpaid worker hours declined more than hired labor hours in the U.S. farm sector, 1948–2017
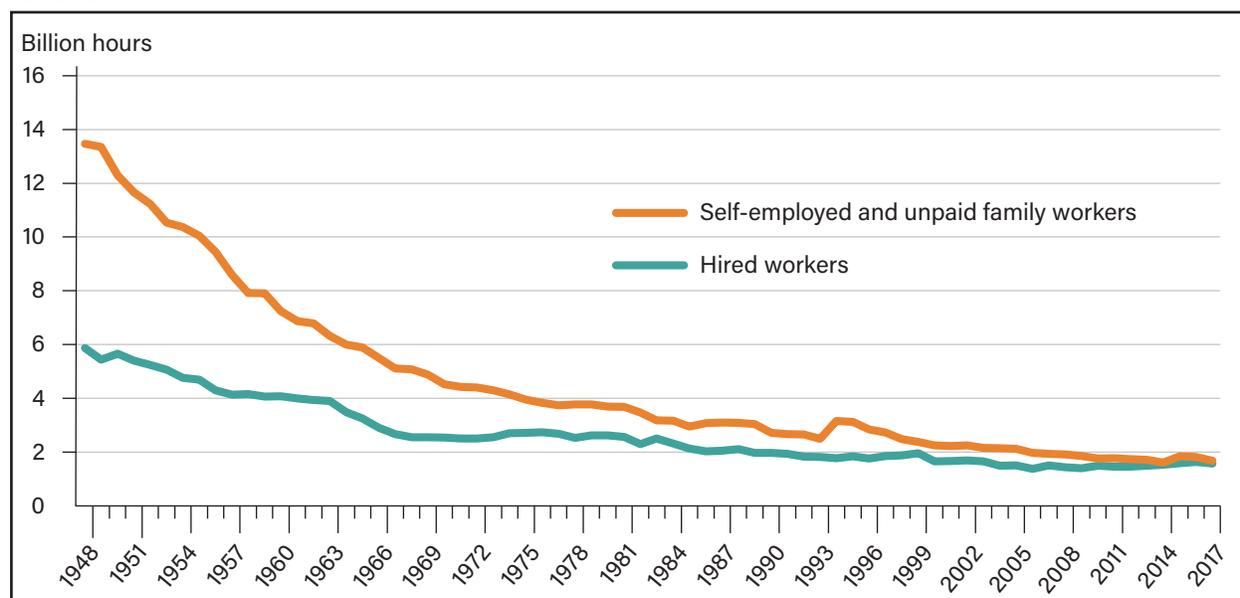
Source: USDA, Economic Research Service, U.S. agricultural productivity accounts.

The contraction in labor use over time is associated with greater specialization, advanced machine use, and increased farm size. The separation of livestock from crop farming in the latter half of the 20th century increased the time available to crop farmers to apply to production, allowing them to manage more acres (MacDonald et al., 2013). Technology also drives increases in farm size by allowing a single farm operator to operate and manage more acres or more animals. Labor-saving innovations—from bigger and faster capital equipment to information technology, chemical herbicides, seed genetics, and changing tillage tech-niques—substantially reduced the total amount of labor in agriculture and facilitated the shift to larger crop farms (Gardner, 2006; Gardner et al., 2009; Fernandez-Cornejo and Pho, 2002; Kislev and Peterson, 1982; Olmstead and Rhode, 2001; Rasmussen, 1968). These could all contribute to why self-employed and unpaid

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[6] Purchased services include custom machinery work (including leasing), machinery repair, building repair, transportation and storage, purchased contracted labor services, veterinary services, and feeding.

family hours worked reduced faster than directly hired labor, although both contracted considerably over time.

Farm production activities vary across regions following local weather patterns, soil characteristics, natural resources, and economic activities. For example, many more labor-intensive specialty crops—including fruits, vegetables, berries, and melons—are produced in California than in the Northern Plains and Corn Belt regions where field crops dominate. According to MacDonald et al. (2018), in 2015, specialty crop farms used 14.4 hours of labor to generate $1,000 of sales, on average, while cash grain farms used 5 hours. Different production activities can result in differences in the types of farm labor needed/used. According to ARMS data, in 2016, the shares of hired workers in the total hours worked in Washington, California, and Florida—States where specialty crop production is prevalent—were higher than States in the Northern Plain or the Corn Belt regions (figure 3). Beside directly hired labor and self-employed and unpaid family workers, farm operators can also purchase contracted labor services[7] to perform some specific tasks during the high labor demand season, especially for the specialty crop farms. The differences in regional/seasonal labor demand can shed light on local agricultural policy development.

Figure 3
U.S. farm sector hired labor's share in total hours worked varied from State to State, 2016
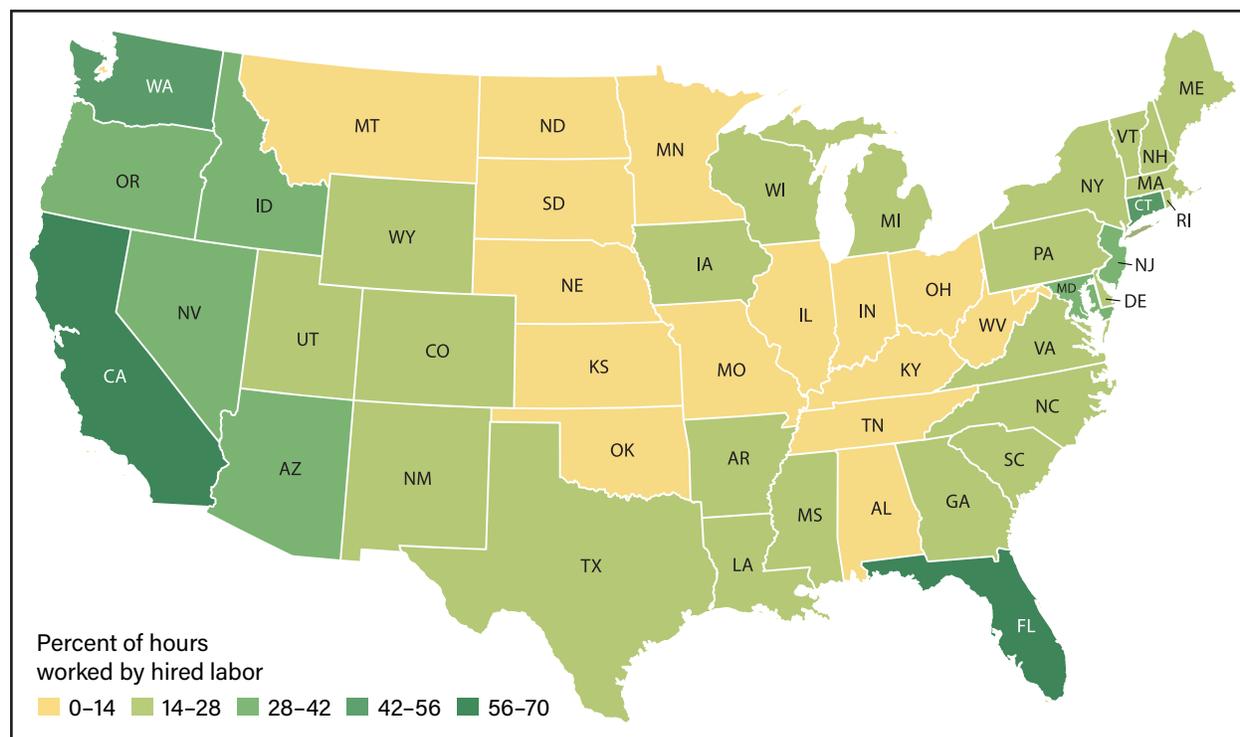
Source: USDA, Economic Research Service calculation using 2016 Agricultural Resource Management Survey data.

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[7] Some contracted workers may come from the H-2A program (a Federal program that allows U.S. employers to bring in foreign workers on short-term labor contracts when farm operators cannot find enough domestic workers.) According to Castillo et al. (2021) the number of H-2A positions certified in the vegetables and melons category and the fruit and tree nuts category increased the most in the last decade by about 330 percent.

Human capital and the structural changes in farm labor input

Human capital can be measured in various ways—including demographic characteristics of labor input, such as gender, age, and education. Among all demographic characteristics of farmworkers, educational attainment has the closest link to productivity growth (Griliches, 1963; 1964; Jorgenson et al., 2005). This report drew data from various sources to provide a broader picture of changes in human capital and labor input structure from different aspects of farm workforce or demographic characteristics.

An overview

Education has been one of the driving forces of U.S. economic growth. Post-World War II, the U.S. population's educational attainment—the highest level of education completed—increased considerably. By 2018, nearly 90 percent of adults aged 25 and older had completed secondary education, compared with only 34 percent in 1950. However, this growth trend in educational attainment seems to slow after the 1990s (figure 4, panel A). The trend was mostly because of the decline or slower growth of those who completed 4 years of high school. People with a college education increased (figure 4, panel B).

Figure 4
Educational attainment of people 25 years and older
Panel A: Percent of people who have completed high school or college, 1950–2018
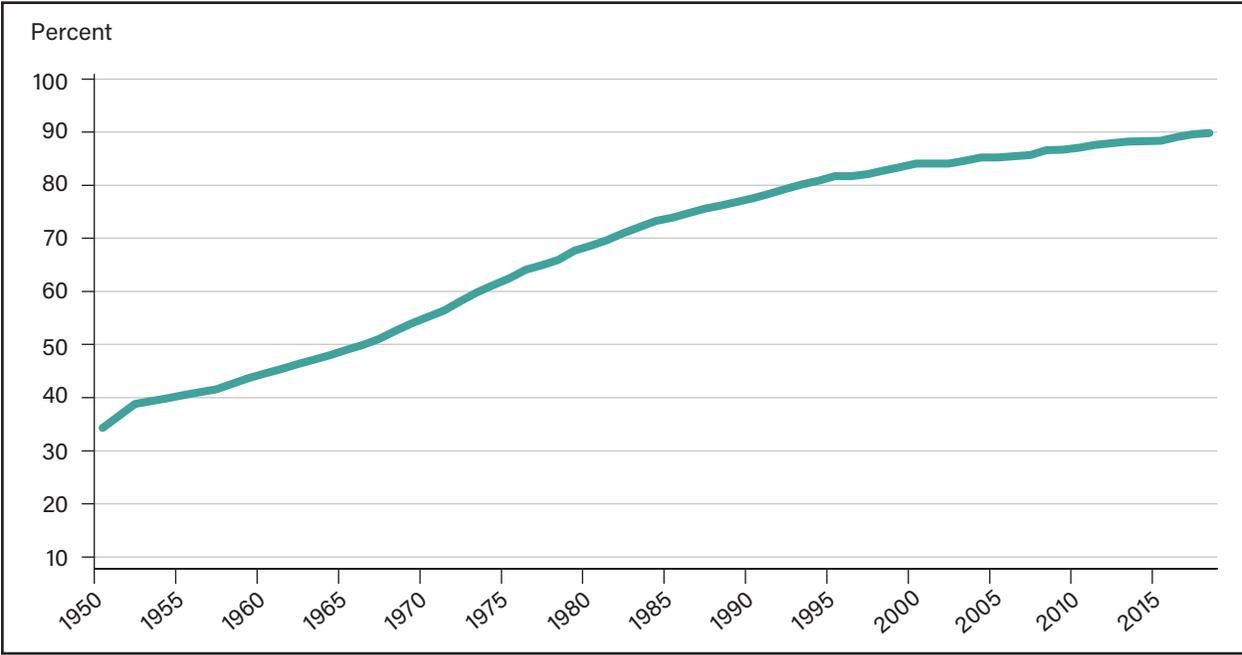
Source: USDA, Economic Research Service using data from the U.S. Department of Commerce, U.S. Bureau of the Census.

Figure 4

Educational attainment of people 25 years and older

Panel B: Number of people who have completed high school or college, 1950–2018
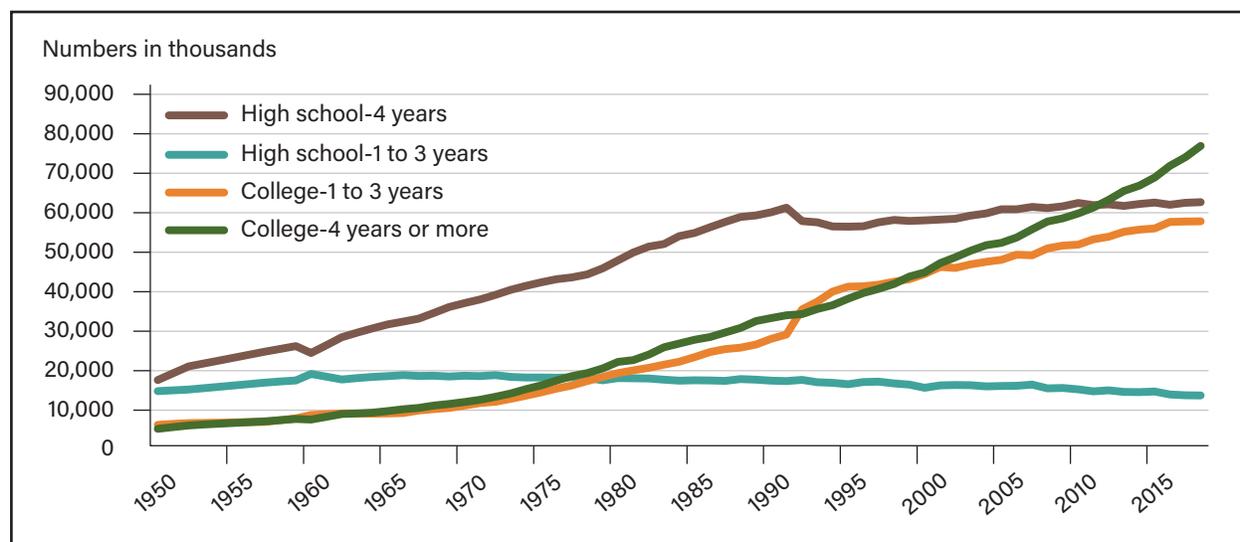
Numbers in thousands

Source: USDA, Economic Research Service using data from the U.S. Department of Commerce, U.S. Bureau of the Census.

Reflecting nationwide trends, educational attainment among farmworkers also changed significantly (table 1). In 1950, farmworkers with 1–8 years of schooling dominated the labor force, accounting for 72 percent of total hours worked in U.S. agriculture. However, the share of total hours this group worked declined to 38 percent by 1970 and further declined to less than half of its 1970 level—16 percent—by 2017. Farmworkers with a 4-year high school diploma started dominating the workforce in 1980, with shares ranging from 35 percent to 47 percent in total hours worked since that time. However, its share peaked in 1990 and then gradually declined. Conversely, the share of total hours from workers with a 4-year college degree and above increased the most—from 1 percent to 25 percent—between 1950 and 2017. Overall, farmworkers who completed 4 years of high school and above have dominated the farm labor market since 1980. The composition accounted for more than three-quarters of the farm workforce and 85 percent of the total cost of labor expense (including self-employed and unpaid workers[8]) in 2017.

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[8] The compensation for self-employed and unpaid workers was imputed using the compensation of hired workers with the same demographic characteristics (see appendix for method.)

Table 1

Farm labor (self-employed and hired) shares by educational attainment, 1950–2017

Classification	1950	1960	1970	1980	1990	2000	2010	2017
Total hours[1] (in million hours)	17,943	11,318	7,059	6,317	4,682	3,903	3,335	3,253
Total hours share (percent)								
1–8 years grade school	72.39	59.91	38.07	22.34	16.32	16.25	16.52	15.70
1–3 years high school	12.92	15.76	18.27	15.12	11.44	10.55	8.35	7.83
Subtotal	85.32	75.67	56.34	37.46	27.76	26.80	24.86	23.53
4 years high school	10.98	18.64	29.30	42.39	47.17	37.69	36.08	35.18
1–3 years college	2.56	4.21	8.50	12.30	14.01	17.52	17.49	16.34
4 years college and above	1.14	1.48	5.85	7.85	11.07	17.99	21.57	24.96
Subtotal	14.68	24.33	43.66	62.54	72.24	73.20	75.14	76.47
Total cost[2] (in 2015 million dollars)	273,492	183,432	128,958	114,505	88,895	80,115	68,699	70,518
Total cost share (percent)								
1–8 years grade school	66.34	54.29	30.94	17.50	12.25	10.39	9.95	9.97
1–3 years high school	13.70	15.57	16.70	12.92	10.13	6.86	5.17	5.19
Subtotal	80.04	69.86	47.64	30.43	22.38	17.25	15.12	15.16
4 years high school	13.13	21.26	33.77	44.92	44.91	35.16	31.92	31.08
1–3 years college	3.92	5.59	10.07	13.91	15.94	18.99	17.92	16.58
4 years college and above	2.91	3.29	8.52	10.74	16.76	28.59	35.03	37.18
Subtotal	19.96	30.14	52.36	69.57	77.62	82.75	84.88	84.84

Notes: The table presents farm workers' hours-worked shares in total hours, and cost shares in total labor cost by workers' educational attainment. Wage rates for self-employed/unpaid farm workers are imputed using wage rates from their hired labor counterparts with the same characteristics (gender, age, educational attainment) to calculate corresponding cost shares for each group of farm workers.
[1]Total hours includes hired labor hours and self-employed and unpaid family workers drawing data from BEA's NIPA and CPS.
[2]Total cost includes compensation for hired workers and imputed cost for self-employed and unpaid family workers.

Sources: USDA, Economic Research Service calculations using data from U.S. Department of Commerce, U.S. Bureau of the Census' Census of Population for 1950–2000, American Community Survey for 2017, and Current Population Survey for 1950–2017.

Table 1 shows shares of the total labor costs attributable to each educational attainment group. Groups that are more highly paid generate shares of labor costs that are higher than their shares of labor hours. The estimates show that the major cost share of farmworkers shifted from those with 1–8 years of schooling in 1950 to those with 4 years of high school education in 1970, and then to those with at least a 4-year college degree in 2017. Between 1950 and 2017, the cost share of those with 1–8 years of grade school attainment dropped from 66 percent to 13 percent, and that of workers with 4 years of high school education increased from 13 percent to 45 percent in 1980, then declined to 31 percent in 2017, largely reflecting underlying patterns in the hours share by group. Over time, the cost share of workers with at least a 4-year college degree increased by more than 12 times, from 3 percent in 1950 to 37 percent in 2017.

Farm operators are more educated

Farm operators make daily decisions for the business. A farm can have multiple operators, and the ARMS survey allows farms to report up to three primary operators. The survey also identifies a principal farm operator as the individual primarily responsible for daily decisions. ARMS provides demographic information for those primary operators. ARMS organizes highly detailed data from individual farms on resources required for agricultural production. It includes information on farm operators' characteristics, such as educational attainment, age, and off-farm income. It also allows linking operators' educational attainment to farm size, commodity mix, and farm income to better understand the connections between educational attainment and

various farm operations, practices, and performance measures. ARMS and its predecessor—the Farm Costs and Returns Survey (FCRS)—are the sources of data on farms, farm households, and farm operators used to examine educational attainment in this section. The report examines the educational attainment of farm operators by farm size, using gross cash farm income (GCFI) to measure farm size.[9] The farm-level detail in the surveys provides comprehensive information not available from more aggregated sources. Those trends are tracked only since 1991, not from 1948 as in the more aggregated sources.

Long-term trends

The most notable change in educational attainment among farm operators is a 17-percentage point decline in the share of farm operators who did not complete high school, from 24 percent in 1991 to just 7 percent in 2016 (figure 5). The decline began earlier than the 1990s. Using various sources, Bellamy (1992) determined that the gap in high school graduation rates between farmers and the general population had largely closed by the late 1980s. At the other end of the education spectrum, the share of farm operators who completed college increased by 13 percentage points during 1991–2016. Nevertheless, the college graduation rate is higher for all U.S. households (34 percent) than for all farm operators (29 percent), as shown in figure 6.

Figure 5
Farm operators' educational attainment has increased over time, 1991–2016
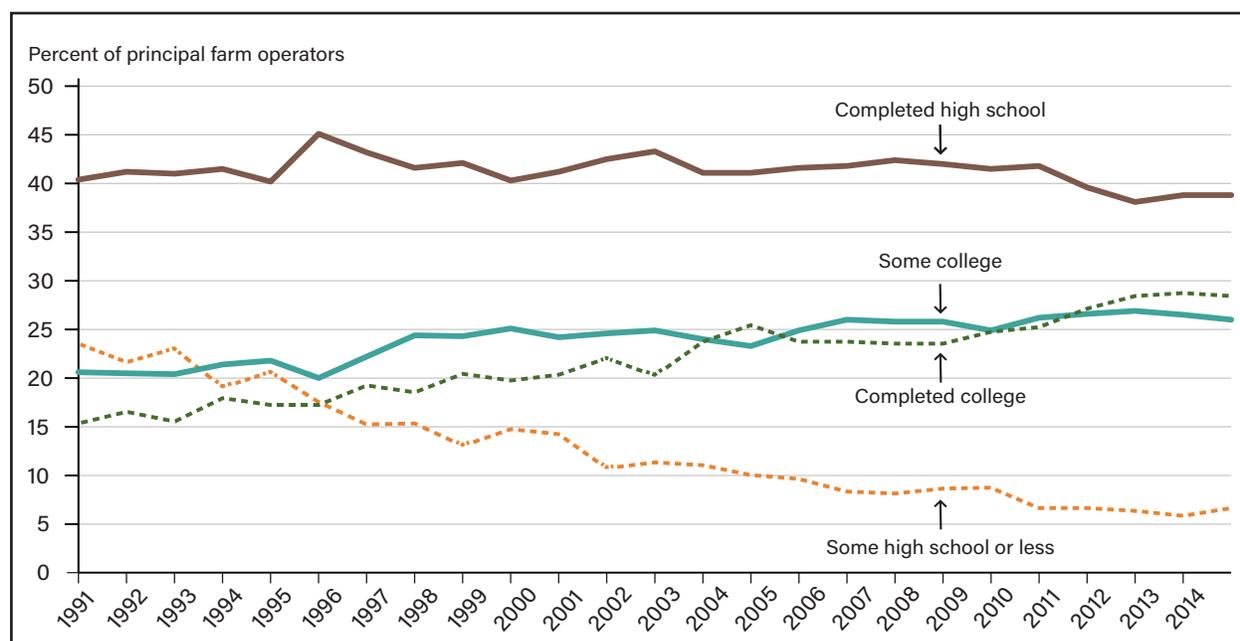
Note: The year 2005 was omitted because it combined the "completed high school" and "some college" categories.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, 1991–1995 Farm Costs and Returns Survey and 1996–2016 Agricultural Resource Management Survey.

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[9] GCFI is the farm's revenue from sales of crops and livestock, production contract fees, Government payments, and other farm-related income, such as receipts from custom work, machine hire, livestock grazing fees, timber sales, outdoor recreation fees, and other sources.

Figure 6
Educational attainment of principal farm operators and all U.S. householders, 2016
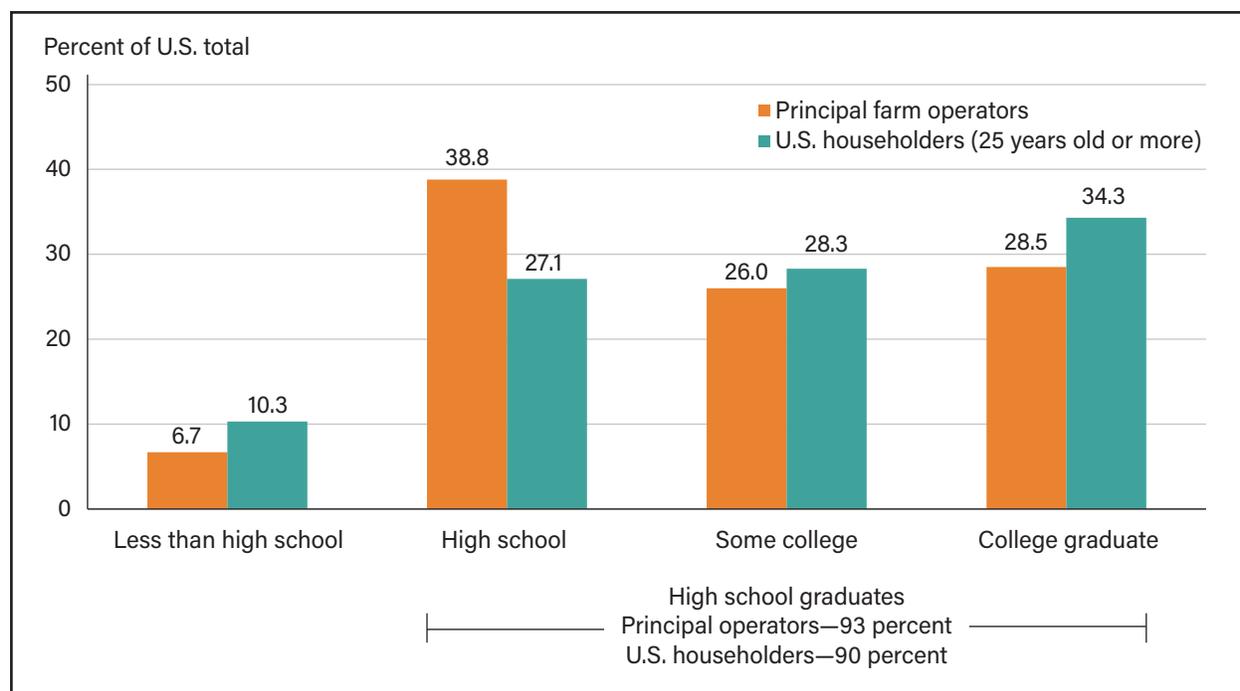
Percent of U.S. total

Legend:
- Principal farm operators
- U.S. householders (25 years old or more)

	Less than high school	High school	Some college	College graduate
Principal farm operators	6.7	38.8	26.0	28.5
U.S. householders	10.3	27.1	28.3	34.3

High school graduates
Principal operators—93 percent
U.S. householders—90 percent

Sources: USDA, National Agricultural Statistics Service and USDA, Economic Research Service, 2016 Agricultural Resource Management Survey for farm operators; U.S. Department of Commerce, Bureau of the Census, Current Population Survey, 2016 Annual Supplement for all U.S. householders.

Variation by farm size

Agricultural production shifted to large farms over the last three decades. The share of the value of production contributed by farms with at least $1 million in sales (in 2015 dollars) increased from 32 percent in 1991 to 52 percent in 2015 (Hoppe and MacDonald, 2016). The principal farm operators associated with larger farms, those with a higher total gross cash farm income (GCFI), are more likely to hold a college degree (figure 7). The 36 percent college graduation rate for operators of large farms (GCFI of at least $1 million) exceeded the rate for all U.S. household members (age 25 or more) in 2016 (34.3 percent). The graduation rate was particularly high for operators of farms with a GCFI of $5 million or more (41 percent) (table 2). College graduation rates for operators of farms with a GCFI of at least $1 million ranged between 31 and 41 percent from 1991–2016, consistently higher than the rates for operators of smaller farms (figure 7). College graduation rates trended upward for the other GCFI classes, although the upward trend was not as clear after 2006 for operators in the $350,000–$999,999 class. Farm profitability increases with farm size, and as less-profitable farms leave the business, restructuring raises productivity levels industrywide (Kirwan et al., 2012; MacDonald et al., 2013; Key, 2019). Higher educational attainment of the operators of million-dollar farms likely contributed to the profitability of their farms. One would expect a higher level of education to help farmers adjust to changes in agricultural markets and to adopt new technology (El-Osta, 2011, p. 96).

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Figure 7
Percent of principal farm operators, with farms grossing $1 million or more, who graduated from college by gross cash farm income (GCFI) class, 1991−2016

Percent of principal farm operators

Note: Gross Cash Farm Income (GCFI) is expressed in 2016 dollars using the Consumer Price Index Series Using Current Methods (CPI-U-RS) to adjust for price changes.

Sources: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, 1991–95 Farm Costs and Returns Survey and 1996–2016 Agricultural Resource Management Survey for farm households. U.S. Department of Commerce, U.S. Bureau of the Census, Current Population Survey, Annual Social and Economic Supplements for all U.S. households.

Table 2

Educational attainment of principal farm operators by gross cash farm income (GCFI) class, 2016

| Item | Principal operator by GCFI class | | | | $1,000,000 or more | | | All principal operators | All U.S. house-holders age 25 or more |
	Less than $10,000	$10,000–$149,999	$150,000–$349,999	$350,000–$999,999	Total	$1,000,000–$4,999,999	$5,000,000 or more		
	Number								
Principal farm operators	128,412	678,950	148,931	1,031,136	64,833	57,258	7,575	2,052,261	NA
	Percent of U.S. total								
Principal farm operators	6.3	33.1	7.3	50.2	3.2	2.8	0.4	100.0	NA
Value of production[1]	23.5	9.6	12.5	0.8	53.6	29.6	24.0	100.0	NA
	Percent of group								
Educational attainment:									
Less than high school	2.7	6.1	6.4	7.9	2.1	2.0	3.3	6.7	10.3
High school	36.9	40.4	41.7	38.1	32.1	32.0	33.2	38.8	27.1
Some college[2]	30.8	24.4	26.2	26.3	29.5	30.4	22.6	26.0	28.3
College graduate or more	29.7	29.1	25.8	27.8	36.3	35.6	40.9	28.5	34.3
	Years								
Average experience farming[3]	31	28	28	23	31	31	29	26	NA
Average age	56	60	57	60	57	57	56	60	NA

NA=not applicable.

Notes: This table shows how principal farm operator's educational attainment vary across different income groups. GCFI indicates Gross cash farm income;

[1] The value of production measures the value of commodities produced in a given year, without the effects of inventory change. It is calculated by multiplying the quantity of each commodity produced by the price of the commodity.

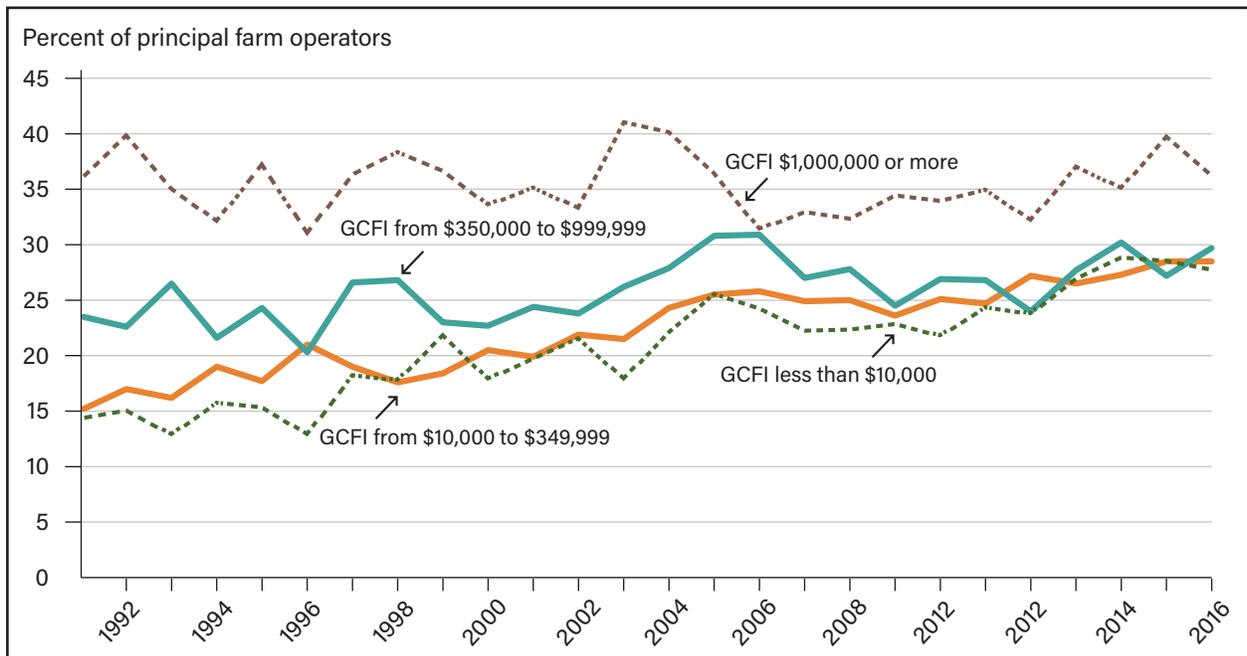[2] Includes associate degrees.

Sources: USDA, National Agricultural Statistics Service and USDA, Economic Research Service, 2016 Agricultural Resource Management Survey for farm operators. U.S. Department of Commerce, Bureau of the Census, Current Population Survey, 2016 Annual Social and Economic Supplement for all U.S. households.

Other demographic characteristics changes

Although other demographic characteristics may have fewer effects on human capital than education, they could still affect labor quality. ERS researchers measured labor quality by considering workers' educational attainment changes and changes in other demographic characteristics. These include age, gender, and work types—hired versus self-employed and unpaid family workers—using decennial Census of Population and American Population Survey microdata.[10] According to the labor accounts in the USAP data, male workers accounted for nearly 90 percent of total hours worked in 1950, while the percentage declined to 81 percent in 2017 as more male workers than female workers left the farm sector (table 3). Over the last seven decades, farmworkers' age groups shifted to older ages. In 1950, most work was conducted by farmworkers ages 34–44 and 45–54, accounting for about 30 percent of total hours worked. By 2017, most work was performed by ages 45–54 and 55–64, accounting for about 35 percent of total hours worked. Work conducted by those 65 and over also increased from 8 percent in 1950 to nearly 10 percent in 2017 (table 3).

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[10] Since estimates are based on survey data, measurement errors can arise when the survey respondent did not answer survey questions correctly.

Table 3

Total hours-worked shares by gender and age groups (in percent), 1950 and 2017

Year	Gender	Age groups								Total
		14–15	16–17	18–24	25–34	35–44	45–54	55–64	65 and older	
1950	Male	1.30	2.30	13.40	15.80	17.50	16.70	14.40	8.20	89.70
	Female	0.10	0.30	0.90	1.70	2.60	2.20	1.70	0.80	10.30
2017	Male	0.00	0.40	6.40	14.20	15.40	17.00	17.80	9.80	81.00
	Female	0.00	0.20	1.90	3.30	4.10	4.20	3.80	1.60	19.00

Notes: This table shows the distributions of hours worked by workers' age groups and gender in the total hours. Authors compared years 1950 and 2017 and found that female workers increased, and younger workers (below age 17) decreased.

Source: USDA, Economic Research Service calculations based on U.S. Department of Commerce, U.S. Bureau of the Census' Census of Population and American Community Survey micro data used in the labor accounts of U.S. agricultural productivity statistics.

NAWS data cover a shorter period, 1989–2016, and a much smaller annual sample size (about 2,400 workers per year on average across survey years) than ARMS and Census data. However, it provides more detailed information on demographic characteristics, including legal status, farm work experiences, and country of birth. It adds additional information to the farm workforce as a complement to other data sources[11] and can shed light on the status of the current labor market. Given its small sample size, the authors presented multi-year averages for those demographic characteristics covering fiscal years 1989–91, 2001–03, and 2014–16 (table 4).

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[11]ERS researchers employ NAWS data to construct a quality-adjusted price index (piece rate) to deflate purchased contract services (see ERS USAP data documentation for details.)

Table 4

Demographic characteristics of hired/contracted crop farm workers in National Agricultural Workers Survey, 1989–2016

	FY1989–91	FY2001–03	FY2014–16
Unweighted sample size	7,244	10,057	8,165
Average age	33	33	38
Percent 14–20	16	15	8
Percent 21–44	66	67	59
Percent 45+	18	19	33
Percent female	27	24	32
Average years of farmwork experience	10	10	14
Percent 0–2	18	29	18
Percent 3–15	62	47	46
Percent 16+	21	24	36
Average years of education	7.7	7.4	8.4
Percent less than 9th grade	53	57	46
Percent 9–12th	41	37	43
Percent > high school	6	6	11
Legal status[1]			
Percent U.S. born	41	26	27
Percent foreign born - SAW	28	9	8
Percent foreign born - other authorized	17	15	18
Percent foreign born - unauthorized	14	50	48
Country of birth[2]			
Percent U.S. (including Puerto Rico)	40	26	26
Percent Mexico	54	72	67
Percent other	6	3	6
Immigrated to U.S. less than 2 years ago (for immigrants only)	4	16	3

Notes: This table presents the distribution of crop-farm workers' demographic characteristics including age, experience, educational attainment, legal status, country born, and immigration status, in three time periods for comparison.
[1] "U.S. born" includes those born in Puerto Rico.
[2] Includes a small number of cases with missing legal status.
FY=Fiscal Year. SAW=Special Agricultural Worker, a category of authorized workers under the Immigration Reform and Control Act of 1986.

Source: USDA, Economic Research Service calculation based on National Agricultural Workers Survey data.

The pattern of demographic and economic change in the NAWS crop farm workforce can be broken down into two periods, as indicated in table 4. Between about 1990 and 2002, change involved a rise in the share of unauthorized immigrant workers, predominantly from Mexico, with concomitant declines in the share of authorized workers, both U.S.- and foreign-born. In particular, in FY 1989–91, just 14 percent of the workforce was unauthorized. Among these, 28 percent were former unauthorized immigrant workers who had been granted legal amnesty and work authorization under the Special Agricultural Workers (SAW) provision of the Immigration Reform and Control Act of 1986. Another 41 percent were U.S.-born. By FY 2001–03, the share of unauthorized workers rose to 50 percent, the SAW share fell to 9 percent, and the share of U.S.-born dropped to 26 percent. Since then, however, legal status shares and the country-of-origin proportions have remained roughly constant.

By contrast, many indicators, including average age, the share of female workers, and years of farm experience, changed little between 1990 and 2002 but have changed considerably since. In particular, the number of new immigrant entrants to agriculture fell sharply, from 16 percent in FY 2001–03 to just 3 percent in FY 2014–16. This reflects the sharp slowdown in net immigration from Mexico, which peaked in 2007 just before the Great Recession (Pew Hispanic Center, 2018). Mexico, however, is still the major source of immigrant farmworkers in the crop farm sector (figure 8).

Figure 8
Most foreign-born crop workers were from Mexico, 1991−2016
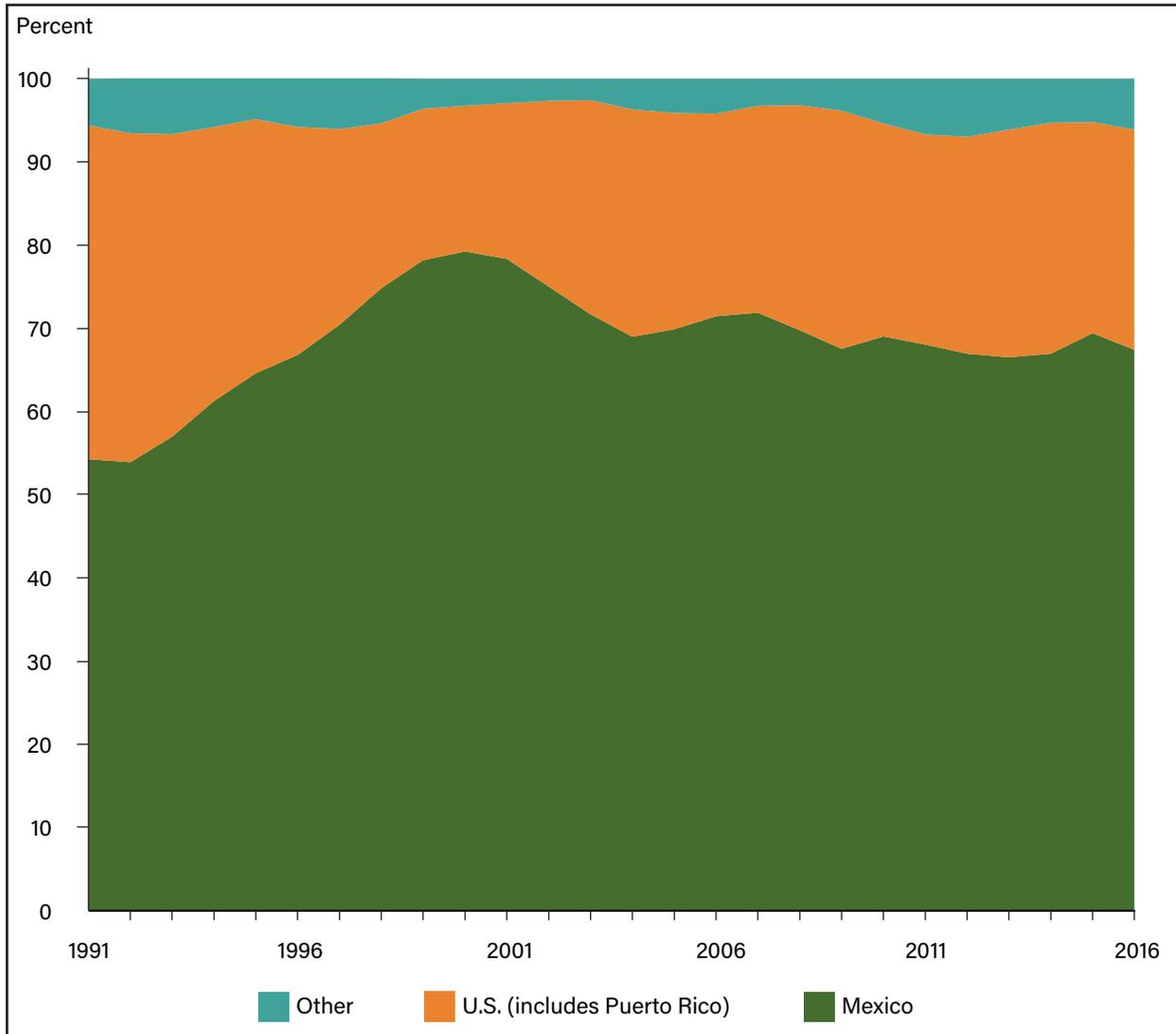
Source: USDA, Economic Research Service calculations using data from U.S. Department of Labor's National Agricultural Workers Survey.

The crop farm workforce is also aging, with the mean age rising from 33 years in FY 2001–03 to 38 years in FY 2014–16. The share of the workforce who are 45 or older rose from about one-fifth to about one-third. Given the physically demanding nature of fieldwork, this increase in age could result in lower productivity.[12]

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[12]One strategy growers deployed to maintain the productivity of older workers was to increase the use of mechanical assistance, such as conveyor belts to reduce the distance that heavy boxes of produce must be carried in the fields or hydraulic platforms to reduce the need to climb ladders.

This may also have permitted more women to work in agriculture. Their share rose by several percentage points over time, consistent with the overall changes shown in table 4. Conversely, an aging workforce is more experienced, and that should raise labor productivity. Average years of experience rose from 10 to 14 years since FY 2001–03. The share with less than 3 years of experience fell from 29 percent to 18 percent.

Lastly, according to the survey, the educational attainment of crop farmworkers improved somewhat over time. The share of those with less than a 9th-grade education fell from 57 percent in FY 2001–03 to 46 percent in FY 2014–16. The trend is like the overall changes in the farm sector. On average, U.S.-born crop farmworkers have a higher average educational attainment (figure 9).

Figure 9
Educational attainment for U.S. crop farm workers: U.S. born versus foreign born, 1991–2016 (3-year moving average)
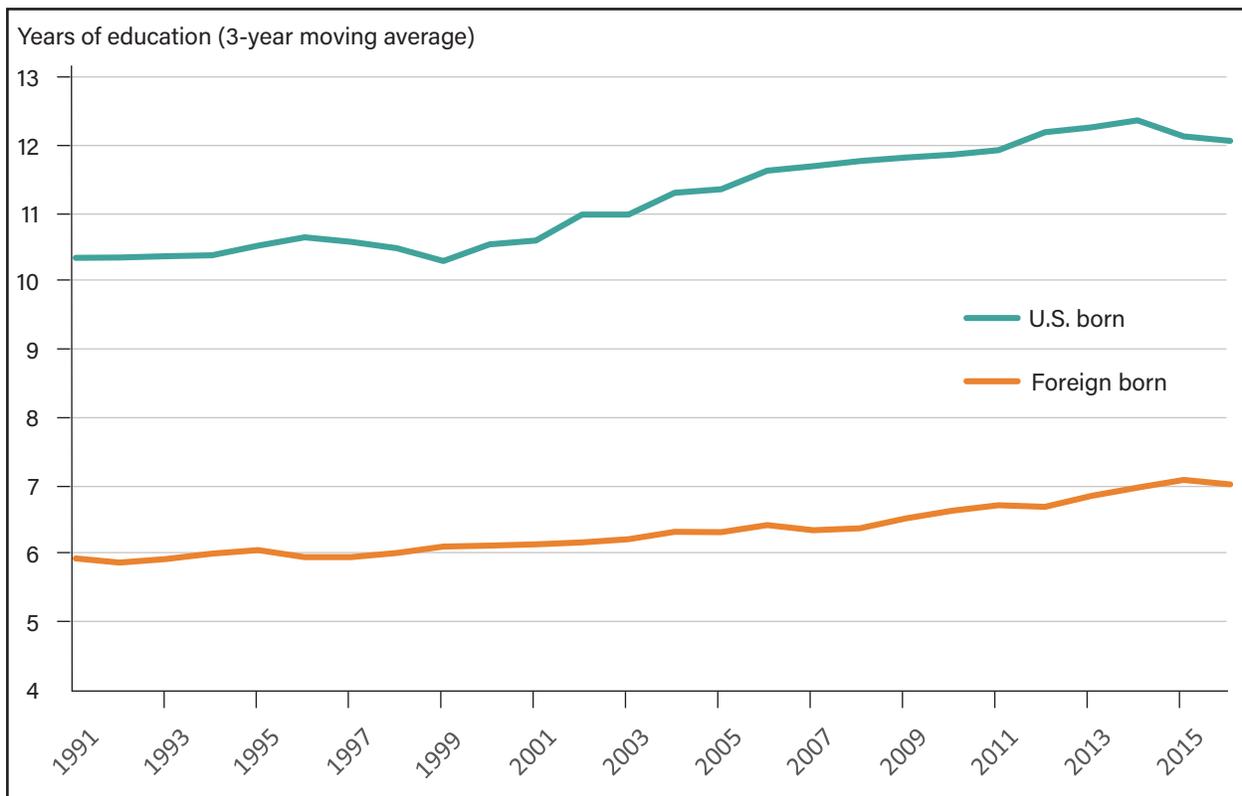
Source: USDA, Economic Research Service calculations using National Agricultural Workers Survey data.

Labor productivity, input use intensity, and farm income

Researchers showed that higher human capital (labor quality) through increased education level could help promote economic growth at the aggregate level (Hulten and Ramey, 2015; Jorgenson et al., 2015) or enhance regional productivity convergence (McCunn and Huffman, 2000; Wang et al., 2019). Nonetheless, current conventions of measuring labor input in productivity analysis are mostly based on total employment or hours-worked measurement. Labor estimates could be biased if labor quality changes embodied in the work-force are not considered, resulting in spurious productivity estimates. Additionally, while labor productivity can be advanced by technical change (TFP growth), it can also be affected using other production inputs. Understanding its sources of growth is critical for policy development.

Labor productivity increased

Labor productivity—average output per unit of labor input—is a popular measure for understanding economic growth. It is also a partial productivity measure that attributes output growth exclusively to changes in labor input. With the declining use of labor and growing total agricultural output, labor productivity increased considerably.

Nevertheless, estimates of labor productivity are sensitive to the measure of labor input. Labor input can be measured as total employment, total hours worked, or quality-adjusted hours.[13] According to USAP estimates, between 1948 and 2017, farm labor employment and total hours worked[14] both fell by about 82 percent, with 65 percent for hired employment, 87 percent for self-employed and unpaid family workers, 73 percent for hours worked by hired workers, and 88 percent for hours worked by self-employed and unpaid family workers. On the other hand, if adjusted for labor quality changes and measuring labor input based on a constant-quality measure, quality-adjusted labor input would decline slower than those without adjustment as the increase in labor quality would offset part of the decline in labor hours worked. Overall, estimates of quality-adjusted labor input fell by 75 percent (66 percent for hired workers and 80 percent for self-employed and unpaid family workers) during the same period. Consequently, labor productivity with the unadjusted hours-worked measure or employment measure would be larger (overstated) than the one based on the quality-adjusted labor measure (figure 10, also see appendix on how the quality-adjusted labor input was constructed). Human capital changes account for about 13 percent (0.5 percentage points) of annual growth of labor productivity on average if labor quality is not adjusted. The discussion focuses on the quality-adjusted labor measure only.

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[13] To account for labor quality changes because of changing demographic characteristics—including gender, age, and educational attainment—the Economic Research Service productivity accounts measure labor input in constant quality or "quality-adjusted labor" units.

[14] In US agricultural productivity accounts, labor estimates are based on data drawn from the US Bureau of Economic Analysis, National Product and Income Accounts, and the Current Population Survey provided by the Bureau of Labor Statistics.

Figure 10
Labor productivity estimates vary depending on how labor input is measured, 1948−2017
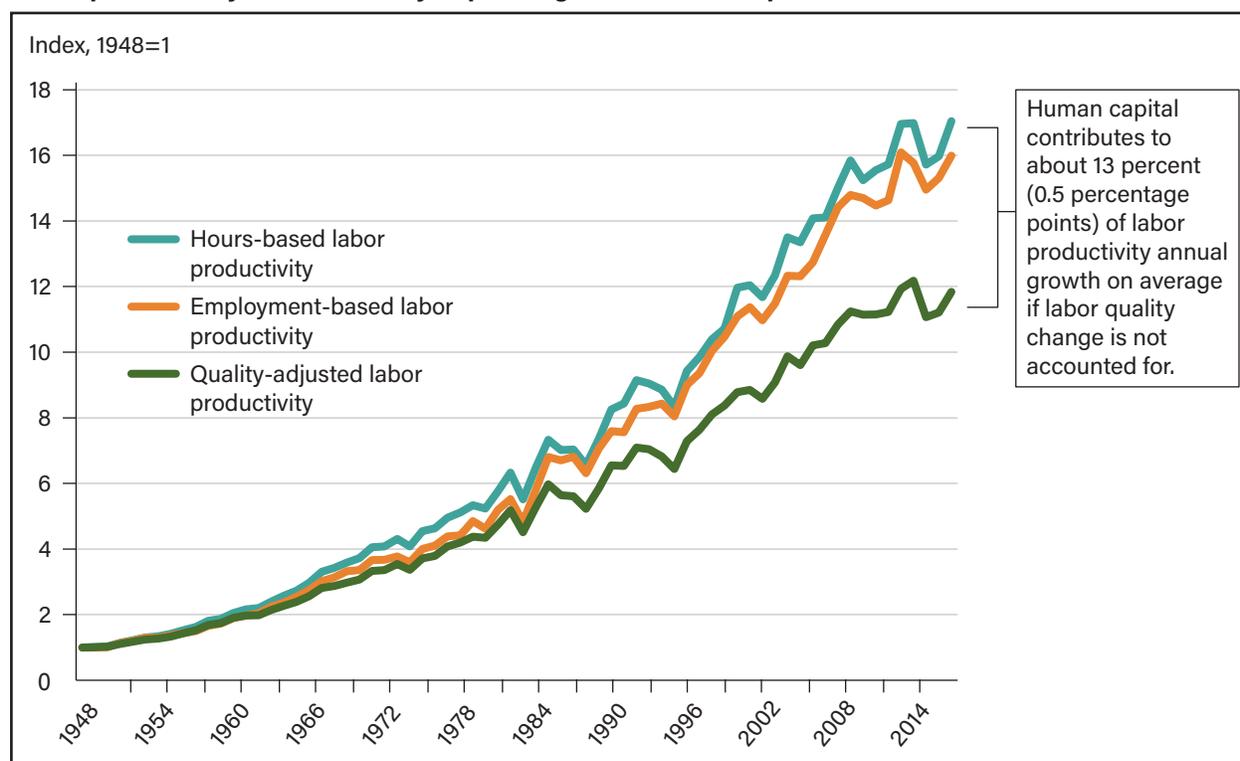
Index, 1948=1

Human capital contributes to about 13 percent (0.5 percentage points) of labor productivity annual growth on average if labor quality change is not accounted for.

Source: USDA, Economic Research Service calculations based on the U.S. agricultural productivity accounts data, updated January 2020.

According to USAP data, in 2017, labor productivity (total output/quality-adjusted labor estimates) was nearly 12 times its 1948 level in the U.S. farm sector. These changes imply that farm production transformed into a much more labor-saving process with increasing human capital (labor quality) embodied in the farm workforce. One interesting feature is that when breaking down the time series into two subperiods (1948–82 versus 1982–2017), labor productivity grew much faster in the first subperiod, with an average annual growth rate of 4.6 percent compared to the second period growth rate of 2.4 percent. The outcome of agriculture production is a combined result of all inputs and technologies going into that production process. Besides technical changes, the differences in labor productivity growth can be affected by input densities.

Input intensities and labor productivity

With substantial reductions in farm labor and land inputs over time, the U.S. farm sector now relies more on capital goods, intermediate inputs—including agricultural chemicals, energy, and purchased services[15] —and technology improvement (TFP) to maintain output growth. Over time, the increase in labor productivity coincides with increases in input densities (figure 11). This pattern implies that input substitution contributed partially to increasing labor productivity, with some other inputs substituting for labor used in the production process. Among all inputs, the densities of agricultural chemicals (pesticide and fertilizer) and purchased services seem to have increased much faster than all others. When compared to the manufacturing sector,

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[15] Some suggest that purchased service expenses, such as repairs and custom machinery work, may also involve some labor component and should consider it as a part of labor input. However, no available data allows us to partition each purchased service into its labor portion, material portion, and capital portion. The authors followed the tradition assigning purchased service expenses as a part of intermediate goods, the same treatment as for the nonfarm sectors by BLS.

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input intensity changes contributed to about 41 percent of labor productivity growth in the farm sector and nearly 70 percent in the manufacturing sector, based on BLS data between 1987 and 2017.

Figure 11
Input intensities and labor productivity, 1948–2017

Input intensities (input use per unit of labor)
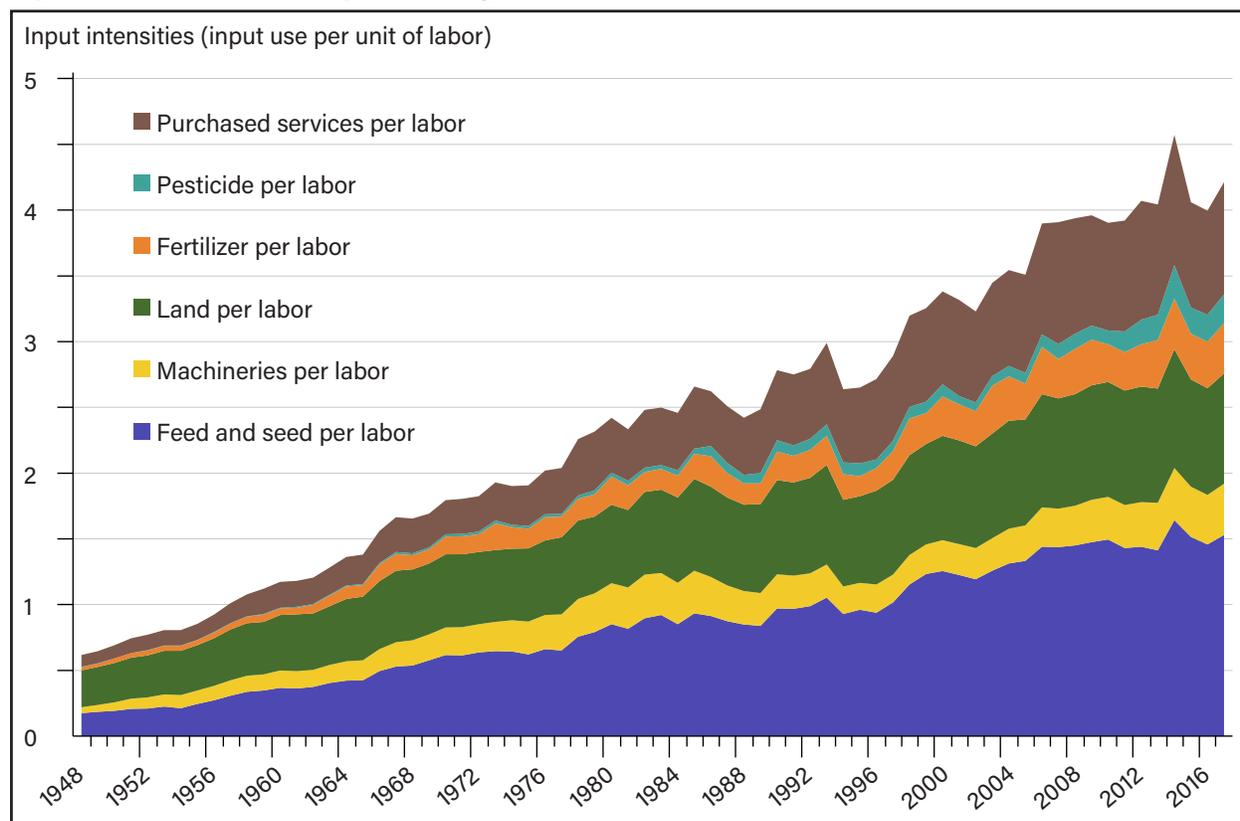
Note: Input intensity lines are stacked lines.

Source: USDA, Economic Research Service calculations based on the U.S. agricultural productivity data table 1a, updated January 2020.

With the considerable contraction of hired farmworkers, farms gradually shifted toward the use of purchased services input—including feeding, purchased contract services,[16] building repair, transportation and storage, veterinary service, custom machinery work, and machinery repair (Wang et al., 2015; MacDonald et al., 2018). Many farm tasks—such as field preparation, spraying, or combine harvesting—are now frequently carried out by specialist providers. Farms can also contract with a service provider, often to provide harvest services in specialty crops. The expense paid to the custom or contract services is reflected in an expense to the farm and is not counted as part of the farm labor input. Part of the decline in farm labor input reflects a shift to a greater reliance on work provided through purchased custom and contract services (figure 12).

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[16] The Agricultural Resource and Management Survey defines contract workers as paid by a crew leader, contractor, buyer, processor, cooperative, or other person who has an agreement with a farmer/rancher. Farm operators paid a lump sum cost to crew leaders, contractors, and others to purchase the services. The cost is recorded as part of "purchased services" under the intermediate goods category in the U.S. production account.

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Figure 12
Labor input versus purchased services, 1960-2017

Billion dollars
(in 2015 prices)
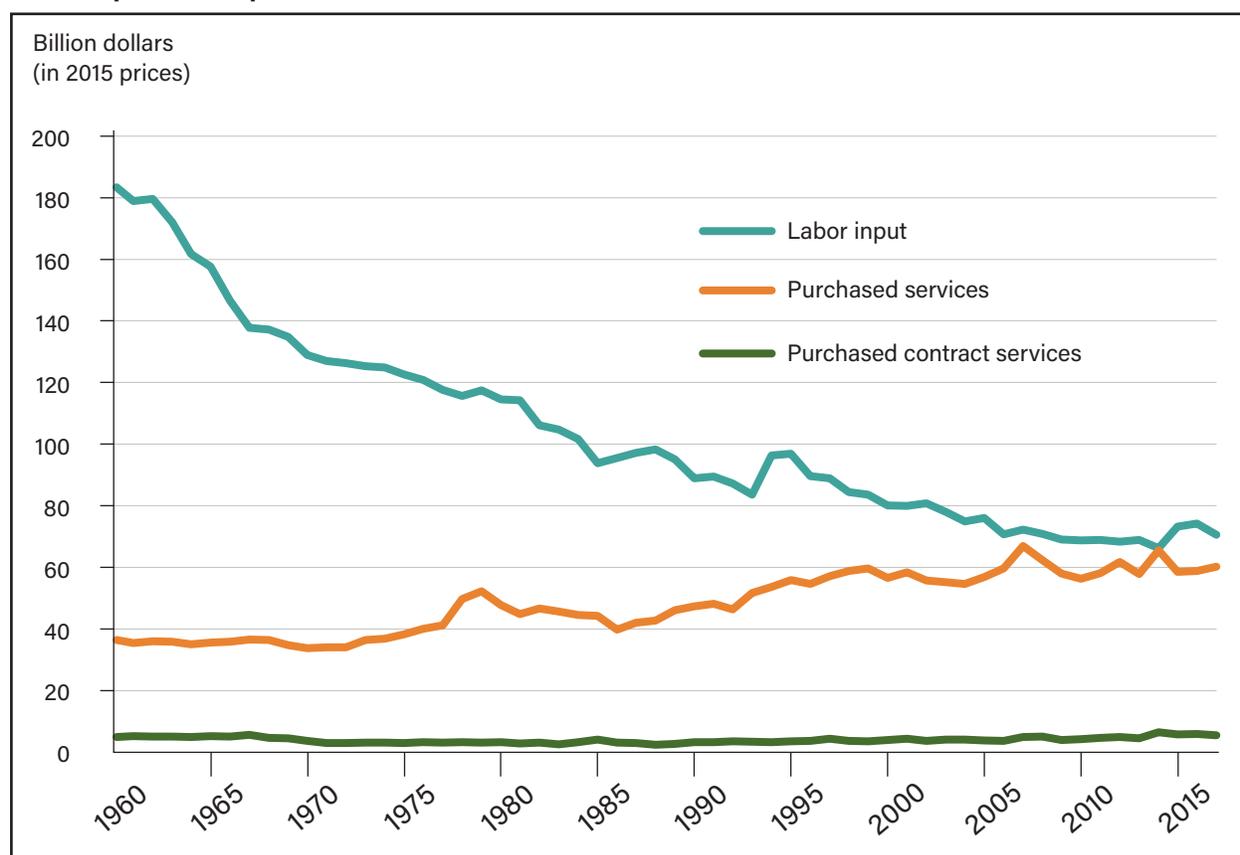
Source: USDA, Economic Research Service calculation based on USDA, ERS U.S. agricultural productivity accounts data, updated January 2020.

In 1948, the ratio of the total cost of labor input—hired labor and self-employed and unpaid workers (see appendix for cost imputation)—to purchased services was about 12 to 1, and this ratio dropped to about 1.3 to 1 in 2017. Purchased contracted labor services accounted for about 10 percent of the total purchased services category in 2017. Interestingly, labor productivity continued to grow when the input densities per unit of labor grew much slower between 1980 and 1996. It can be attributed primarily to the growth of total factor productivity (TFP), a productivity estimate that accounts for the unexplained part of output growth after considering all inputs used.

Farm worker salaries and farm household income

Higher labor productivity can promote a higher salary level for farmworkers. According to BEA Wages and Salaries data, the average annual salary level per full-time equivalent (FTE) employee in the farm workforce increased by about 13 times between 1948 and 2017. The ratio of farmworker salary to the average of all domestic industries was about 0.55 in 1948 (figure 13). While this ratio fell to 0.4 between 1954 and 1961, it rose to the highest of 0.66 during 2007–08 and then fell to 0.57 in 2017.

Figure 13
Annual salaries—farm sector versus domestic industries, 1948–2017
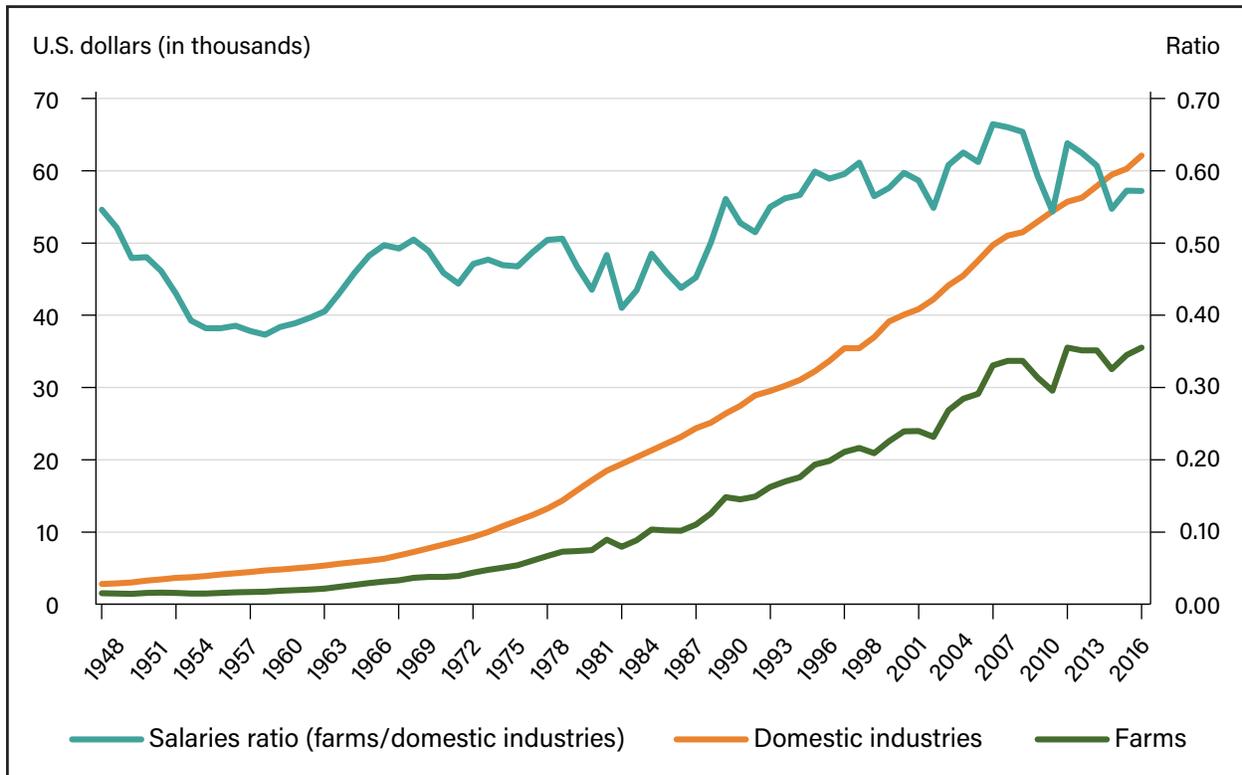
Source: USDA Economic Research Service calculations based on data from Bureau of Economic Analysis National Income and Product Accounts. Tables 6.6 A-D Wages and Salaries Per Full-Time Equivalent Employee by Industry.

Increasing labor productivity, along with other factors, may contribute to rising welfare for farm operators through higher farm income. Historically, farm households had low income relative to other households.[17] Beginning in 1984, ERS provided a survey-based estimate of the income of farm operator households that showed that the average income of farm operator households was 74 percent of U.S. households (Ahearn, 1986). Over time, the incomes of farm operator households continued to rise relative to U.S. households. By 1998, the farm household median income was 103 percent of the U.S. median income level (figure 14). It has remained above the U.S. median level since, with some variation over the years.

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[17] The earliest series that allowed for a comparison between farm and nonfarm family incomes was for those who lived on farms, which differs conceptually from the farm operator household population of interest.

Figure 14
Ratio of median income for farm households to median income for all U.S. households, 1991–2016
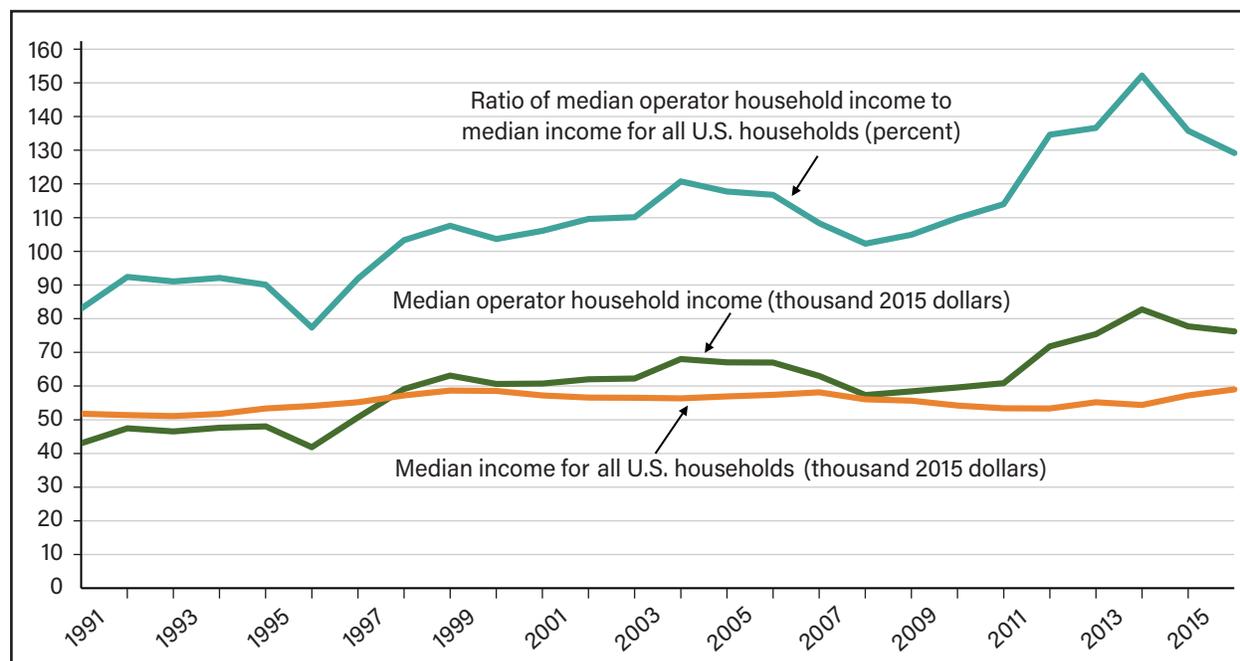
Note: Household income is expressed in 2015 dollars using the Consumer Price Index Series Using Current Methods (CPI-U-RS) to adjust for price changes.

Sources: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, 1991–1995 Farm Costs and Returns Survey and 1996–2016 Agricultural Resource Management Survey for farm households. U.S. Department of Commerce, U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements for all U.S. households.

What this means is that the income gap reversed—median household income was now higher for farm households than for all U.S. households. This reversal may have created incentives for farm operators to enter or remain in farming to seek higher income and could explain the slower decline in agricultural employment since the 1970s, as shown previously in figure 1. Nevertheless, the gap still existed for some farm households. Thirty-eight percent of farm households had income below the U.S. median in 2016, despite the reversal of the income gap in the aggregate data. Forty-two percent of households operating farms with a GCFI less than $10,000 received income below the U.S. median, a higher share than any other GCFI class. In addition, the GCFI class accounted for the majority (57 percent) of farm households with income below the U.S. median. Operator households with a GCFI less than $10,000 are unlikely to decide to leave farming based on the gap between their farm earnings and U.S. household income. Virtually all the group's income already came from off-farm sources. Many of these farms are residential or retirement farms, and three-fourths lost money farming (Burns and MacDonald, 2018).

Human capital, total factor productivity, and U.S. agricultural growth

Sources of agricultural growth

The authors used a standard growth accounting framework to estimate the share of agricultural output that may be attributed to growth in each input—labor, capital (durable equipment, farm structure, and land), and intermediate goods (energy, agricultural chemicals, purchased services, seed, feed, etc.)—and TFP growth. To better measure the effect of human capital on U.S. farm production, labor changes were partitioned into quality (human capital) and quantity (hours) components.[18] Furthermore, labor quality changes were decomposed into two sources—education versus other factors combined (gender, age, and employment type).[19] The results are shown in the lower part of table 5, along with other inputs' quality decomposition, the estimates of agricultural output growth, and sources of growth on the top section of table 5. Estimates are also grouped into 12 subperiods (measured from cyclical peak to peak in aggregate economic activity) other than the entire period between 1948 and 2017.

Overall, agricultural output grew at an average rate of 1.53 percent per year between 1948 and 2017. With total input growth contributing 0.07 percentage points, the major source of output growth was due almost entirely to TFP growth, at 1.46 percentage points per year. Over the last seven decades, labor quality increased by 44 percent through increasing educational attainment in the farm workforce and other demographic changes. Since quality improvement offset part of the labor quantity reduction, the quality-adjusted labor estimate declined by 76 percent, or less than the reduction of 83 percent in total labor quantity (hours worked). The average annual growth rates of quality-adjusted labor, labor quality, and labor quantity (hours) were -0.45 percent, 0.12 percent, and -0.57 percent, respectively (table 5).

While the decrease in hours worked contributed negatively to output growth in all subperiods, most of the contraction in hours worked occurred between 1948 and 1969, contributing 0.92 to 1.24 negative percentage points to total output growth rates. This was caused by the post-World War II economic expansion pulling a significant amount of labor away from the farm sector. In contrast, labor quality changes contributed positively to output growth in all subperiods averaging 0.11 percentage points per year, except for 1979–81, which coincided with the oil crisis. The slight declines in labor quality during the energy shock and recession (1979–81) were mainly caused by demographic composition shifts other than education, such as gender, age, and employment type. The negative effect of the contraction of labor quantity to annual output growth shrank to -0.16 percentage points in the last subperiod (2007–17), the smallest among all subperiods, as the declining trend of total hours worked slowed.

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[18] Jorgenson and Griliches (1967) first extended the Solow (1957) growth-accounting framework that attributes the economic growth into three contributors—labor, capital, and technology—by separating labor input into its quantity and quality components to identify labor quality's contribution in economic growth. The authors follow a similar approach proposed by Jorgenson et al. (1987) to cross-classify labor demographic characteristics changes by gender, education, age, and work type to contrast a quality-adjusted labor input (see appendix for more detail regarding the measurement).

[19] The growth decomposition in this study is based on index number approach under the growth accounting framework. One limitation to this method is that it does not permit performing statistical tests as those reported in the econometric analysis.

Table 5

Sources of output growth in the U.S. farm sector (average annual growth rate in percent), 1948–2017

	1948–2017	1948–1953	1953–1957	1957–1960	1960–1966	1966–1969	1969–1973	1973–1979	1979–1981	1981–1990	1990–2000	2000–2007	2007–2017
Output growth	1.53	0.97	0.52	3.71	1.21	2.25	2.53	2.44	2.59	0.80	1.89	0.77	1.18
Sources of growth													
Input	0.07	0.66	-0.01	0.33	0.07	-0.26	0.49	1.56	-1.25	-1.28	0.30	0.13	-0.03
Labor	-0.45	-0.83	-1.11	-0.88	-0.86	-0.65	-0.41	-0.19	-0.23	-0.45	-0.23	-0.37	-0.07
Capital	-0.06	0.57	0.00	-0.12	0.03	0.13	-0.15	0.30	0.04	-0.76	-0.22	-0.01	0.07
Intermediate goods	0.58	0.92	1.10	1.33	0.89	0.26	1.06	1.44	-1.05	-0.07	0.75	0.51	-0.02
TFP	1.46	0.31	0.53	3.38	1.15	2.50	2.04	0.88	3.84	2.09	1.60	0.64	1.21
Input Decomposition													
Labor													
Hours	-0.57	-1.06	-1.24	-0.92	-1.14	-0.95	-0.46	-0.21	-0.20	-0.52	-0.40	-0.40	-0.16
Quality	0.11	0.23	0.12	0.04	0.28	0.30	0.05	0.01	-0.03	0.07	0.17	0.02	0.09
Quality decomposition													
Education	0.10	0.10	0.08	0.04	0.20	0.23	0.14	0.10	0.06	0.05	0.10	0.04	0.11
Others	0.01	0.13	0.04	0.00	0.08	0.07	-0.09	-0.09	-0.09	0.02	0.07	-0.02	-0.02
Capital													
Stocks	-0.11	0.19	-0.18	-0.20	-0.06	-0.24	-0.36	0.14	-0.13	-0.34	-0.09	-0.13	-0.01
Quality	0.05	0.37	0.18	0.08	0.09	0.37	0.21	0.16	0.17	-0.42	-0.13	0.12	0.08
Intermediate goods													
Quantity	0.55	1.03	0.92	1.24	0.92	0.06	1.10	1.55	-1.34	-0.20	0.77	0.44	-0.06
Quality	0.04	-0.11	0.19	0.09	-0.03	0.21	-0.04	-0.10	0.29	0.13	-0.02	0.06	0.04

TFP=total factor productivity

Notes: This table presents sources of agricultural output growth. Decompositions between quality and quantity changes are shown for each input category. The subperiods are measured from cyclical peak to peak in aggregate economic activity. Labor attributes include gender, age, educational attainment, and employment types. "Others" under the labor quality decomposition refers to the combination changes in workers' gender, age, and employment type. The contribution of an input aggregate to growth reflects changes in the quantity and quality (composition of specific components) of the aggregate.

Source: USDA, Economic Research Service. Agricultural Productivity in the U.S. data, updated January 2020.

Between 1948 and 2017, education contributed 0.10 percentage points to labor quality changes annually, more than 90 percent of the average contribution of labor quality to output growth. Nevertheless, education can have various contributions to labor quality and, thus, output growth in different periods. For example, labor quality had greater contributions to output growth in 1948–53, 1960–66, and 1966–69 than in other subperiods, at 0.23, 0.28, and 0.3 percentage points, respectively. Although education was the major contributor to labor quality in almost all subperiods in the post-World War II period, "other factors" contributed slightly more than education to labor quality changes during 1948–53. In that period, the percentage of male workers increased, and the reduction of young workers (groups of 14–15 and 16–17 years old) could have contributed to quality changes for the "other factors" category. However, over the 70 years, the percentage of male workers declined.
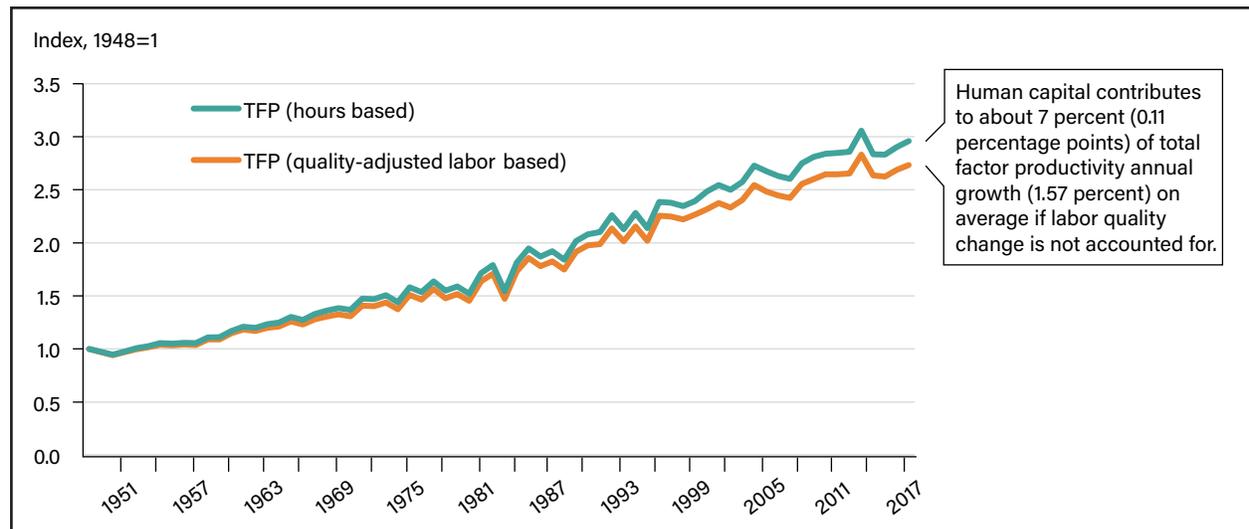
Increasing educational attainment continued to improve labor quality, peaking during the 1960s, contributing more than two-thirds of labor quality improvement and nearly 0.3 percentage points to annual output

growth rate, on average. The G.I. Bill [20] of 1944, which provided a range of benefits to veterans and granted stipends covering tuition and expenses for veterans attending college or trade schools, helped generate a considerable amount of human capital in the post-World War II period. Quality changes in the farm sector also match the growth of the percentage of people age 25 years and older who completed high school or college. Recently, while education still dominated other factors in improving labor quality, its effect declined since the 1970s as the growth of educational attainment slowed in the entire employment pool. In the coming years, slower growth in the educational attainment of farmworkers may reduce the effect of labor quality changes on future agricultural growth. Based on a study on the growth of 65 U.S. industries, Jorgenson et al. (2018) also suggested that "growing average educational attainment will gradually disappear as a source of U.S. economic growth."

Human capital versus total factor productivity

Researchers showed that adjusting the labor input for quality changes can reduce the contribution of TFP to economic growth (Jorgenson and Griliches, 1967; Bowlus and Robinson, 2012). Without accounting for quality changes, the estimated growth of labor input would be less, leading to lower aggregate input estimates, and more of the increase in total output would be attributed to changes in TFP. The authors constructed estimates of TFP using alternative labor estimates—quality-adjusted versus non-adjusted labor inputs—to illustrate the effect of labor quality adjustment on TFP estimates (figure 15). In 2017, the TFP estimate based on quality-adjusted labor input was 2.7 times its 1948 level. However, the TFP estimate would be about three times its 1948 level in 2017 based on the unadjusted labor input (total hours worked). Therefore, if the changes in human capital and the growth in TFP were not distinguished, the annual TFP growth rate would be 1.57 percent per year instead of 1.46 percent based on the quality-adjusted labor estimate. It implies that human capital accounted for about 8 percent of TFP growth if labor quality changes were not accounted for in the labor input and, thus, productivity measurement.

Figure 15
Total factor productivity estimates comparison using quality-adjusted labor versus unadjusted labor, 1948–2017

Index, 1948=1

TFP (hours based)

TFP (quality-adjusted labor based)

Human capital contributes to about 7 percent (0.11 percentage points) of total factor productivity annual growth (1.57 percent) on average if labor quality change is not accounted for.

TFP= total factor productivity
Source: USDA, Economic Research Service calculation based on U.S. Agriculture Productivity data, updated January 2020.

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[20] The G.I. Bill gave World War II veterans many options and benefits. Those who wished to continue their education in college or vocational school could do so tuition-free up to $500 while also receiving a cost-of-living stipend. From 1944 to 1949, nearly 9 million veterans received close to $4 billion from the Bill's unemployment compensation program. The education and training provisions existed until 1956, while the Veterans Administration offered insured loans until 1962. The Readjustment Benefits Act of 1966 extended these benefits to all veterans of the Armed Forces, including those who had served during peacetime (U.S. Department of Veterans Affairs, 2020).

Conclusion

Agricultural employment and total hours worked fell considerably in the last seven decades, while agricultural output nearly tripled during the same period. Along with contraction in labor quantity, the U.S. farm workforce experienced changes in demographic characteristics, especially educational attainment, and hence labor quality. After adjusting for labor quality changes, the decline in labor input led to a 11-fold increase in a quality-adjusted measure of labor productivity. The rise can be attributed to the increased use of other inputs as well as technical change—measured as total factor productivity.

Between 1948 and 2017, agricultural output grew at 1.53 percent annually, with the labor hours reduction contributing -0.57 percentage points per year, according to Economic Research Service estimates. The effects of the decline in labor hours were partially offset by increasing human capital (labor quality), at 0.11 percentage points per year, on average, mainly because of increasing educational attainment. The effects of human capital were especially crucial before 1970. Human capital accounted for about 10 percent to 25 percent of total output growth per year. While education still dominates other factors in improving labor quality, its effect declined since the 1970s as the trend growth of educational attainment slowed in the entire employment pool. In the coming years, slower growth in the educational attainment of farmworkers may reduce the effect of labor quality changes on future agricultural growth. The workforce is aging, immigration is slowing (Taylor et al., 2012), and domestic workers are showing less interest in working on farms. As a result, labor supply may be more challenging in years to come. Farm operators may need to intensify the use of other inputs to address labor shortages, such as increased mechanization. However, increases in some nonlabor inputs may come with negative environmental effects, such as increases in marginal lands or increases in agricultural chemicals. In the long run, continuously improving human capital in the workforce and promoting TFP growth through innovation are critical to maintaining sustainable agricultural growth.

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Appendix

Measurement of quality-adjusted labor input and total factor productivity

Labor measurement

Labor input is usually measured as labor force—counted by workers or hours worked. Jorgenson, Gollop, and Fraumeni (1987) (referred to as JGF in the remainder of the report) asserted that hours worked and labor force are heterogeneous. For example, experienced workers with an advanced education usually receive higher wages than less experienced and less educated workers. Therefore, JGF proposed that hours worked should be disaggregated by characteristics—including educational attainment, gender, employment type, and age—of individual workers to generate a constant quality index of labor input that accounts for substitution between different types of labor. Within this context, the estimated labor input is a constant quality index, and labor input growth can then be decomposed into quality change and quantity change components.

Following JGF's conceptual framework, the Economic Research Service constructed a quality-adjusted labor index that partitions the labor estimate into its quantity and quality components using a Törnqvist index number approach. The authors further decomposed labor quality changes into changes in education component and changes in other factors. A Törnqvist index is a discrete approximation of a continuous Divisia index. [21] Diewert (1978) indicated that the Törnqvist index procedure is "exact" for the translog production function in the sense that given a change in prices and an optimal response in quantities, the level of the index will change exactly as much as the change in production. Under the Törnqvist index framework, the changes in the aggregate prices (or quantities) for two subsequent time periods can be expressed as the weighted sum of changes in its individual components using their corresponding average cost shares or revenue shares from two periods as the weights. Because it is consistent with a flexible functional form for the underlying aggregator function, the Törnqvist index is also categorized as a "superlative index" (Diewert, 1978).

Quality-adjusted labor input

To develop a constant quality index of labor input (Jorgenson and Griliches, 1967), report authors first constructed "quality-adjusted" (with constant labor quality) Törnqvist indices of prices and quantities of hired labor, and self-employed and unpaid family labor using hours worked and corresponding cost shares [22] of 192 demographic labor groups. In the measurement, the value of total labor input equals the value of labor payments plus the imputed value of self-employed/unpaid family labor. The imputed wage rate is set equal to the mean wage of hired workers with the same demographic characteristics.

The authors assumed that labor input {L} can be expressed as a translog function of its individual components, {L$_l$}, and the change of the labor estimate can be expressed as

$$ln \frac{L_t}{L_{t-1}} = \sum \frac{1}{2}(v_{lt} + v_{lt-1})ln \frac{L_{lt}}{L_{lt-1}} \tag{1}$$

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[21] A Divisia index is an index number measure for continuous-time data on prices and quantities of individual commodities or inputs. It is the weighted sum of growth rates, where the weights are revenue/cost shares in the total value of the production of individual commodities or inputs (Hulten,1973).

[22] The labor cost for each demographic labor group is calculated as total hours worked multiplied by imputed wage rate per hour for that group. Cost-share for each demographic group is calculated as the labor cost divided by total compensation of all farmworkers in that year.

where *ln* indicates the natural logarithm function, $\frac{1}{2}(v_{lt} + v_{lt-1})$ is the average cost share of each labor group *l*—classified by their corresponding demographic characteristics—in two time periods *t* and *t-1*. L_{lt} is the quantity (hours worked) of the *l*th demographic group.

The matrices of employment, hours worked, and compensation per hour (for hired labor) are cross-classified by gender (male or female), age (eight groups), education (six categories; five categories before year 1980), and employment class (hired versus self-employed or unpaid workers; see table 1 for details). Therefore, there are 192 demographic groups (160 groups for the data before 1980 because of changes in the Census of Population survey regarding educational attainment) in constructing the Törnqvist indices of labor input. Under the Törnqvist index specification, these indexes reflect demographic changes in the composition of hours worked. For example, labor quality increases as components with higher compensation of labor input per hour grow more rapidly and fall otherwise. 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. This approach 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-efficiency units, which are adjusted for compositional shifts. Data on farm workers' compensation, hours worked, and employment are drawn from the decennial Census of Population, American Community Survey, Current Population Survey, and BEA National Income and Product Accounts.

Appendix table 1
Labor—demographical characteristics

Sex			
	(1) Male		
	(2) Female		
Age			
	(1) 14–15 years	(2) 16–17 years	(3) 18–24 years
	(4) 25–34 years	(6) 35–44 years	(6) 45–54 years
	(7) 55–64 years	(8) 65 years and older	
Education			
	(1) 1-8 years grade school	(2) 1-3 years high school	
	(3) 4 years high school	(4) 1-3 years college	
	(5) 4 years college	(6) more than 4 years college	
Employment class			
	(1) Wage/salary worker		
	(2)Self-employed and unpaid family worker		

Note: This table presents the demographical characteristics used in adjusting for labor quality.

Source: USDA, Economic Research Service estimates based on U.S. Department of Commerce, U.S. Bureau of the Census' Census of Population and American Community Survey micro data.

Labor index decomposition: quantity versus quality

JGF show that equation (1) can be rewritten in a more general form as:

$$\Delta ln L_t^G = \sum_{esca} \bar{v} \, \Delta ln H_{esca,t} \tag{2}$$

where L^G is the quality-adjusted labor input index; t is the time subscript; the e, s, c, a subscripts denote educational attainment, sex, class of workers, and age, respectively; $\bar{v}$ denotes $\frac{1}{2}(v_{lt} + v_{lt-1})$ and H denotes the hours worked of each demographic group. The index of labor quality for the entire labor force $(Q_{L,t}^G)$ can be defined as a quality-adjusted labor input (L_t^G) divided by total hours worked (H_t) :

$$Q_{L,t}^G = \frac{L_t^G}{H_t} \tag{3}$$

Representing those estimates in the form of natural log, then the change in the quality-adjusted labor input can be decomposed into the quality change and hours (quantity) change components as follows:

$$\Delta ln L_t^G = \Delta ln Q_{L,t}^G + \Delta ln H_t \tag{4}$$

Labor quality decomposition: education component versus other factors

The changes of a partial index[23] of labor input corresponding to education (education partial index, thereafter) can be expressed as

$$\Delta ln L^e = \sum_e \bar{v}_e \, \Delta ln H_e = \sum_e \bar{v}_e \, \Delta ln \left(\sum_a \sum_s \sum_c H_{saec} \right) \tag{5}$$

where ve is the cost share of the labor force within the same educational attainment group e and $\bar{v}_e$ is the average cost shares from two subsequent time periods, which can be written as:

$$\bar{v}_e = \frac{1}{2} \left[v_{e,t} + v_{e,t-1} \right] \tag{6}$$

$$v_{e,t} = \sum_a \sum_s \sum_c v_{saec,t} \tag{7}$$

The change in education's contribution to labor quality, $\Delta ln Q_e$, is the difference between the growth rates of the education partial index and the hours worked, or

$$\Delta ln Q^e = \Delta ln L^e - \Delta ln H \tag{8}$$

The overall labor quality changes can also be represented as the sum of the changes of all four first-order partial indexes—education (Q^e), sex (Q^s), age (Q^a), and class of work (Q^c)—all six second-order indexes—Q^{es}, Q^{ea}, Q^{ec}, Q^{sa}, Q^{sc}, and Q^{ac}—all three third-order indexes—Q^{esa}, Q^{esc}, and Q^{eac}—and one fourth-order index—Q^{esac}. The partial index of education captures substitution among five education groups. Substitutions among age groups, gender groups, class of employment groups, and other interactive effects are "other factors." Because the focus is to identify the contribution of the overall educational attainment changes

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[23]JGF refer to the partial index as a "first-order index."

embodied in the farm labor force to labor quality changes, labor quality changes are decomposed into educational changes (ΔlnQ^e) and the changes from other factors (ΔlnQ^o) as shown in the following equation:

$$\Delta lnQ^G = \Delta lnQ^e + \Delta lnQ^o \tag{9}$$

Total factor productivity measurement and sources of output growth

Total factor productivity (TFP) measures changes in the efficiency with which all inputs are transformed into outputs. The definition of an aggregate output model is based on the translog aggregate production possibility frontier, which relates growth rates of multiple outputs to the cost-share of the weighted growth rates of labor, capital (including land), and intermediate goods. The rates of TFP growth are constructed using Törnqvist index number approach. TFP growth over two time periods is measured as:

$$ln\left[\frac{TFP_t}{TFP_{t-1}}\right] = \Sigma\left[\frac{R_{it}+R_{i,t-1}}{2}\right]ln\left[\frac{Y_{i,t}}{Y_{i,t-1}}\right] - \Sigma\left[\frac{W_{jt}+W_{j,t-1}}{2}\right]ln\left[\frac{X_{j,t}}{X_{j,t-1}}\right] \tag{10}$$

where Y_i are individual outputs, X_J are individual inputs, R_i are output revenue shares, W_J are input cost shares, and t and $t-1$ are time subscripts.

Let Y denote aggregate output. The rate of aggregate output growth is the revenue share weighted growth rates of individual output:

$$ln\left[\frac{Y_t}{Y_{t-1}}\right] = \Sigma\left[\frac{R_{i,t}+R_{i,t-1}}{2}\right]ln\left[\frac{Y_{i,t}}{Y_{i,t-1}}\right] \tag{11}$$

Output growth, lnY_t/Y_{t-1}, is decomposed into its sources of growth—labor, capital, intermediate goods, and TFP—by rearranging equation (10):

$$ln\left[\frac{Y_t}{Y_{t-1}}\right] = \Sigma\left[\frac{W_{j,t}+W_{j,t-1}}{2}\right]ln\left[\frac{X_{j,t}}{X_{j,t-1}}\right] + ln\left[\frac{TFP_t}{TFP_{t-1}}\right] \tag{12}$$

When labor input can be partitioned into its quantity and quality components, or moreover education and other factors (equations 1–9), the authors further calculated contributions of labor quantity and labor quality (education as well) to output growth using equation 12.

TFP growth is usually treated as a synonym of technology advancement. TFP growth estimate was also termed "Solow's residual" under the growth accounting framework (Solow, 1957), as it captures the part of output growth that cannot be explained by total input growth. According to equation (4), the change in the quality-adjusted labor input is the sum of labor quality change and total hours (labor quantity) changes. The increase in labor quality results in a higher amount of quality-adjusted labor input. If the authors do not account for labor quality changes in the labor measurement, TFP growth estimates can be overstated as part of the TFP growth rates are from labor quality changes instead of technical changes. It is also the main reason that researchers tend to relate productivity growth to human capital changes using parametric/frontier analyses when labor quality is not accounted for in the labor measurement. To show how TFP estimates can vary in response to alternative labor measures, the authors constructed two TFP series based on two labor estimates—quality-adjusted labor input versus total hours worked—in this report for comparison. The difference between these two estimates is the contribution of labor quality changes to output growth when labor quality is not accounted for in the labor measurement.