Journal of Economic Perspectives—Volume 28, Number 1—Winter 2014—Pages 147–166

American Farms Keep Growing: Size, Productivity, and Policy

Daniel A. Sumner

According to the official US government definition, about two million farms operate in the United States, a total that has changed little for more than three decades. However, the US government defines a "farm" as an operation that produced or normally would produce at least $1,000 in gross value of output per year (O'Donoghue, Hoppe, Banker, and Korb 2009). The tiny threshold of $1,000 in sales represents an agricultural output of less than two acres of corn, less than one-half of a milk cow, and less than half of one litter from one mother sow. This inclusive threshold has public relations and political rationales. Farm lobby groups, political officials at the US Department of Agriculture, and elected representatives laud the efforts of "two million American farms" to feed the world or support the rural economy.

In fact, most of these "farms" contribute approximately nothing or less than nothing to these objectives. About 600,000 farms, about 30 percent of the two million, have any significant farm production, and about 120,000 farms, or 6 percent of the total, produce three-quarters of all US farm output. Using the $1,000 threshold to define a farm, about half of all farms in the United States gross less than $5,000 per farm. As a group, the tiny farms have expenses well in excess of revenue. Based on survey data from the National Agricultural Statistics Service of the US Department of Agriculture (USDA) and the Census of Agriculture, operators of the tiny farms garner their livelihood from other sources including employment in the nonfarm economy and retirement income. Indeed, one reason the average age of farmers

■ *Daniel A. Sumner is the Frank H. Buck, Jr. Professor of Agricultural and Resource Economics, University of California at Davis, Davis, California. His email address is dasumner@ucdavis.edu.*

http://dx.doi.org/10.1257/jep.28.1.147 doi=10.1257/jep.28.1.147

has been over 55 for decades is that many individuals continue to operate very small farms as a retirement activity after they have left nonfarm employment. Despite negative returns from farming, operators of tiny farms have incomes well above the national average—for them, in most years, farming is a costly avocation. In 2012, a year with record net farm income, farms with sales less than $100,000 generated negative aggregate net farm income of about –$2,500 per farm (Economic Research Service, USDA, 2013).

In this article, I concentrate on commercial farms—those that typically provide some positive net income and might engage an operator on a full-time basis. The size of these farms has more than doubled over the past two decades. Acres of corn per corn farm rose to 600 acres in 2007 from 200 acres in 1987 for the farm at the center of the production distribution, meaning half of production came from larger farms and half from smaller farms. Corn yield per acre rose by more than one-third over the same period. Acres per farm at the center of the production distribution for cotton, rice, soybean, and wheat also more than doubled. For some commodity industries, farm size growth has transformed the industry. For example, the hog operation at the center of the production distribution sold 30,000 hogs per year in 2007 compared to 1,200 in 1987. The central-sized dairy herd size was 570 in 2007 compared to 80 in 1987. Since aggregate acreage, inflation-adjusted farm revenues, and farm value added have changed relatively little in recent decades, expansion of farm size and farm consolidation become synonymous.

This article summarizes the economics of commercial agriculture in the United States, focusing on how growth in farm size and other changes in size distribution have changed in recent decades. I also consider the relationships between farm size distributions and farm productivity growth and farm subsidy policy. The search for causation among these relationships remains challenging. To focus on the recent evolution of farming in the United States, our time horizon is roughly three decades, from the early 1980s to the present. For a sweeping view of developments in US agriculture during the twentieth century, Gardner (2002) is a useful starting point. Economists at the Economic Research Service of the US Department of Agriculture have advanced our knowledge of farm size and the industrial organization of farming along with the relationships between farms and farm supply and marketing firms. They have used unique USDA data, including individual farm records from successive rounds of the Census of Agriculture and the annual Agricultural Resource Management Survey (ARMS). This article draws upon and cites much of this work.

The Size Distribution of American Farms

The growth of farm size is not a simple proposition to document with aggregate data. Farm size is often measured by sales or by quantities of output or land and other inputs, but none of these measures suits all questions. Farm sales data are affected directly by changes in relative prices over time, and commodities differ in value added and also in management effort per unit of gross sales. Land area can

Table 1
The Size Distribution of Farms by Gross Sales

	Number and share of farms (in 1,000s and percent)			*Aggregate sales and shares of aggregate sales for firms in the sales category (in 1,000s of dollars and percent)*		
Sales category	*1987*	*1997*	*2007*	*1987*	*1997*	*2007*
< $25k	1,099.7 (54.7%)	1,017.7 (53.2%)	1,355.9 (61.5%)	8,222.6 (6.1%)	6,943.2 (3.5%)	6,314.8 (2.1%)
$25k–$50k	219.6 (10.5%)	170.7 (8.9%)	154.7 (7.0%)	7,868.7 (5.8%)	6,084.3 (3.1%)	5,480.5 (1.8%)
$50k–$100k	218.1 (10.4%)	158.2 (8.3%)	125.5 (5.7%)	15,661.4 (11.5%)	11,346.5 (5.8%)	8,961.3 (3.0%)
$100k–$250k	202.6 (9.7%)	189.4 (9.9%)	147.5 (6.7%)	31,178.2 (22.9%)	30,143.3 (15.3%)	24,212.9 (8.1%)
$250k–$500k	61.1 (2.9%)	87.8 (4.6%)	93.4 (4.2%)	20,739.7 (15.2%)	30,505.2 (15.5%)	33,409.9 (11.2%)
$500k–$1 million	20.9 (1.0%)	42.9 (2.2%)	60.8 (2.8%)	14,076.3 (10.3%)	29,365.1 (14.9%)	42,690.8 (14.4%)
$1 million–$2.5 million*	11.1 (0.5%)	19.1 (1.0%)	40.4 (1.8%)	37,876.0 (27.8%)	27,938.7 (14.2%)	60,549.3 (20.4%)
$2.5 million–$5 million*	N/A	4.1 (0.2%)	9.6 (0.4%)	N/A	13,802.4 (7.0%)	32,299.5 (10.9%)
> $5 million*	N/A	2.8 (0.1%)	5.5 (0.3%)	N/A	40,369.9 (20.5%)	82,951.0 (27.9%)

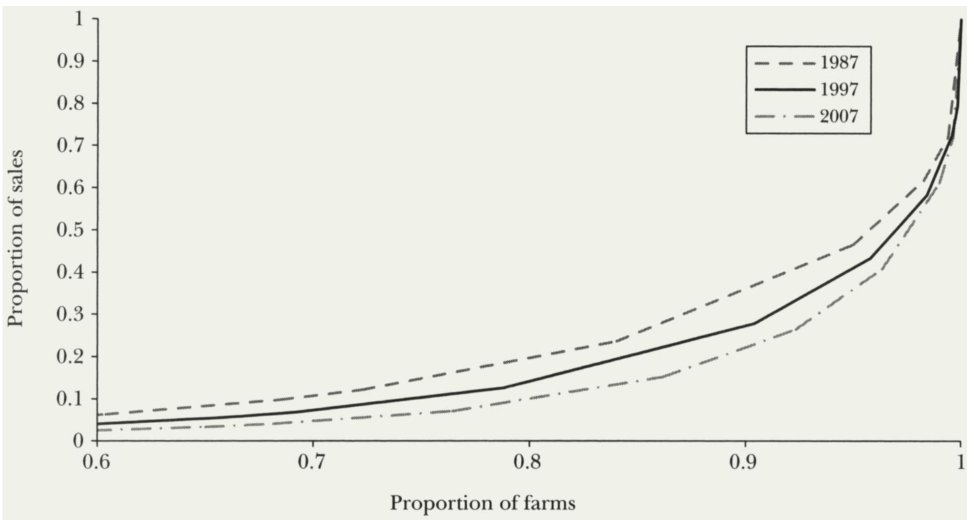
Source: United States Department of Agriculture, Census of Agriculture, 2007 Table 2: "Market Value of Agricultural Products Sold Including Landlord's Share and Direct Sales 2007 and 2002," 1997 Table 2: "Market Value of Agricultural Products Sold and Direct Sales: 1997, 1992 and 1982."
*($1MM+ for 1987), 1987 Census of Agriculture did not provide the numbers of farms of sales for separate categories over $1 million.

work for a particular commodity (or commodity mix) and location. Within specific commodity industries and regions, farm size is typically measured by input quantities (like harvested cropland or number of milk cows), output quantities (bushels of corn or hundredweight of milk), or value of output. In theory, farm size might also be measured by value added, net revenue, or total returns to management and fixed assets, but such data are not widely available. Farm size is almost never measured by the value of the capital stock or the number of employees, the dimensions that are commonly used in measuring size across firms outside of agriculture.

By any measure, commercial US farm sizes have risen dramatically in the last few decades. This growth in size applies across the distribution of farm sizes: midsized commercial farms have gotten larger, and so have larger farms. As commercial farms grow larger, the number of tiny farms has been increasing slightly, so mean and median farm sizes for official aggregate data have been getting larger only slowly.

Table 1 presents aggregate data on the share of farms across sales classes for census years 1987, 1997, and 2007. The left three columns show the number and

Figure 1
Changing Distribution of Farm Sizes, 1987, 1997, and 2007
(farm size measured in terms of sales)



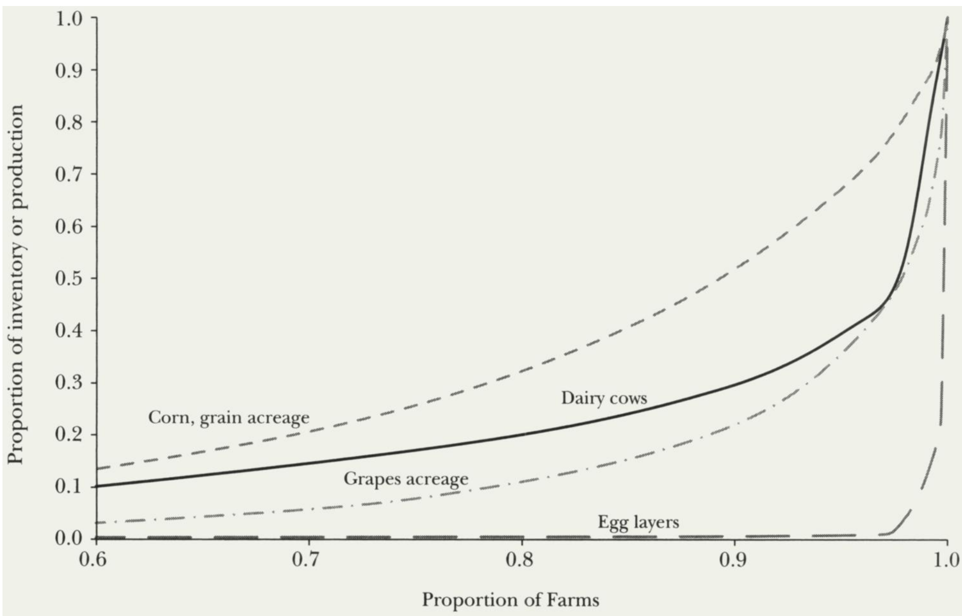
Source: US Department of Agriculture, Census of Agriculture, 1987, 1997, and 2007, http://www.agcensus.usda.gov/index.php.

share of farms in each category of sales; the right three columns show aggregate sales and shares of aggregate sales from firms in those sales classes. Farms that gross less than $25,000 per farm, making up approximately 60 percent of all farms, only accounted for about 2 percent of US farm output in 2007. (Farm output prices were stagnant from 1982 to 2002, but rose by about 40 percent from 2002 to 2007, and have risen another third since.) At the upper end of the distribution, the share of total sales from farms with sales of $1 million or more rose from less than 30 percent to 60 percent in 2007. Table 1 presents categories in nominal dollars. O'Donoghue et al. (2011) adjusted sales categories to be in constant 2007 dollars and found that farms producing more than $1 million of output (in 2007 constant dollars) rose by 243 percent from 1982 to 2007 to reach 55,500 farms.

Figure 1 shows the shifting concentration over time. At the bottom left, the smallest 60 percent of farms by sales generate about 5 percent of total sales over time. The smallest 60 percent of farms as well as 70 percent, 80 percent, and 90 percent, all have a lower share of total sales in 1997 than in 1987 and a lower share in 2007 than in 1997.

Measuring farm size by inputs, like cropland, requires care concerning differences across crops. As an extreme example, operating 1,000 acres of strawberries would entail many employees and tens of millions of dollars in revenue, whereas 1,000 acres of wheat entails part-time employment for a single operator and revenue of less than $0.5 million. Corn and grape farms are often measured by acreage.

Figure 2
Distribution of Farm Size for Corn, Grapes, Dairy, and Egg Industries
(farm size measured in acreage for corn and grapes; in livestock numbers for dairy cows and egg layers)



Source: USDA, Census of Agriculture, 2007, http://www.agcensus.usda.gov/index.php.

Dairy and egg farms are typically measured by number of livestock. Figure 2 shows how the size distributions of these types of farms differ. The corn industry is least concentrated, with the largest 20 percent of farms operating on about 70 percent of the acreage. About 10 percent of the farms operate on about half the corn acreage.

Among dairy farms, 20 percent of the farms milk about 80 percent of the total cows, and less than 5 percent of the farms milk more than half of the total cows. Small commercial dairy farms milk fewer than 100 cows and have milk sales gross revenue of perhaps $300,000. Larger dairy farms have in the range of 10,000 cows and milk sales in the range of $30 million. Dairy farms differ by more than just herd size, and degree of vertical integration matters. For example, some grow their own feed or breed replacement heifers, but herd size remains a useful measure of overall size (Sumner and Wolf 2002).

About 90 percent of grape farm acreage is on the largest 20 percent of grape operations, and 80 percent of acreage is on the largest 10 percent. The egg farm size distribution is clearly the most concentrated shown in Figure 2. The largest egg farms tend to have operations in multiple locations and millions of hens. But even in the egg business, where markets are national and regional, dozens of farms compete in most markets.

Farm consolidation raises few market power issues. Farms that produce the bulk of US output still number in the tens of thousands, and few are large enterprises by nonfarm standards. Some farms do have sales in the tens of million dollars. These tend to be in industries with low value added per unit of sales, such as livestock feeding, where cost of young livestock and feed comprise up to 90 percent of gross sales. The crop industries with high-sales farms include fruits, tree nuts, and vegetables. Even in these industries, dozens or even hundreds of farms compete in the relevant markets.

Are the large farms generally operated as parts of large publicly held corporations that primarily engage in nonfarm enterprises? The available data say no. In 2007, 1 percent of farms with sales of at least $100,000 were organized as nonfamily-held corporations, while 71 percent are held by individuals (according to the Census of Agriculture). Family farms, where the operator or immediate family members own at least half the farm, account for about 87 percent of crop output. Of nonfamily farms, corporations produce about half of the value of crop output. Corporate operation of livestock feeding accounts for a much larger share of output, probably exceeding 50 percent.

Market power in agriculture is typically exercised by downstream firms or is attributable to consumer product brands that may be controlled by large farms or groups of farms operating as marketing firms. Some farm-based market power in American agriculture may also derive from location-specific attributes affecting consumer willingness to pay, such as the case of winegrapes from a particular vineyard, but these are rare cases, similar to the market power of a few extremely talented athletes or celebrities.

At the same time that the skewness of farm size distributions has increased, shares of output and numbers of farms have been declining in size categories that were considered mid-size two decades ago. Does that mean farm size distributions are becoming bimodal, with some huge farms, many tiny farms, and few in-between? In fact, there is little or no evidence of multiple modes in farm size distributions. Whole distributions have shifted to the right such that formerly mid-sized commercial farms are now small and what would have formerly been a large farm is now considered mid-sized. In the only study using appropriate nonparametric tools (Wolf and Sumner 2001), we rejected the bimodal hypothesis for US dairy farm data, a farm commodity industry where measurement of size is among the least complicated.

What about the small organic farms that market directly to consumers through farmers' markets, home delivery, or to local retailers—the farms that seem to dominate urban elite consciousness? Though such farms may frequently appear in the popular press, organic production amounts to 1–2 percent of farm output, mainly concentrated in milk and fresh produce and on the East and West Coasts. Moreover, large farms that ship products nationally have a large share of the organic market. Farm output from *small farms* that *supply local markets* with *organic products* comprises the intersection of three already small sets and is simply not a significant part of agricultural production in the United States.

Finally, we may consider farm size distributions in relation to distributions of other business firms. In general, even large farms are small businesses. Indeed, most business firms are also small, many employing no workers in addition to the operator and most with very few employees (Evans and Leighton 1989; Cabral and Mata 2003; Luttmer 2011). The US Small Business Administration (undated) defines a "small" business in the context of the industry. In manufacturing, the maximum number of employees for a "small" firm may range from 500 to 1,500, depending on the type of product manufactured. In wholesaling, the maximum number of employees for a "small" firm may range from 100 to 500, depending on the particular product being provided. In services, the annual receipts of a "small" firm may not exceed $2.5 to $21.5 million, depending on the particular service being provided. In general construction, annual receipts for a "small" firm may not exceed $13.5 to $17 million.

In farming, the Small Business Administration criteria for annual receipts of a "small" farm may not exceed $0.5 to $9.0 million, depending on the agricultural product. For certain farm product industries, such as grains and oilseeds, the limit for a small business is set much below those in other industries. But the sales limit for "small" for livestock feeding is set at a range comparable to services or construction. Manufacturing is categorized for size by number of employees, and the minimum number of workers for a small business is well above that of all but a tiny share of commercial farms.

The most obvious difference between farming and manufacturing or services is that, unlike other industries, there are no farms with tens of thousands of employees that operate on a global scale. No firms that are primarily engaged in farming are among the 500 largest firms in the economy, and very few farms have familiar company names.

What Drives Differences in Farm Size and Shifts in Farm Size Distributions Over Time?

Commercial farms have increased in size by every measure, both for US farming as a whole and across the full range of commodities. Characterizing and explaining farm size distributions and their change over time is complex, and economists have not yet developed fully satisfying models to account for observed patterns. This section considers the attempts to understand farm size distributions.

Among the first questions is why farm size distributions differ from what is typical in the rest of the economy. In particular, why are there few very large farms? One may suggest hypotheses to explain this fact, but no studies have provided satisfying empirical tests. The most promising avenues of explanation involve cost of monitoring and rewarding performance in large farms and gains to specific local knowledge. For example, it may be more difficult to monitor effort and ability when weather and biological variations dominate performance, especially with few workers per location. It may also be more difficult to integrate production and marketing when generic products dominate and the return to branding is small. Animal feeding establishments operated by firms such as Cargill and Smithfield are examples where local conditions are less important and standardization of performance expectations allow a large operation to match efficiencies of independent farms. Also, although most large wineries buy most of the grapes they process, some large firms with well-known wine brands produce grapes on winery-operated farms.

There has been relatively little cross-fertilization between the general literature on firm size and the farm size literature. Hall (1987) pointed out how farm size distributions had much in common with other industries. At that time, Gibrat's law, which holds that the size of a firm and its growth rate are independent, captured the size distribution of firms and farms fairly well, especially for smaller firms. While economists who study farm size refer to the early models developed for size and growth of business firms (such as Lucas 1978; Jovanovic 1982; Evan and Jovanovic 1989), they generally have not tested such models with data on farms or compared their results to those for business firms (for example, Evans 1987; Cabral and Mata 2003; Angelini and Generale 2008).

In one of the most prominent contributions to the literature on farm size, Kislev and Peterson (1982) focused on land operated per farm as the measure of farm size. They assumed, consistent with the facts across much of the US Midwest during their period of investigation, that each farm had a single operator who also supplied most of the labor on the farm. Using a series of plausible simplifying assumptions, they showed how an increase in the income potential in nonfarm occupations would raise "machinery-capacity" per farm (because machine capital would be substituted for labor). Then, as the capacity of machinery to cultivate, plant, or harvest more acreage in limited time-windows increased, acreage per farm and per farmer would increase. The result was that the opportunity cost of earning labor off the farm would generate more cropland per farm operator. This model also implied fewer farms, given a fixed or almost fixed amount of cropland. Kislev and Peterson (1982) showed that data from US agriculture in the middle of the twentieth century was consistent with their assumptions about substitution between land, labor, and capital, and their model could help explain the pattern of crop farm growth in the United States. No published work has tested the relevance of nonfarm wages for farm size using the more recent data.

Most commercial farms in the United States no longer match the stylized facts that Kislev and Peterson (1982) used in generating their result. For example, commercial farms employ more than one tractor and harvester (or buy equipment services) and operate fields at several locations, and farm managers often do not operate farm equipment themselves. Many farms have several manager/operators who share returns. Real wages for hired farm workers (and other workers) have stagnated, while many farm tasks have increased in complexity and technical expertise required. At the same time, the human capital of farmers and their opportunity cost of forgoing off-farm careers have risen. That said, many farmers are middle-aged or older and have little nonfarm work experience, so their employment opportunities at nonfarm occupations are now limited. Also, with the amount of labor and land per farm variable rather than fixed, labor-saving technology may increase land-to-hired-labor ratios without affecting the total acreage, production, or revenue per farm.

Determinants of farm size in current farming may be derived more from managerial ability and selection for better managers, as in models of Lucas (1978) and Jovanovic (1982). The following nine stylized facts and hypotheses are useful in summarizing ideas about how human capital and managerial capabilities affect the economics behind observed patterns of commercial farm size and growth in the United States. They may serve as building blocks for those seeking to model these patterns.

First, farm average cost curves are generally L-shaped. Costs fall rapidly as size expands for a limited range, but after a minimum size, costs decline very gradually, if at all, and farms are distributed across a range of sizes based on some criteria other than economies and diseconomies of scale. Without further elaboration, such a model is silent about why firms larger than the minimum grow or why farms have different sizes. Although it is difficult to measure the opportunity cost of the farm owner/operator in terms of earnings at an alternative occupation, it seems likely that farms differ in optimal size, and somewhat smaller farms may remain competitive with larger farms that have slightly lower measured costs, because the smaller farms have a lower opportunity cost of using their human capital in farming.

This pattern of L-shaped average cost curves suggests the presence of technology that is not scale neutral, perhaps because of lumpy physical assets, such as tractors or planting machinery, milking parlors, or hen housing facilities, or lumpy managerial capital for firms with one or very few managers. However, the evidence suggests that these economies of scale seem to almost level out at some medium level of input. The evidence is mixed. For example, using a cross section of dairy farms in 2000, Mosheim and Lovell (2009) find scale economies throughout the range of their data. While, using individual records from several rounds of the Census of Agriculture, Melhim, O'Donoghue, and Shumway (2009) find that scale economies are relatively unimportant at larger farm sizes. They also find greater diversification by large firms, which suggests economies of scope—and managerial skill may well be useful in discovering and implementing such economies of scope. Recent accounting data on a larger random sample of farms shows rates of return on equity rising through all farm acreage classes for corn, soybeans, wheat, fruits and nuts, and vegetable and melon farms (MacDonald, Korb, and Hoppe 2013, table 5). Larger crop farms use less labor and less capital per acre.

Second, although the cost curves are L-shaped, changes in technology have meant that the minimum-cost farm size has been shifting out over time. This observation is consistent with growth of farm size, and with entrants to the farm sector having larger size at time of entry. There is evidence of this occurring for both crop and livestock industries (MacDonald, Korb, and Hoppe 2013).

Third, consistent with recognition of economies of scope, farms also grow by adding commodity enterprises with different specific patterns of labor, management, and specialized capital across the year and across the farm. Corn and soybeans are grown in rotation on the same land to increase yields, which means that farms often grow both each year. Reasons not to specialize in a single crop each year include different seasonal patterns that allow more complete annual use of machinery and management. Moreover, even similar land in the same region is often best suited for particular crops, so as farms expand they naturally occupy land that may be suited for different commodities. Of course, diversification across enterprises also contributes to risk management, especially for vertically integrated commodities such as feed and livestock production.

Fourth, larger farms typically rent land, while smaller farms own more of the land upon which they operate (based on Census of Agriculture data; see also MacDonald, Korb, and Hoppe 2013). Larger farms tend to use their capital for operation and rely on outsiders—often former farmers and farm heirs—to invest in farmland ownership. This separation of farm operation from land ownership involves a variety of contracts, which range from hired managers earning salaries and incentive bonuses, through a variety of share tenancy arrangements (where tenants and landlords share costs and returns), to cash rental contracts where the landlord is involved in few of the farm decisions and faces none of the variability of farm costs and returns. The contract arrangements differ by the particular conditions and capabilities of landlords and tenants (Allen and Lueck 2002).

Fifth, managerial capability in agriculture may be a lumpy input, which in turn limits scale economies and the potential for farm growth (Tolley 1970; Alvarez and Arias 2003). In Sumner and Leiby (1987), we showed that human capital of operators determined farm size and improving managerial ability among dairy farmers helped explain increasing average herd size and growth. Hierarchical management systems may be difficult to employ in farming, because so much of the production effort is highly specific to the location in which it happens. This restriction on exercise of managerial capability, and a reliance on family and ownership relationships, limits farm size compared to the very large firms in other industries. Where standardization and monitoring allow operations in multiple locations and with many managers, such as in the livestock feeding and egg industries, farms can and do become much larger.

Sixth, when the payoff to nonfarm opportunities for farmers rises relative to the cost of capital, the result is more capital per farmer. As real interest rates have fallen over the past 30 years and returns to human capital have risen, capital per farm rises as well as capital per unit of hired labor (which has received largely stagnant wages). When capital substitutes for farm operator and manager time rather than routine hired labor, farmland operated, gross sales, and value added per farmer and per farm all rise. This insight is related to the Kislev and Peterson (1982) hypothesis, but focuses on farmer management, not farm labor.

Seventh, managerial capability has become more similar between farming and nonfarm occupations, especially in organizations with specialized technical personnel or contracted specialist services, such as from animal nutritionists or pest consultants. Thus, compared to technical farming skills, managerial capability is more likely to be human capital that is general across occupations and less farm-industry-specific.

The implication is that farms must be large enough to attract and retain farm operators and managers who have high opportunity costs off the farm. Moreover, higher returns to management at larger farms create incentives for farm consolidation.

Eighth, farms with more-capable managers are larger for two reasons: a) because farmers who are more capable compete effectively for land and other resources and acquire farms previously operated by less-capable farmers; and b) because the returns to managerial capability are high in nonfarm occupations, only those with opportunity to operate large farms, which have scope for relatively high incomes, select farming as an occupation. Moreover, as farm operators with less managerial capability have been replaced by those with higher capability, farm size has grown as a consequence. Without a large operation over which to spread their managerial capabilities, better managers would not enter or continue in farming. These empirical relationships are not axiomatic. In some parts of the world where farm opportunities have been restricted or farming has been otherwise unattractive, the best potential farmers leave the rural areas, and those remaining tend to have below-average capability. Opportunities off the farm draw away the best, and farm size and productivity is left to flounder.

Recent data on farm size, schooling, and managerial capability is compelling. The best recent information comes from analysis of farmers who also work off the farm (Brown and Weber 2013). Of those farms with some off-farm employment, 44 percent of operators of farms with at least $250,000 were employed in managerial and professional occupations compared to 35 percent of operators of smaller farms. About half the operators of the larger farms work off the farm in agriculture or government. In 2010, 58 percent of these employed operators of farms with at least $250,000 in sales (and two thirds of their spouses) had some college, compared to 45 percent of operators of farms with $50,000 to $249,999 in sales.

Technical change and management information systems extend the payoff to managerial capability and the result is higher returns to management in larger farms. The payoffs to finding lower input prices, searching for higher output prices, managing production and price risk, and managing improved productivity of hired labor are all higher for larger operations. Thus, the process of managerial replacement (better managers for worse) complements and is complemented by innovations in technology and information systems that pay dividends to better management.

Finally, ninth, the interaction between technology, managerial replacement, and larger farm size affects the pace of productivity gains just as productivity changes affect the distribution of farm size. Farm size may also be affected by government subsidy policy and regulatory policy. These are the topics of the next two sections.

Farm Size and Productivity

In much of the economy, economists use "productivity" as shorthand for labor productivity (as when they refer to output per worker) and "firm size" to refer to number of employees. For crops, output per acre ("crop yield") is the common

Table 2
National Single Factor Productivity Growth for Grapes, Corn, and Milk

	Average yield		*Average revenue (1,000s of dollars)*		*Compound growth rate (%)*	
Commodity	*1991–93*	*2009–11*	*1991–93*	*2009–11*	*Yield*	*Revenue*
Table grapes/Acre	8.2 tons	11.5 tons	3.7	6.4	1.7	2.7
Wine grapes/Acre	7.4 tons	7.2 tons	2.7	4.4	–0.1	2.4
Corn/Acre	114 bu.	155 bu.	0.26	0.76	1.5	5.5
Milk/Cow	15,441 lbs.	21,022 lbs.	1.9	3.5	1.6	2.9

Source: National Agricultural Statistics Service, US Department of Agriculture.

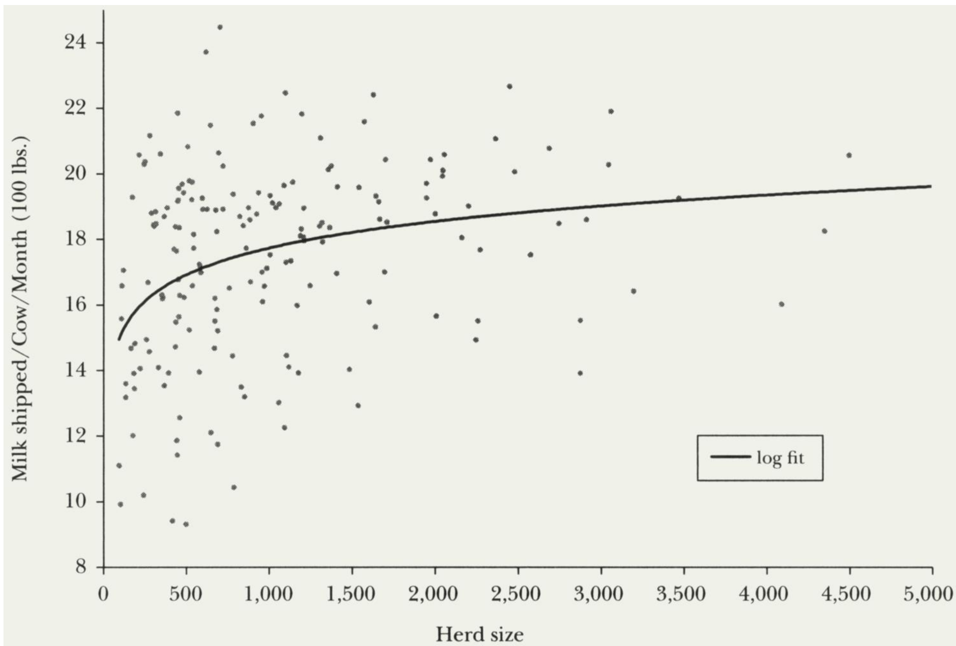
measure of single factor productivity, whereas for livestock, output per animal is common. For example, on US dairy farms, milk per cow is the most common benchmark. For farming as a whole, multifactor or total factor indicators must be used to compare productivity.

Productivity growth has characterized US agriculture for many decades. Rapid increases in crop outputs per acre or outputs per animal apply across almost all commodity groups. Table 2 shows rates of growth over a two-decade period in output and revenue per acre for wine grapes, table grapes, and corn, as well as output and revenue per cow for milk. This group of commodities illustrates the diversity and complexity of single factor productivity measures.

Average milk per cow and corn per acre both rose by about one-third and table grape yield rose by 28 percent in the almost two decades from 1991–1993 to 2009–2011. Wine grape yields, however, fell marginally over this period. Of course, single factor measures have limitations. In the case of wine grapes, changes in product characteristics (and location) mask yield growth for many varieties in many regions. In the case of milk and corn, some yield growth was caused by more feed per cow and more fertilizer per acre that represent movements along isoquants rather than shifts in the isoquant over time.

Applying sophisticated measures of productivity like total factor productivity requires great attention to detail. For example, challenges have included creating indexes of labor and management to account for quality, where much of the labor is entrepreneurial and part time, and operator and family hours of work on farms are not well measured. Aggregating capital across everything from milk cows to tractors and land improvements raises concerns about input quality and quantity. Creating indexes of output to allow aggregating a ton of Cabernet Sauvignon grapes from Napa ($8,000 per ton) with grapes from Fresno ($300 per ton) is equally complex—leaving aside aggregating these with a ton of wheat from Kansas. Notwithstanding these challenges, several teams of researchers have shown that total factor productivity has grown rapidly for US farming and for most significant commodity industries and regions (Alston, Anderson, James, and Pardey 2010; Fuglie, MacDonald, and Ball 2007).

Figure 3
Milk Shipped per Cow, per Month, by Herd Size



Source: California Department of Food and Agriculture, Cost of Production Feedback data, http://cdfa.ca.gov/dairy/uploader/postings/copfeedback/.

The relationships between productivity growth and farm size appear to run through several channels, and in both directions. A large literature focuses mostly on very small farms in poor countries and often finds that crop yields per acre are higher on farms operating less land (Feder 1985; Eastwood, Lipton, and Newell 2010). Higher labor and management inputs per unit of land imply higher output-to-land ratios. On very small farms, the farmer knows his land very well and applies considerable attention to increase yield per acre (Eastwood, Lipton, and Newell 2010).

This pattern is not standard for rich-country agriculture and does not seem to hold in the United States. If the best managers operate larger farms with the best technology, they are likely to have higher productivity. For example, in Iowa corn yields in 2007 increase with acres of corn per farm up to about 1,000 acres. For dairy farms in the San Joaquin Valley of California, the highest milk production region in the United States, there is a clear positive relationship between herd size and milk per cow, as shown in Figure 3. Doubling cows per herd from 500 to 1,000 increases milk production per cow by about 6 percent. Nationally, the gains of larger dairy farms are much more from reduced labor and capital per unit of milk production rather than more milk per cow (MacDonald and McBride 2009).

When larger commercial farms have higher productivity, as farms consolidate and the less-productive operations leave the industry, productivity grows over time. That means part of the measured productivity growth may be due to increases in farm size. The growth in the size of commercial farms, and consolidation that facilitated improved management of farms, contributed to the rapid productivity gains in the half century after 1945. It is not clear if productivity growth associated with these changes has continued to be as rapid, or if more such productivity gains are available (MacDonald, Korb, and Hoppe 2013). Causation in the other direction can also arise from any size bias of improved technology or new technology that favors higher-capability managers who operate larger farms.

Total factor productivity growth in farming continues, but the rate of productivity growth seems to have slowed down since around 1990 (as Alston and Pardey explain in this symposium). The rate of investment in agricultural research and development spending seems to have slowed as well. Other contributors to a growth slowdown may be unmeasured improvements in output quality and more resources devoted to environmental concerns that tend to reduce productivity growth as conventionally measured. Economists have paid considerable attention to these issues, but including them in input and output indexes for productivity growth is inherently difficult.

Because of consolidation in livestock feeding, much of total farm production now comes from farms that seem to have exhausted available scale economies. For example, McBride and Key (2013) document very rapid consolidation and productivity growth that seems to have now exhausted scale economies in hog production. For dairy and field crop operations, rapid consolidation over the past 15 years has corresponded with the period of the productivity growth slowdown. Further research needs to examine productivity growth and farm consolidation patterns across commodity industries and locations in the United States to attempt to assess causation in that relationship.

Farm Subsidies and Farm Size

The evolution of farming in the United States is inevitably connected to the evolution of farm subsidies (Dimitri, Effland, and Conklin 2005; Gardner 1992; Gardner 2002; Sumner, Alston, and Glauber 2010). As commercial farms have become larger and more productive and farm operators have become wealthy relative to other Americans, farm policy in the United States has also evolved. Prominent farm subsidies mostly transfer income to owners of resources on farms that grow the politically favored crops and livestock commodities. Our question here is the extent which farm subsidy policies have influenced farm size distributions overall and for the most heavily subsidized commodities. This has been a topic of vigorous speculation and some research for many decades (Sumner 1985). For example, on one side Key and Roberts (Key and Roberts 2007; Roberts and Key 2008) argue that farm policy has tended to hasten the movement toward larger farms. My own reading of the evidence is that although farm policy has for some commodities leaned against the prevailing winds of consolidation, it has had little overall effect on limiting consolidation of farming—a conclusion that is consistent with evidence assessed by MacDonald, Korb, and Hoppe (2013) and White and Hoppe (2012). After presuming that an objective of farm subsidies was to slow farm consolidation, Eastwood, Lipton, and Newell (2010) came to a similar conclusion for high-income countries overall. They summarize (p. 3374): "In fact, OECD farm support has not overcome the tendency of farm size to grow and of farm numbers and employment to decline." We will discuss the evidence behind these conclusions, after quickly summarizing farm subsidies in the United States.

Farm subsidies differ widely by commodity, but most of the subsidy and the highest subsidy rates still go to what are called the "program crops": grains, cotton, and oilseeds (through government payments), sugar (through trade barriers), and milk (through an array of payments and price regulations). Trade barriers, such as those for frozen concentrated orange juice and fresh market tomatoes, have provided protection to certain commodities for many years. However, most fruits, tree nuts, vegetables, and hay are much less subsidized, and eggs and meat products are largely unsubsidized.

In the old price support programs, the federal government set minimum prices and acquired any supplies not bought at those prices. About three decades ago, these direct price supports began to be replaced by payments that made up the difference between the government-set target and the market price. These payments effectively set a minimum price for farm suppliers, but the market price cleared the market. In 1996, under a program that only economists appreciated, the Congress supplemented the payments tied to specific commodity production and prices with payments based on a farm's history of production of the subsidized crops. Such approximately lump-sum payments reduced production distortions inherent in payments tied to specific commodities. Over the past decade, government agricultural policy has shifted toward heavily subsidized crop insurance (Glauber 2013; White and Hoppe 2012). The Risk Management Agency at the US Department of Agriculture (2013) estimates that government costs were about $15.8 billion for crop year 2012, up from about $9.4 billion for crop year 2011. Insurance programs suffer from substantial moral hazard and adverse selection because farm differences and farm behavior are expensive to monitor. Subsidized crop insurance programs transfer benefits to participating farms, while also offsetting unanticipated variability in prices and yields.

One would expect subsidies to affect which crops are grown and the aggregate supply of farm output, but given the complexity of farm programs, the supply response has not been easy to assess. Aggregate supply functions tend to be inelastic. In the medium-run, even supply response of major program crops such as corn and soybeans remain inelastic because suitable land for these crops is already engaged and because profitable crop rotations planned several years in advance limit adjustments (Hendricks and Sumner, forthcoming). However, for crops that use a small share of potentially suitable land and receive high subsidy rates, such as cotton, medium-run supply functions are more elastic.

The effect of subsidies (including crop insurance) on commercial farm size distributions is harder to assess than the effect of subsidies on aggregate supply response. First, gross empirical relationships do little to illuminate effects of subsidy on size. Major commodity subsidy programs are tailored mostly to field crops that tend to be smaller (by gross sales) than farms producing nonsubsidized commodities. Second, the fact that farms tend to be larger in crop and livestock industries without subsidies suggests subsidies may have inhibited consolidation where they have been important. Third, truly tiny farms (half the total official number) often do not bother filing for subsidies, but this has no relationship with commercial farm size. Fourth, subsidies vary from year to year inversely with market price and yield, so subsidies jump in years with size declines as measured by sales or output.

Conceptual effects can be subtle. Subsidies that offset market variability may allow weaker farms to access capital not otherwise available. Payments based on historical production allow even farms with less productivity growth to remain viable longer, and subsidy income capitalized into farm land and other farm assets allow equity owners to survive when farms might otherwise consolidate.

The empirical evidence on the effects of farm programs and related policies on farm size distributions is mixed. A series of papers by Key and Roberts (for example, their 2007 article) used panel data from Census records and provided support for the hypothesis that farm subsidies encouraged farmland consolidation and made farms bigger. However, Census data did not allow researchers to identify effects of specific farm programs on different eligible crops and the various potential relationships with government payments, trade protection, and subsidized crop insurance. The major conclusions of Key and Roberts seem to be most heavily influenced by impacts on tiny farms that are of little interest for aggregate farm production or other issues of commercial agriculture. Key and Roberts also cannot account for the differences in subsidy and size across crop industries (MacDonald, Korb, and Hoppe 2013).

There is evidence that certain farm program features affect size in direct ways. Foltz (2004) showed that some very small New England dairy farms delayed exiting the industry in response to a targeted payment that raised the effective price of milk for farms in that region. Kirwan, Uchida, and White (2012) showed that elimination of the tobacco program that operated as a supply control cartel and restricted downstream marketing relationships allowed rapid farm consolidation that had been delayed by the operation of the program. Sneeringer and Key (2011) document how regulations that create size thresholds for more intensive and costly regulatory compliance have caused livestock operations to limit operational size to just below the threshold. Finally, the Food Safety Modernization Act of 2012 explicitly exempted small farms from some rules. One rationale for such exemptions is that large farms may have lower per unit costs of understanding and implementing regulatory requirements.

The answers as to how government farm subsidy programs affect farm size ultimately hinge on the degree of relative subsidy rates across competing commodities and farm sizes, the supply elasticities of the subsidized crops, and effects on such second-order factors as variability of returns, access to operating capital, and potential risk aversion.

Conclusion

Commercial agriculture in the United States is comprised of several hundred thousand farms, and these farms continue to become larger and fewer. The size of commercial farms is sometimes best-measured by sales, in other cases by acreage, and in still other cases by quantity produced of specific commodities, but for many commodities, size has doubled and doubled again in a generation. That does not mean that typical commercial farm operations are becoming large by any nonfarm corporate standard, or that there is any near-term prospect that these large firms will be able to exercise market power. For example, even as the typical herd size of dairy farms rises from 500 cows to 1,000 to 2,000, there will remain thousands of commercial farms operating the national milk cow herd of eight or nine million cows. The few dairy farms with 10,000 cows are located in several units in distinct locations and remain a small share of the relevant national and international market into which they deliver.

In a few farm commodity industries, multi-location operations and hierarchical management systems have emerged. In some commodity industries, such as eggs and some specialized fruits, tree nuts, and vegetables, farms have consolidated enough that most national production derives from fewer than 100 major producers who operate at several locations separated by hundreds or thousands of miles. These industries are characterized by close relationships between growing and marketing, seemingly smaller uncontrollable crop-to-crop variations, and therefore less costly monitoring of managerial outcomes.

In some industries, such as intensive animal feeding, farms are often operated as franchises in which farms are connected closely with larger processing and marketing firms through contractual relationships (MacDonald and McBride 2009). Many commodity industries have traditionally used contractual relationships between farms and processors or marketers to coordinate timing of shipments and commodity characteristics. For example, the processing tomato industry links growers and processors in annually negotiated contracts, and wineries work closely with contracted grape growers, often providing long-term guarantees to encourage vineyard development. Growth in farm size in these industries has occurred at roughly the same pace as for commodity industries with fewer contractual relationships. Economists do not yet have a good understanding of the relationships between contractual relationships, farm size patterns, and productivity, and this remains an area of active research.

Changes in farm size distributions and growth of farms seems closely related to technological innovations, managerial capability, and productivity. Opportunities for competitive returns from investing financial and human capital in farming hinge on applying managerial capability to an operation large enough to provide sufficient payoff. Farms with better managers grow, and these managers take better advantage of innovations in technology, which themselves require more technical and managerial sophistication. Farms now routinely use outside consultants for technological services such as animal health and nutrition, calibration and timing of fertilizers and pesticides, and accounting. The result is higher productivity, especially in reducing labor and land per unit of output. Under this scenario, agricultural research leads to technology that pays off most to more-capable managers who operate larger farms that have lower costs and higher productivity. The result is reinforcing productivity improvements.

Subsidy programs seem to be relatively unimportant in the evolution of farming in the United States. Farm sizes are growing, numbers of commercial farms are falling, and farm operations are transforming industries with and without commodity subsidies. In specific instances and for specific commodities, farm programs have affected the patterns of farm size and growth. But the broader swath of agricultural transformation is affected, not by subsidies, which in recent years amount to about 5 percent of US farm revenue, but by markets that reward innovation.

Agriculture continues to evolve rapidly in the United States. Recent research has been stimulated by annual US Department of Agriculture surveys of relatively large, repeated cross sections of farms that can be appropriately weighted to be representative of particular commodity industries. These data along with repeated individual farm records from the US Census of Agriculture are providing a rich source of information that will allow us to better understand how and why farm size distributions are changing and what this means for the agricultural landscape, public policy, and agricultural productivity.

■ *The author thanks research assistants John Bovay, Eric Coughlin, Georgi Gabrielyan, and Jisang Yu. Rick Barichello provided useful comments. I especially appreciate correspondence and conversations with James MacDonald of the Economic Research Service, US Department of Agriculture. The work of MacDonald and his colleagues has brought substantial new evidence and analysis to bear on the issues considered in this article.*

References

Allen, Douglas W., and Dean Lueck. 1998. "The Nature of the Farm." *Journal of Law and Economics* 41(2): 343–86.

Alston, Julian M., Matthew A. Andersen, Jennifer S. James, and Philip G. Pardey. 2010. *Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending.* New York: Springer.

Alvarez, Antonio M., and Carlos Arias. 2003. "Diseconomies of Size with Fixed Managerial

Ability." *American Journal of Agricultural Economics* 85(1): 134–42.

Angelini, Paolo, and Andrea Generale. 2008. "On the Evolution of Firm Size Distributions." *American Economic Review* 98(1): 426–38.

Brown, Jason P., and Jeremy G. Weber. 2013. *The Off-Farm Occupations of U.S. Farm Operators and Their Spouses.* Economic Information Bulletin 117, Economic Research Service, US Department of Agriculture. September.

Cabral, Luís, and José Mata. 2003. "On the Evolution of the Firm Size Distribution: Facts and Theory." *American Economic Review* 93(4): 1075–90.

Dimitri, Carolyn, Anne Effland, and Neilson Conklin. 2005. *The Twentieth Century Transformation of U.S. Agriculture and Farm Policy.* Economic Information Bulletin No. 3, Economic Research Service, US Department of Agriculture. June.

Eastwood, Robert Michael Lipton, Andrew Newell. 2010. "Farm Size." Chap. 65 in *Handbook of Agricultural Economics*, vol. 4, edited by Prabhu L. Pingali and Robert E. Evenson, 3323–97. Elsevier.

Economic Research Service. United States Department of Agriculture (USDA). February 2013. *USDA Long-Term Agricultural Projection Tables.* http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192.

Economic Research Service, United States Department of Agriculture (USDA). 2013. "ARMS Farm Financial and Crop Production Practices/Tailored Reports." Results from the Agricultural Resource Management Survey (ARMS). http://www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/tailored-reports.aspx#P0288e93c65b24def9c83f9336087cd84_5_66iT0R0T0R0x5.

Evans, David S. 1987. "Tests of Alternative Theories of Firm Growth." *Journal of Political Economy* 95(4): 657–74.

Evans, David S., and Boyan Jovanovic. 1989. "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints." *Journal of Political Economy* 97(4): 808–27.

Evans, David S., and Linda S. Leighton. 1989. "Empirical Aspects of Entrepreneurship." *American Economic Review* 79(3): 519–35.

Feder, Gershon. 1985. "The Relation between Farm Size and Farm Productivity: The Role of Family Labor, Supervision and Credit Constraints." *Journal of Development Economics* 18(2–3): 297–313.

Foltz, Jeremy D. 2004. "Entry, Exit, and Farm Size: Assessing an Experiment in Dairy Price Policy." *American Journal of Agricultural Economics* 86(3): 594–604.

Fuglie, Keith O., James M. MacDonald, and Eldon Ball. 2007. "Productivity Growth in U.S. Agriculture." Economic Brief No. EB-9, United States Department of Agriculture, Economic Research Service, September.

Gardner, Bruce L. 1992. "Changing Economic Perspectives on the Farm Problem." *Journal of Economic Literature* 30(1): 62–101.

Gardner, Bruce L. 2002. *American Agriculture in the Twentieth Century: How It Flourished and What It Cost.* Harvard University Press.

Glauber, Joseph W. 2013. "The Growth of the Federal Crop Insurance Program, 1990–2011." *American Journal of Agricultural Economics* 95(2): 482–88.

Hall, Bronwyn H. 1987. "Empirical Analysis of the Size Distribution of Farms: Discussion." *American Journal of Agricultural Economics* 69(2): 486–87.

Hendricks, Nathan P., and Daniel A. Sumner. Forthcoming. "The Effects of Policy Expectations in Crop Supply, with an Application to Base Updating." *American Journal of Agricultural Economics.*

Jovanovic, Boyan. 1982. "Selection and the Evolution of Industry." *Econometrica* 50(3): 649–70.

Key, Nigel D., and Michael J. Roberts. 2007. "Commodity Payments, Farm Business Survival, and Farm Size Growth." Economic Research Report No. EER-51, United States Department of Agriculture, November.

Kirwan, Barrett E., Shinsuke Uchida, and T. Kirk White. 2012. "Aggregate and Farm-Level Productivity Growth in Tobacco: Before and After the Quota Buyout." *American Journal of Agricultural Economics* 94(4): 838–53.

Kislev, Yoav, and Willis Peterson. 1982. "Prices, Technology and Farm Size." *Journal of Political Economy* 90(3): 578–95.

Lucas, Robert E., Jr. 1978. "On the Size Distribution of Business Firms." *Bell Journal of Economics* 9(2): 508–23.

Luttmer, Erzo G. J. 2011. "On the Mechanics of Firm Growth." *Review of Economic Studies* 78(3): 1042–68.

MacDonald, James M., and William D. McBride. 2009. *The Transformation of U.S. Livestock Agriculture: Scale, Efficiency and Risks.* Economic Information Bulletin No EIB-43. US Department of Agriculture, Economic Research Service, January.

MacDonald, James M., Penni Korb, and Robert A. Hoppe. 2013. *Farm Size and the Organization of U.S. Crop Farming.* Economic Research Report No. ERR-52, Economic Research Service, US Department of Agriculture. August.

McBride, William D., and Nigel Key. 2013. "U.S. Hog Production from 1992 to 2009: Technology, Restructuring, and Productivity Growth." Economic Research Report No. ERR-158, US Department of Agriculture, Economic Research Service, October.

Melhim, Almuhand, Erik J. O'Donoghue, and C. Richard Shumway. 2009. "Do the Largest Firms Grow and Diversify the Fastest? The Case of U.S. Dairies." *Review of Agricultural Economics* 31(2): 284–302.

Mosheim, Roberto, and C. A. Knox Lovell. 2009. "Scale Economies and Inefficiency of U.S. Dairy Farms." *American Journal of Agricultural Economics* 91(3): 777–94.

National Agricultural Statistics Service, United States Department of Agriculture. 1994. *California Agricultural Statistics 1993,* November, pg. 16. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/1993cas-all.pdf.

National Agricultural Statistics Service, United States Department of Agriculture. 1994–2011. "Agricultural Statistics Annual." United States Department of Agriculture. http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp (accessed March 7, 2013).

National Agricultural Statistics Service, United States Department of Agriculture, 2012. *California Agricultural Statistics, 2011 Crop Year.* October 31. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2011cas-all.pdf.

O'Donoghue, Erik J., Robert A. Hoppe, David E. Banker, Robert Ebel, Keith Fuglie, Penni Korb, Michael Livingston, Cynthia Nickerson, and Carmen Sandretto. 2011. *The Changing Organization of U.S. Farming.* Economic Information Bulletin No. EBI-88, Economic Research Service, US Department of Agriculture. December.

O'Donoghue, Erik J., Robert A. Hoppe, David Banker, and Penni Korb. 2009. *Exploring Alternative Farm Definitions: Implications for Statistics and for Program Eligibility.* Economic Information Bulletin No. EBI-49, Economic Research Service, US Department of Agriculture. March.

Risk Management Agency, United States Department of Agriculture. 2013. "Program Costs and Outlays." http://www.rma.usda.gov/aboutrma/budget/costsoutlays.html.

Roberts, Michael J., and Nigel Key. 2008. "Agricultural Payments and Land Concentration: A Semiparametric Spatial Regression Analysis." *American Journal of Agricultural Economics* 90(3): 627–43.

Sneeringer, Stacy Ellen, and Nigel Key. 2011. "Effects of Size-Based Environmental Regulations: Evidence of Regulatory Avoidance." *American Journal of Agricultural Economics* 93(4): 1189–1211.

Sumner, Daniel A. 1985. "Farm Programs and Structural Issues." In *U.S Agricultural Policy: The 1985 Farm Legislation,* edited by Bruce L. Gardner, AEI Symposia series no. 85C, pp. 283–320. Washington, DC.

Sumner, Daniel A., and James D. Leiby. 1987. "An Econometric Analysis of the Effects of Human Capital on Size and Growth among Dairy Farms." *American Journal of Agricultural Economics* 69(2): 465–70.

Sumner, Daniel A., Julian M. Alston, and Joseph W. Glauber. 2010. "Evolution of the Economics of Agricultural Policy." *American Journal of Agricultural Economics* 92(2) 403–23.

Sumner, Daniel A., and Christopher A. Wolf. 2002. "Diversification, Vertical Integration, and the Regional Pattern of Dairy Farm Size." *Review of Agricultural Economics* 24(2): 442–57.

Tolley, George S. 1970. "Management Entry into U.S. Agriculture." *American Journal of Agricultural Economics* 52(4): 485–93.

US Department of Agriculture. 1992, 1997, 2002, 2007. "Census of Agriculture." http://www.agcensus.usda.gov/Publications/Historical_Publications/index.php (accessed March 7, 2013).

US Small Business Administration. Undated. "What is SBA's Definition of a Small Business Concern?" United States Small Business Administration. http://www.sba.gov/content/what-sbas-definition-small-business-concern (accessed March 9, 2013).

White, T. Kirk, and Robert A. Hoppe. 2012. *Changing Farm Structure and the Distribution of Farm Payments and Crop Insurance.* Economic Information Bulletin No. EIB-91, Economic Research Service, US Department of Agriculture. February.

Wolf, Christopher A., and Daniel A. Sumner. 2001. "Are Farm Size Distributions Bimodal? Evidence from Kernel Density Estimates of Dairy Farm Size Distributions." *American Journal of Agricultural Economics* 83(1): 77–88.