CHAPTER 2

A Brief History of U.S. Agriculture

Almost 150 years have passed since U.S. public-sector agricultural research and development (R&D) began in earnest with the establishment of the U.S. Department of Agriculture and the passage of the Morrill Land Grant College Act in 1862, to be followed 25 years later by the passage of the Hatch Experiment Station Act in 1887. During that time, and especially in the more recent decades, U.S. agriculture changed dramatically. Public and private agricultural R&D played a major role in bringing about those changes, and the R&D systems and institutions evolved alongside and as part of agriculture.

To provide some context for our econometric assessment of the impacts of agricultural R&D, which is presented in later chapters, this chapter provides an overview of some important structural changes in the role of agriculture in the economy, in the spatial location of production within the United States, and in the number of farms and their size distribution. The following chapters in Part II describe some of the more pertinent developments regarding agricultural inputs, outputs and productivity in the United States.

In this part of the book in particular we take a long-run perspective, emphasizing developments since the beginning of the 20th Century.[1] In later parts of the book, while the analysis focuses on agriculture during the period since World War II, we emphasize the point that the long R&D lags mean that the postwar changes in U.S. agriculture were much influenced by agricultural R&D and related policies during the first half of the 20th Century.

2.1 Trends in Agricultural Output

Over the past 150 years, the share of U.S. gross domestic product (GDP) accounted for by farm value-added declined significantly—from 37.5 percent of

1 See Cochrane (1958 and 1993), Olmstead and Rhode (2000 and 2006), Gardner (2002) and Dimitri, Effland and Conklin (2005) for additional details on these developments.

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GDP in 1869 to 0.8 percent of GDP in 2006 (Figure 2-1, Panel a). This decline in the farm share of GDP was not the result of a shrinking farm sector. Indeed, farm value-added increased rapidly over the period but the U.S. economy expanded even more rapidly. Over the period 1929–2006, U.S. farm value-added grew nearly six fold, from $17 billion to $98 billion (2000 prices), while U.S. GDP increased thirteen fold, from $866 billion to $11.3 trillion. As agriculture declined as a share of the economy and became increasingly more productive, substantial labor was released from the sector, helping to fuel growth elsewhere in the economy.

Data on the share of national income by sector are available since 1929 and summarized in Figure 2-1, Panel b. The graph shows that the share of national income attributable to agriculture (here, including forestry and fisheries) held steady through to the end of the World War II, averaging about 9 percent over the period 1929–1948, but since then it declined to around 0.8 percent of national income during the period 2000–2007. Agriculture now represents a much smaller share of the industrial sector which itself shrank as a share of the economy. During the period from the 1930s through to the mid-1950s, the share of national income generated by industry increased generally (although with a temporary dip after the cessation of war in 1945) to a peak of 48 percent in 1953. Since then, the share of national income generated by industry declined to around 23 percent in 2007, while the share generated by the service sector increased inexorably, up to almost two-thirds of national income by 2007.

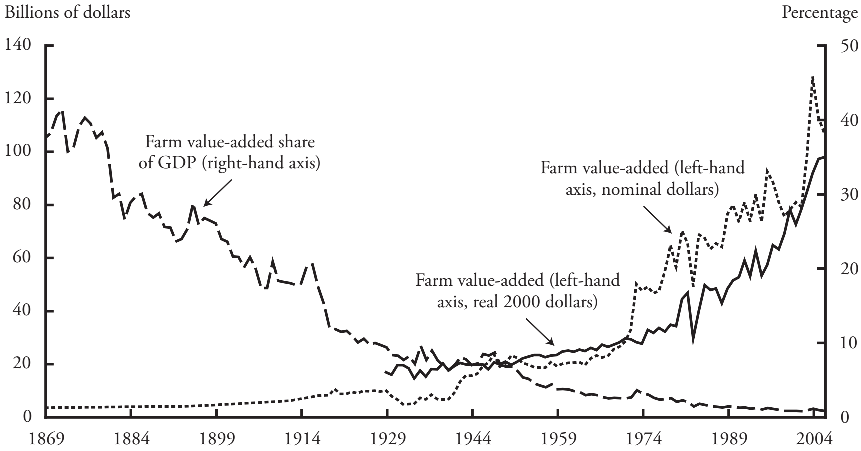
Geography of U.S. Production

During the second half of the 20th Century, U.S. agricultural production shifted generally south and west and became much more spatially concentrated (Figure 2-2). In the mid-1920s, Texas and Iowa were the largest states in terms of agricultural production (with an average of 6.9 and 6.7 percent of the 1924–1926 value of U.S. production, respectively). The Central region produced around one-third of the entire U.S. agricultural output at this time. This region includes Iowa and Illinois, then the third-largest producer with a state share of 5.5 percent, along with the rest of the generally fertile, well-watered heartland of the United States. California was the fourth-ranked state in the mid-1920s, producing 5.4 percent of national production. The Northeast region produced 11.2 percent of U.S. agricultural output at that time.

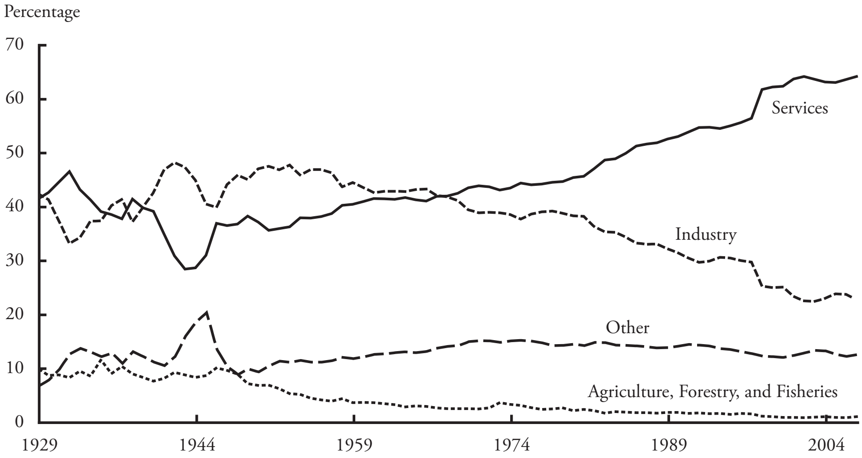
While the value of agricultural output grew overall, regional and state shares had not changed much by the middle of the 20th Century. Thereafter agriculture was on the move. Changes in domestic and export demand as well as changes in off-farm technology contributed to changes in the composition of demand for U.S. agricultural output, which in turn contributed to the changes in the

Figure 2-1 U.S. Output Trends

Panel a. Farm value-added and share of GDP, 1869–2006



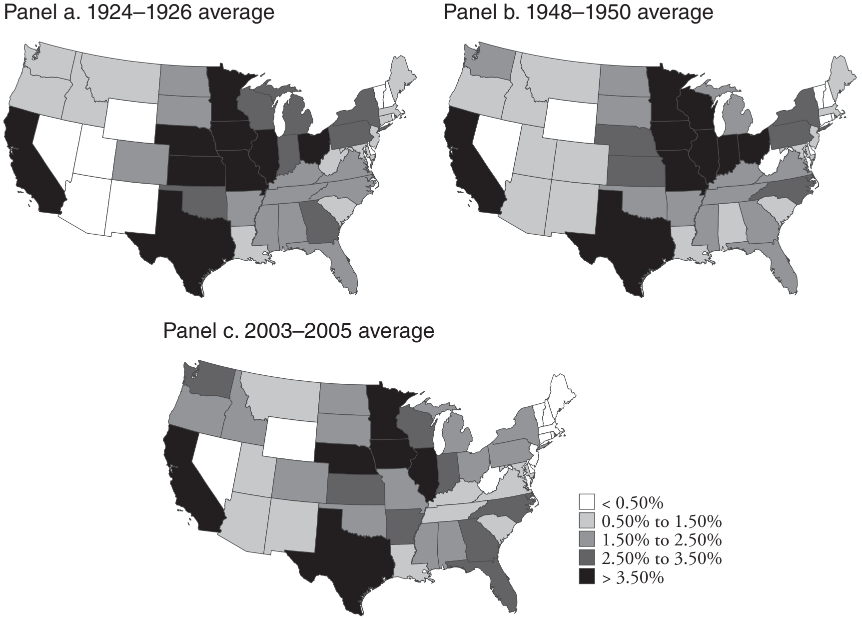
Panel b. National income share by sector, 1929–2007



Sources: Panel a. Data on farm value-added for 1869–1928 are from U.S. Bureau of the Census (1975, series F-127); 1929–2006 are from BEA (2007a, NIPA Table 1.3.5). Nominal GDP for 1869–2002 data are from Sutch (2006); values for 2003–2006 are from BEA (2007a, NIPA Table 1.3.5). Real series expressed in 2000 prices using "Price Indexes for Gross Value Added by Sector (series: Farm Business)" taken from BEA (2007a, NIPA Table 1.3.4). Panel b. Data were taken from national income disaggregates in the National Income and Product Accounts (NIPA) compiled by the BEA (2008b).

Notes: Panel a. Farm value-added for 1869–1928 was estimated by applying the annual rate of change in series F-127 to the 1929 value for gross farm business value added from BEA (2007a, NIPA Table 1.3.5). Panel b. While measures such as Gross Domestic Product represent the value of what is produced, national income measures denote the net incomes resulting from that production (net of the consumption of fixed capital). In theory, these measures should be equivalent, but in practice, however, they vary to some degree. See Gutierrez et al. (2007) and BEA (2008a).

Figure 2-2 Shares of the Value of Agricultural Production Among States



Sources: Compiled by authors from data in InSTePP data files along with USDA (various years) *Agricultural Statistics*, USDA ERS (2007), U.S. Bureau of the Census (1956-1991), USDA NASS (2000-2009) and Johnson (1990).

Notes: The value of production dataset covers 194 commodities for the period 1924–2005. For 73 commodities we used price and quantity data from the cited USDA sources. Most of the quantity data are reported quantities produced per state, and the price data are state-specific prices received on farms. For 139 commodities that are almost wholly sold off farm, we used cash receipts (i.e., sales) data to represent value of production, where the implied price data represent farm-gate or first-point-of-sale measures and the implied quantity data are marketings. Data for the greenhouse nursery and marketing category constitute cash receipts for the period 1924–1948, and for 2005. For all other years, InSTePP data assembled from multiple other USDA sources were used.

composition and location of production.[2] The shifting geography of population (as well as a substantial migration off farms)—combined with improved infrastructure for communication, electrification, transportation, and logistics, which meant that perishables and pre-prepared foods could be moved efficiently over much longer distances—also contributed to this changing spatial pattern of production in the second half of the 20th Century. Substantial on- and off-farm technological innovation underpinned much of these changes.

The regional shifts were substantial. The Central region lost some ground (averaging 27.0 percent of the total value of output in the 2003–2005 period

2 Changes in diets and food consumption habits from increasing per capita incomes and an increasing share of women working outside the home explain some of the changes in the composition of demand for food and fiber commodities, especially during the latter half of the 20th Century (e.g., Senauer, Asp and Kinsey 1991).

compared with 32.4 percent in 1924–1926), while the Northeast region's share of national agricultural output fell markedly from 11.2 percent in 1924–1926 to 6.2 percent in 2003–2005. The big increase was in the Pacific region, whose share more than doubled over the almost 80 years since 1924–1926 to average 18.3 percent of U.S. agricultural output in 2003–2005.

Part of the shift south and west in the value of production was a quantity effect, but part was a move to a larger share of higher-valued output nationally, combined with a massive increase in the share of that higher-valued output being produced in the Pacific region. In the mid 1920s, the Pacific region produced 29 percent of the country's specialty crops (including fruits, vegetables and ornamental crops); by the beginning of the 21st Century that share had grown to more than 50 percent (Table 2-1).[3] Over the almost 80-year period from the mid-1920s to the early 2000s, for all the output categories in Table 2-1, the share of national output from the Northeast region declined, and by 2003–2005 this region produced just 6.2 percent of the total U.S. value of agricultural production. The Central region captured a much larger share of U.S. output of "other crops" (including field crops such as corn, soybeans, and wheat), up from 24.3 percent in the mid 1920s to almost 44 percent by 2003–2005, such that "other crops" accounted for nearly 55 percent of the region's total agricultural output. Livestock production moved heavily out of the Central and Northeast regions to become increasingly concentrated in the Southern Plains and Southeast.

Input versus Output Trends

The long-run aggregate output and input indexes plotted in Figure 2-3 show a remarkable pattern. Over the period 1912–2002, the aggregate quantity of U.S. agricultural output increased by a factor of 4.95 (equivalent to an annual rate of growth of 1.73 percent) whereas aggregate input use grew only 1.11 fold (or 0.14 percent per year). Clearly, output was growing faster than inputs and productivity was growing throughout the entire 90 year period, though not necessarily at a constant rate.

The comparative patterns of input and output growth varied between the first and second halves of the 20th Century. While output grew at similar rates during both halves of the century (1.61 percent per year for 1912–1948 and 1.81 for 1949–2002) the growth rate in input use contracted (from 0.47 percent per year for 1912–1948 to -0.08 percent per year for 1949–2002). In other words, the relationship between measured growth in aggregate inputs and measured growth in aggregate outputs changed, implying a faster rate of measured productivity growth in the second half of the century.

3 In 2003–2005 specialty crops also constituted almost two-thirds of the total value of agricultural production of the Pacific region.

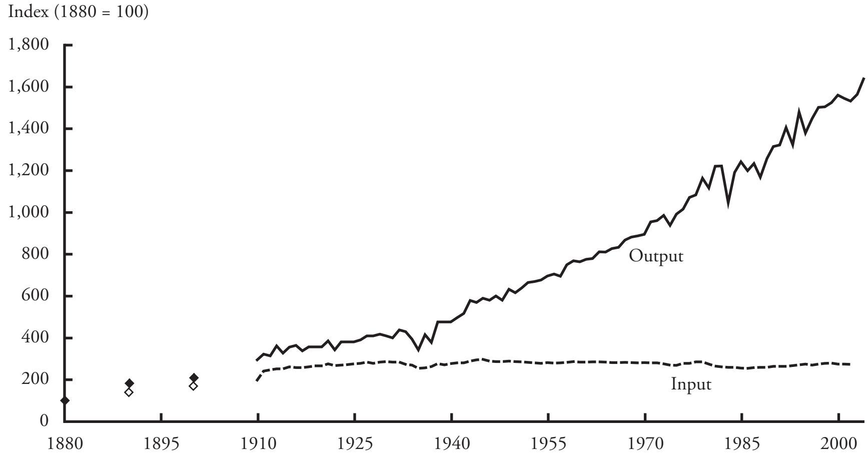
Table 2-1 Regional Production Shares: Three-Year Averages Centered on 1925, 1949, and 2004

	Regional Shares of National Commodity Group Production Value				Commodity Group Shares of Region Production Value		
	Total	Specialty Crops	Other Crops	Livestock	Specialty Crops	Other Crops	Livestock
United States				*percentage*			
1924–1926	100.0	100.0	100.0	100.0	12.8	44.3	42.9
1948–1950	100.0	100.0	100.0	100.0	11.9	40.3	47.8
2003–2005	100.0	100.0	100.0	100.0	22.3	31.5	46.1
Pacific							
1924–1926	7.8	28.8	2.9	6.7	47.0	16.3	36.7
1948–1950	9.8	36.1	5.7	6.8	43.8	23.4	32.8
2003–2005	18.3	51.8	6.7	10.0	63.3	11.6	25.1
Mountain							
1924–1926	5.6	5.5	4.5	6.8	12.5	35.3	52.2
1948–1950	6.2	7.9	5.7	6.2	15.1	36.8	48.1
2003–2005	7.8	6.4	5.8	10.0	18.2	23.1	58.7
Northern Plains							
1924–1926	12.1	1.3	12.5	15.0	1.4	45.7	52.9
1948–1950	10.7	1.7	14.0	10.2	1.9	52.8	45.3
2003–2005	11.4	1.2	18.4	11.5	2.4	50.9	46.7
Southern Plains							
1924–1926	14.8	6.4	25.2	6.6	5.5	75.4	19.1
1948–1950	13.2	6.0	18.6	10.4	5.4	56.8	37.8
2003–2005	14.0	5.3	13.3	18.6	8.5	30.0	61.4
Central							
1924–1926	32.4	18.3	24.3	45.1	7.2	33.2	59.6
1948–1950	35.8	14.4	34.6	42.2	4.8	38.9	56.3
2003–2005	27.0	8.8	43.7	24.3	7.3	51.1	41.6
Southeast							
1924–1926	15.9	16.1	25.0	6.5	12.9	69.6	17.5
1948–1950	14.4	15.5	18.2	11.0	12.8	50.8	36.3
2003–2005	15.4	18.0	9.8	17.9	26.2	20.1	53.7
Northeast							
1924–1926	11.2	23.7	5.7	13.3	27.0	22.3	50.7
1948–1950	9.9	18.5	3.3	13.3	22.4	13.3	64.3
2003–2005	6.2	8.5	2.3	7.7	30.8	11.5	57.7

Sources: See Figure 2-2.

Several factors could account for these patterns. First, different indexing procedures were used for the two sub-periods, 1912–1948 and 1949–2002. These differences, in conjunction with differences in the nature of the data being indexed, may have resulted in false findings of differences in the relative rates of growth of aggregate output and input between the two periods. Second, unmeasured changes in the quantity and composition of the inputs (and out-

Figure 2-3 Aggregate Agricultural Output and Input Quantity Trends, 1880–2004



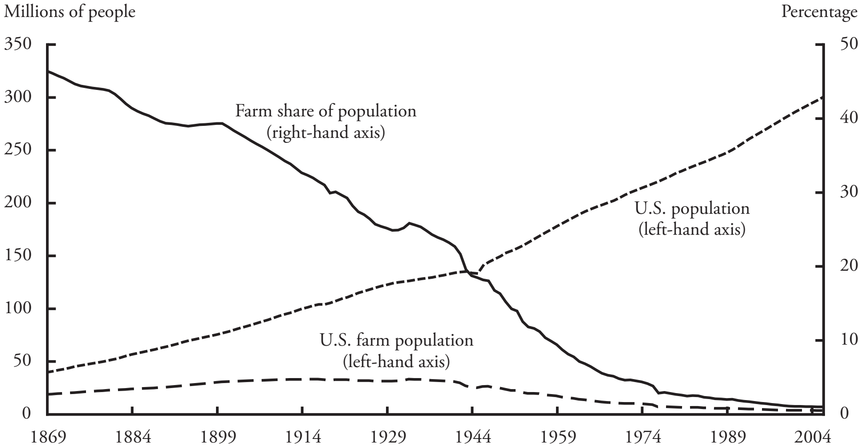
Sources: Indexes of the quantity of output and input are from USDA ERS (1984) for 1880–1938; from USDA ERS (1986) for 1939–1948; and from InSTePP for 1949–2004 (for output), 1949–2002 (for input).

Notes: Additional details concerning the 1880–1949 data can be found in Olmstead and Rhode (2006, series Da 1117 for outputs and Da 1118 for inputs). The InSTePP Fisher indexes of inputs and outputs for 1949–2002 were backcast using the annual growth in the corresponding Laspeyres index for the period 1880–1949 from the aforementioned USDA publications.

puts) between the two periods might be a source of some differences.[4] Chapters 3 and 4 in Part II address the use of indexing procedures to correct for index number problems and changes in composition and quality of input and output aggregates. A third possibility is that actual as well as measured productivity growth accelerated in the second half of the 20th Century as a result of research investments in earlier years or other factors. Chapter 5 explores this aspect using data corrected to address some of the potential input and output measurement pitfalls.

4 The pre-1949 aggregates were formed using a fixed-weight (Laspeyres) indexing procedure, whereas the measures for 1949 and later were formed using chain-linked Fisher indexes. If the relative prices of the components of the aggregates changed markedly over time and the components grew at different rates, then the use of fixed- versus variable-weight aggregation procedures would have measurable consequences for the quantity aggregates so formed (see, for example, Star 1974). Changes in the relationship between inputs and outputs may reflect either changes in the technical relationship between inputs and outputs (attributable to R&D and other influences) or economies of scale or scope effects attributable to gains from specialization as the structure of farms changed over time (for example, the shift to larger farms with, generally, less heterogeneous production processes and output mixes).

Figure 2-4 U.S. Population Trends, 1869–2006



Sources: General population data for 1869–1999 are from Haines and Sutch (2006, series Aa7); values for 2000–2006 are from U.S. Bureau of the Census (2007). Farm population data for 1860–1970 are from U.S. Bureau of the Census (1975, series K-1) and Wells (1937); 1971–1991 data are from Olmstead and Rhode (2006, series Da 1).

Notes: Farm population intercensal values from 1869 through 1889 are a linear interpolation and extension of values from series K-1 and those presented by Wells (1937); 1992–1999 were derived using a linear interpolation of the 1991 and 2000 values. Values for 2000–2006 were derived assuming that population per farm remained constant over that period.

2.2 Farms and Farmers

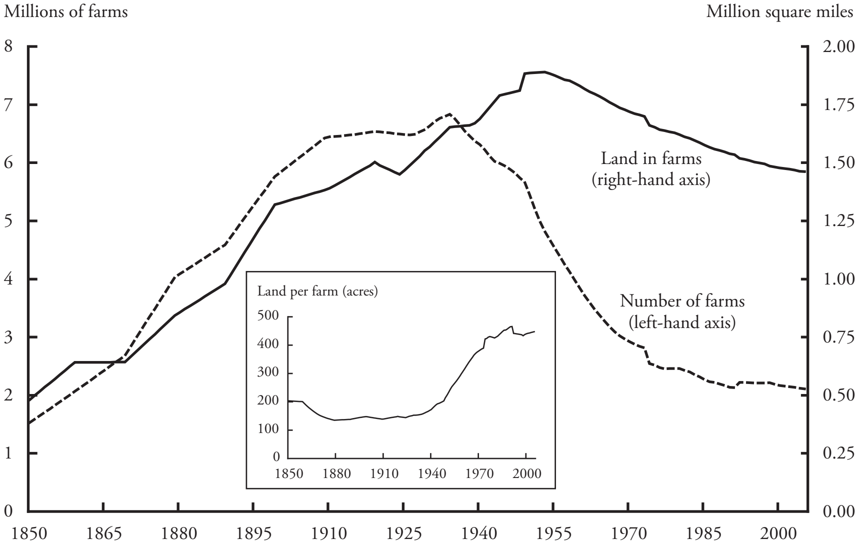
The structure of agriculture changed markedly, along with the amount, composition and spatial location of production. In 1869, the U.S. farm population constituted 46.3 percent (18 million people) of the total U.S. population of 38.9 million. The farm population increased at an average annual rate of 1.26 percent to 32.5 million people in 1916; 31.9 percent of the total population of 102.0 million in 1916. Thereafter, the U.S. population continued growing while the farm population steadily declined to 2.9 million in 2006; just 1.0 percent of the total population of 299.4 million (Figure 2-4).

Average farm size changed markedly over time as well.[5] The number of acres per farm, calculated as the total land area in U.S. farms divided by the number of farms, is one indicator of farm size.[6] The 1.4 million U.S. farms in 1850 averaged

5 The statistical notion of a farm has changed over time. For example, the 1890 Census of Agriculture definition used both acreage and sales criteria (at least 3 acres or annual agricultural sales of at least $500) while the censuses beginning in 1974 required only that agricultural product sales be at least $1,000. See Olmstead and Rhode (2006, pp. 4.41) for other examples.

6 As discussed by Sumner (1985 and 1986), for example, acres per farm can be a useful measure of size for comparing similar types of mid-western cropping farms, but other measures of farm size, such as value of sales, herd size, or number of employees may be more appropriate for comparing

Figure 2-5 U.S. Farm Acres, Farm Numbers and Average Farm Size, 1850–2006



Sources: Number of farms (1910–1999) and Land in farms (1911–1999) are from Olmstead and Rhode (2006, series Da 4 and Da 5, respectively). For both variables, values for 2000–2006 are from USDA ERS (2007); 1900 and 1890 values for farm numbers are from the U.S. Bureau of the Census (1975, series K-4 and K-5); 1910, 1900, and 1890 values for land in farms are from series K-5 of the same resource.

Notes: For farm numbers, intercensal values were estimated using a linear interpolation wherever no value was provided.

203 acres per farm (Figure 2-5, Inset).[7] For about the next 85 years, the number of farms increased (roughly in line with the growth in the farm population) to 6.8 million in 1935, while the area in farms also expanded with new settlement, such that average farm size crept up to 162.1 acres per farm in 1938 (Figure 2-5, Inset). Thereafter, and again in parallel with farm population trends, the number of farms in the United States declined at a rapid rate (by 2.33 percent per year) through to 1980 and thereafter at the much slower rate of 0.60 percent per year (through to 2006).[8] The obverse of these trends in total farm area and

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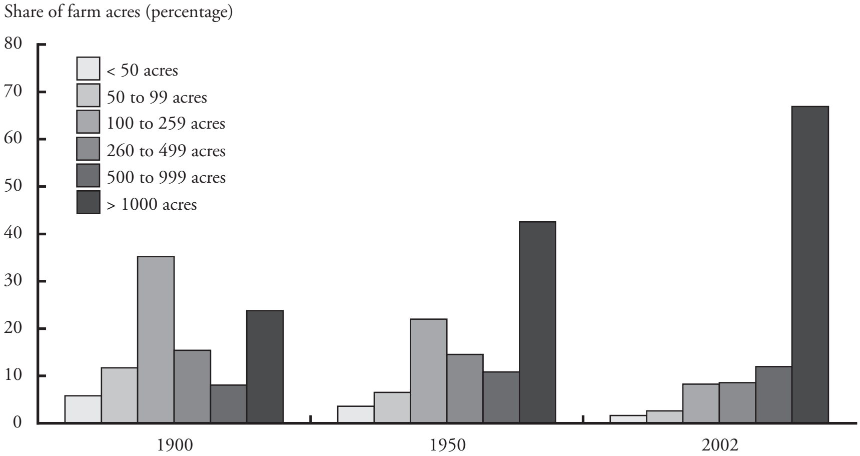
among specialty crops producers, among intensive livestock producers, or across different types of farms.

7 According to USDA (2004, p. 1) "Land in farms is all land operated by farms and ranches during the year. It includes crop and livestock acreage, wasteland, woodland, pasture, land in summer fallow, idle cropland, and land enrolled in the Conservation Reserve Program (CRP), Wetland Reserve Program (WRP), and other set aside or commodity acreage programs. It excludes public, industrial and grazing association land and nonagricultural land."

8 Hoppe and Korb (2006, p. i) noted that " . . . the rate at which U.S. farms go out of business, or exit farming, is about 9 or 10 percent per year, comparable to exit rates for nonfarm small businesses in the United States. The relatively stable farm count since the 1970s reflects exits and entries essentially in balance. The probability of exit is higher for recent entrants than for older, more established farms. Farms operated by Blacks are more likely to exit than those operated by

Figure 2-6 Distribution of Total U.S. Farm Acreage by Farm Size, 1900–2002



Sources: Authors' calculations based on Olmstead and Rhode (2006, Table Da 597-611) for the period 1900–1950; USDA (2004, Table 55) for 2002.

farm numbers is that average farm size grew rapidly from 162.1 acres per farm in 1938 to 464.2 acres per farm in 1992. Since then average farm size shrank a little, down to 431.8 acres per farm by 1999, and then inched up again to 446.1 acres per farm by 2006.

Other aspects of the distribution of farm size changed along with the average (Figure 2-6). In 1900, 17.5 percent of U.S. farm acreage was in holdings less than 100 acres; by 2002, just 4.3 percent. At the other end of the spectrum, the share of acreage in large farms (i.e., farms of 1,000 acres or more) grew from just under 24 percent of the total in 1900 to nearly 67 percent of the total in 2002. The comparative stability of average acres per farm in recent years masks a good deal of continuing structural change, including some further concentration of agricultural land in larger operations. Key and Roberts (2007) report that the number of farms with more than 1,000 acres increased by 14 percent between 1982 and 2002, while the number with 50 to 1,000 acres declined by about 17 percent, and the number with fewer than 50 acres increased by about 17 percent.

Some writers have attributed the consolidation of farms into larger units mostly, if not entirely, to the adoption of new technology, particularly embodied in machinery that directly reduced labor requirements and involved economies

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Whites, but the gap between Black and White exit probabilities has declined substantially since the 1980s. Exit probabilities differ by specialization, with beef farms less likely to exit than cash grain or hog farms."

of size.[9] Such innovations imply a less labor-intensive and larger minimum efficient scale in farming operations. But rising nonfarm wages, drawing labor away from agriculture, played a role in stimulating the development and adoption of these innovations.[10] The relative importance of on-farm technology, pushing labor off the farm, versus off-farm technology, pulling it, remains a matter for conjecture, but clearly both forces were at work along with other economy-wide changes.

Notwithstanding the growth in the share of U.S. agricultural output produced on "nonfamily" (sometimes described as "industrial" or "corporate") farms, family operated farms continue to account for the bulk of U.S. agricultural production; around 86 percent in 2003 (MacDonald, Hoppe and Banker 2006).[11] Most striking, however, has been the rapid growth in agricultural output coming from very large family operations with sales of at least $500,000 per farm per year (in 2003 prices). They accounted for 45 percent of U.S. agricultural output in 2003, up from 32 percent in 1989 (Figure 2-7, Panel a). Correspondingly, the share of production coming from smaller family farms ($10,000 to $250,000 per farm per year in sales) fell from 40 to 26 percent.

Over recent decades the distribution of farm numbers stratified by farms of differing sales classes has changed markedly. The number of very large family farms (sales greater than $500,000 per year) grew from 39,000 in 1989 to 66,700 in 2003; the number of farms with sales between $250,000 and $500,000 per year totaled 85,300 in 2003. Collectively, the 152,000 farm operations with sales in excess of $250,000 per year represented just 7 percent of all commercial farms in the United States in 2003 but accounted for 70 percent of the value of farm sales (Jones, El-Osta and Green 2006).[12] The 1.77 million farms—85 percent of total farms—with sales of less than $100,000 per year accounted for only 12.9 percent of U.S. farm sales. Jones, El-Osta and Green (2006) also report that operators of these small farms derived almost all of their household income from

9 In contrast, Kislev and Peterson (1982, p. 578) found that they could explain "…virtually all of the growth in the machine-labor ratio and in farm size [in the United States] over the 1930–1970 period by changes in relative factor prices without reference to 'technological change' or 'economies of scale'."

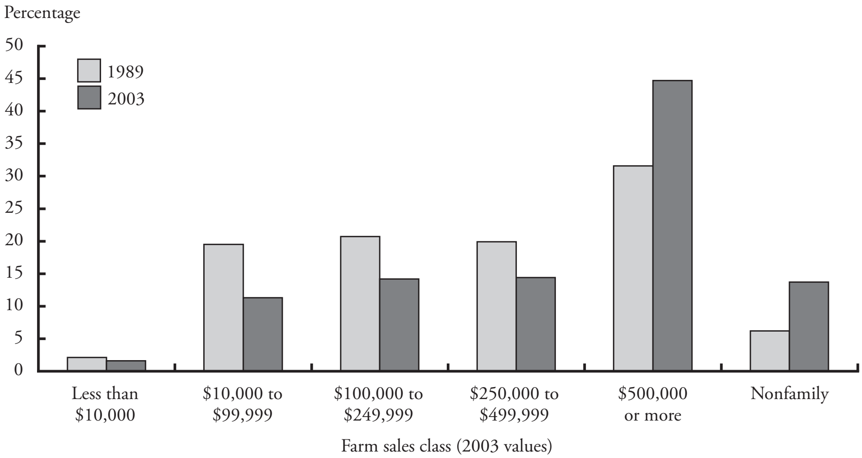
10 Hayami and Ruttan (1970 and 1971) were the first to extensively examine the factor-biased direction of technical change in U.S. agriculture induced by changes in relative factor prices.

11 The USDA Economic Research Service has developed a typology for different categories of farms, as described in Hoppe (2001), including various kinds of non-commercial farms, and several different sizes of family farms, as well as "nonfamily farms," which are farms organized as nonfamily corporations or cooperatives, as well as farms operated by hired managers. See, also, Hoppe et al. (2007).

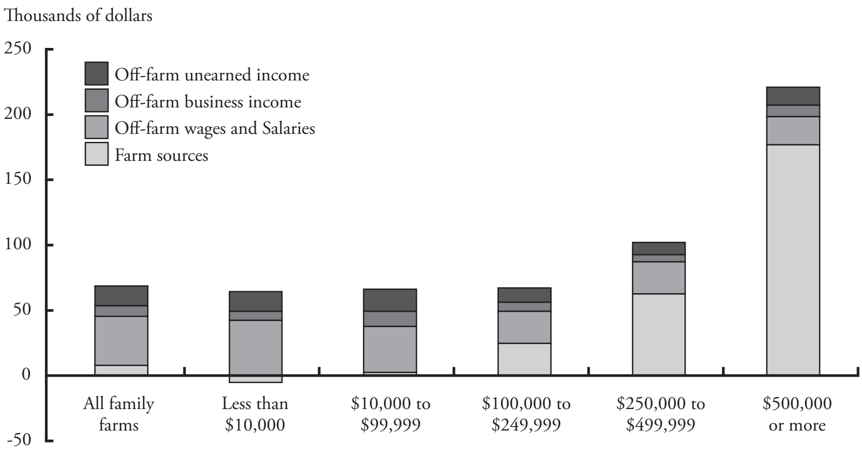
12 The concentration of production in very large farms (farms with sales greater than $500,000 per year) spans all agricultural sectors. MacDonald, Hoppe and Banker (2006) report that in 2003, these types of farms accounted for 61 percent of U.S. hog production and 75 percent of poultry and egg production, and also produced rapidly growing shares of cash grains, soybeans, tobacco, cotton and peanut production.

Figure 2-7 Distribution of Agricultural Production and Household Income Sources by Farm Size

Panel a. Share of agricultural value of production by sales class of farms, 1989 and 2003



Panel b. Agricultural household income by sales class of farm, 2003



Sources: Panel a. MacDonald, Hoppe and Banker (2006, Figure 1). Panel b. Reconstruction of Jones, El-Osta and Green (2006, Figure 2) based on extraction from USDA ERS (2008a).

off-farm work and from unearned income such as social security, pensions and investments (Figure 2-7, Panel b). Meanwhile, those households operating farms with sales in excess of $250,000 per year derived 74 percent of their household incomes from farm sources in 2003.

2.3 Conclusion

In spite of the evident, seismic shifts in the structure of American agriculture, some elements are little changed. The agricultural production sector is still composed of comparatively small, mainly family-owned and -operated farming units. Natural inputs such as rainfall, sunlight, and temperature are still paramount. As a consequence, the vagaries of weather and site-specific differences in climate, topography, soil and other agroecological attributes still shape crop and livestock production choices. In turn, variations in these natural factors influence the management and technological options designed to deal with them.

Variable production conditions confer advantages on a decentralized (perhaps family) form of farm management (Olmstead and Rhode 2000, p. 740). Sectors of agriculture where capital and other knowhow have substituted for, or ameliorated the effects of, these natural variations (such as confinement poultry and pork production) have muted but by no means eliminated the need for on-the-spot management protocols. They have also meant these natural elements have less impact on choices regarding the location of production, with consequences for the scale and concentration (and perhaps ownership) of the means of production.[13]

These enduring natural elements are influenced by, or have influences on, the nature and pace of the technical changes designed to affect agricultural production, as well as production choices more generally. Changes in inputs, outputs, and productivity are reviewed in the next three chapters with some additional attention given to the locational aspects of these production indicators.

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13 Key and McBride (2007, p. i) noted that "During the past 15 years… the number of farms with hogs has declined by over 70 percent, as hog enterprises have grown larger. Large operations that specialize in a single phase of production have replaced farrow-to-finish operations that performed all phases of production. The use of production contracts has increased. Operations producing under contract are larger than independent operations and are more likely to specialize in a single phase of production. These structural changes have coincided with substantial gains in efficiency for hog farms and lower production costs. Most of these productivity gains are attributable to increases in the scale of production and technological innovation. Productivity gains likely contributed to a 30-percent reduction in the price of hogs at the farm gate." MacDonald (2008) documents parallel developments in the U.S. broiler industry.

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