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Consolidation in U.S. Dairy Farming

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Abstract

The number of licensed U.S. dairy herds fell by more than half between 2002 and 2019, with an accelerating rate of decline in 2018 and 2019, even as milk production continued to grow. As a result, production has been shifting to much larger but fewer farms. Larger operations realize lower costs of production, on average, and those advantages persist. This structural change also features shifts in the location of dairy farming and in the production practices used on farms. This report, following upon two earlier ERS reports on the subject, details how the dairy sector has been transformed, and assesses the financial and productive factors behind that transformation.

Keywords: Farm consolidation, dairy sector, milk production, dairy farms, dairy herd size, commodity costs and returns, net returns.

Acknowledgments

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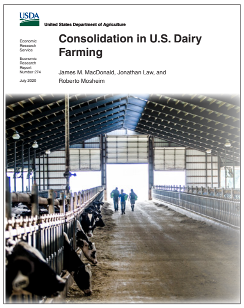


Consolidation in U.S. Dairy Farming

James M. MacDonald, Jonathan Law, and
Roberto Mosheim

What Is the Issue?

Dairy farm closures have attracted widespread news coverage in recent years. Small and midsized dairy farms have been facing significant financial challenges. During 2018, milk prices fell, and the gap between milk prices and feed costs narrowed. As a wave of farm closures in the industry hit many traditional dairy States in the Northeast and Midwest, the number of dairy farms licensed to sell milk fell by 15 percent between 2017 and 2019.

In response to these financial challenges, Congress expanded support for dairy farms in 2018, with a primary focus on smaller operations. In the Bipartisan Budget Act of 2018, and later in the 2018 Agriculture Improvement Act, Congress restructured premiums charged to farmers and extended coverage of a major Federal dairy support program, renamed the Dairy Margin Coverage (DMC), and made adjustments to other dairy-related programs. These changes are expected to substantially increase Federal expenditures in support of dairy producers.

This report details the continuing structural and geographic transformation of U.S. dairy farming, identifies the financial and productive factors that have driven those structural and geographic shifts, and evaluates prospects for further consolidation.

What Did the Study Find?

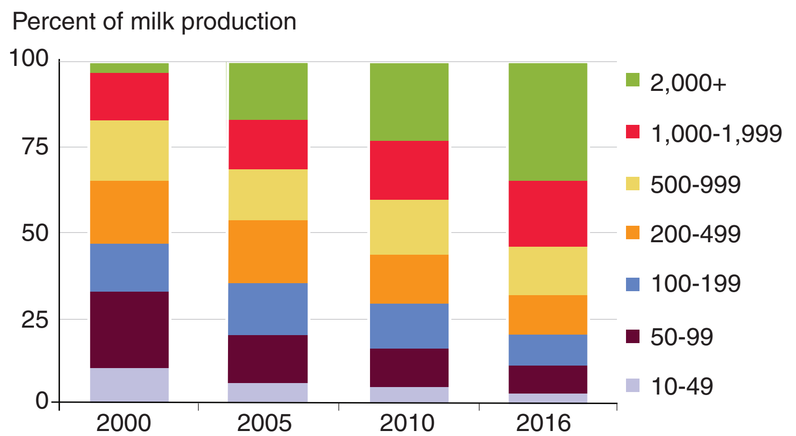
- In 1987, half of all milk cows in the United States were in herds of 80 or more, and half were in herds of 80 or fewer. Since that time, the midpoint size has risen consistently; by 2017, the midpoint was 1,300 cows. The pace of consolidation in dairy far exceeds the pace of consolidation seen in most of U.S. agriculture.

- The 2017 Census of Agriculture counted 54,599 farms with milk cows. Of those farms, 30,373 were small commercial farms, with 10–199 cows. The number of small commercial dairy farms has fallen substantially over time, from 47,873 a decade before (in 2007), and 146,685 three decades before (in 1987).

- By 2017, nearly 2,000 farms had herds of at least 1,000 milk cows, and those farms milked over half of U.S. cows. Twenty-five years earlier, there were just over 500 such farms, and they milked less than 10 percent of cows. Over time, production has shifted toward much larger farms, often with 5,000 or more cows.

- The major dairy States in the Northeast and Midwest have long had many small commercial dairy farms, while production in the major Western Dairy States has revolved around large farms. Production in all States is shifting to larger operations, but the decline of small commercial dairy farms is concentrated in the Midwest and Northeast, and in four States in particular: Minnesota, New York, Pennsylvania, and Wisconsin.

Milk production has shifted to larger herds



- There are powerful cost incentives behind farm consolidation. Larger dairy farms have substantially lower costs of production, on average, than smaller farms. This cost advantage appears to extend across a wide range of larger sizes, with farms with 2,000 cows realizing lower costs than farms with 1,000 cows, which in turn realize lower costs than farms with 500 cows.

- Some farms in each size class are profitable. Although herd size is a powerful determinant of costs and returns, there is wide variation of costs and of net returns among farms, even within narrowly defined size classes. Weather, location, physical infrastructure, and management can each affect the financial performance of a dairy farm.

- Dairy farms that are certified organic showed higher net returns per hundredweight (cwt) than similarly sized conventional dairy farms in 2016. Organic operations with 100–199 cows and larger showed positive net returns on average, while only very large conventional operations of 2,000 or more cows showed positive net returns on average. However, there are significant costs associated with making a transition from conventional to organic production.

- Many farms with gross returns less than total costs will continue to operate if they are covering all noncapital costs, as their operators can earn a better living from dairy farming than from other pursuits. Dairy farm exit is therefore a gradual process, playing out over years, and so consolidation is also a gradual process.

- The number of licensed dairy herds fell by more than half between 2002 and 2019, and the rate of decline accelerated in 2018–2019, even as milk production continued to grow. Consolidation will likely continue. Dairy finances still favor larger operations, and while there are fewer small commercial dairy farms today, many operators are approaching retirement age. Should the number of farms continue to decline at a rate of 4 percent per year, in line with past trends and a model developed in the report, then we should expect to count about 31,500 licensed dairy herds at the end of 2021, down from 34,187 in 2019.

How Was the Study Conducted?

The study relied on farm-level records drawn from two U.S. Department of Agriculture (USDA) sources: the Census of Agriculture and the Agricultural Resource Management Survey (ARMS). Census records provide detailed information on farm structure and location, while ARMS records supplement census evidence on farm structure, and add information on farm costs, production practices, and financial performance. The report also relies on data from USDA's National Agricultural Statistics Service (NASS), Agricultural Marketing Service (AMS), and Economic Research Service (ERS) for further information on industry prices and production trends.

Introduction

Dairy farming in the United States continues to undergo a major transformation. Thirty years ago, over 200,000 farms had milk cows, with most of those cows in herds of 80 or fewer. Today, even though total U.S. milk production is about 50 percent greater than it was 30 years ago, the number of dairy farms has fallen by three-quarters, and most cows are on farms with well over 1,000 cows.

This long-term structural change toward far fewer but much larger farms also features important shifts in how and where dairy farming is done. Production has shifted to Western States and is concentrated in a smaller number of counties. Families that own larger dairy farms provide less of the labor used on farms, with that labor provided primarily by hired workers. Cows are less likely to graze in pastures and are more likely to be confined within large barns and lots. Most farms still grow crops for feed, but more of the feed ration is purchased, with some large farms relying entirely on purchased feed.

Recently, small and midsized dairy farms have been facing significant financial challenges, which may accelerate consolidation. During 2018, milk prices fell and the gap between milk prices and feed costs narrowed. Net returns to milk production, an average reported by the USDA's Economic Research Service (ERS), fell to -$3.10 per hundredweight (cwt) of milk produced, from -$0.05 in 2017 (that is, total costs exceeded gross returns). As a wave of farm closures hit many of the traditional dairy States in the Northeast and Midwest, the number of dairy farms licensed to sell milk fell by 15 percent between 2017 and 2019.

In response to these closures, Congress took steps in 2018 to expand support for dairy farms, with a primary focus on smaller operations. In the Bipartisan Budget Act of 2018, Congress amended existing legislation to reduce premiums charged to farmers for margin coverage under the Margin Protection Program for Dairy (MPP-Dairy). Later, in the 2018 Agriculture Improvement Act, Congress made further substantial changes to the program—renamed the Dairy Margin Coverage (DMC) program—and made adjustments to other dairy-related programs. These changes are expected to lead to substantial increases in Federal expenditures in support of dairy producers.

Dairy farm closures have attracted widespread news coverage, with some reporting focused on recent financial pressures and policy developments (McCausland, 2018; Rappeport, 2019; Healy and Pager, 2019), and other reporting focused on longer term trends affecting the industry (Goodman, 2018; Wertlieb and Bodette, 2018; Eller, 2018), including shifts of production to larger dairy operations.

This report focuses on the long-term structural shift toward larger dairy farms. It measures and describes that shift, analyzing differences in production costs and returns between large and small farms, as well as differences in technology and organization that underlie differences in production costs. The report places these developments in the context of long-term trends in milk prices, feed costs, dairy farm financial performance, and milk production.

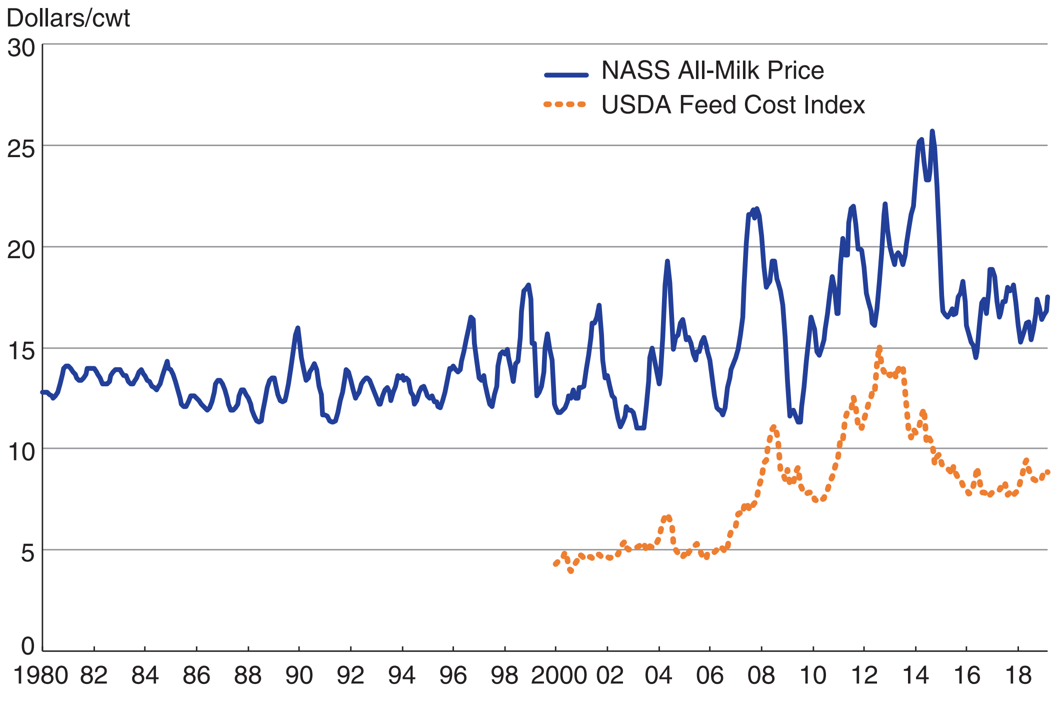
We extend the analysis from two earlier ERS reports on structural change in dairy farming. MacDonald et al. (2007) assessed dairy farm consolidation through the 1990s and into the early 2000s, with an additional focus on the associated consolidation of manure production and nutrient runoff. MacDonald, Cessna, and Mosheim (2016) assessed dairy consolidation through 2012, tying the analysis to important changes in domestic dairy product demand, international trade in dairy products, and dairy policy. This report extends the analysis of consolidation through 2018 and emphasizes structural change and industry financial performance.

The report relies heavily on two USDA data sources: the Census of Agriculture, conducted every 5 years, and the annual Agricultural Resource Management Survey (ARMS). Census records provide detailed information on farm structure and location, while the ARMS supplements census evidence on farm structure, and adds information on farm costs, production practices, and financial performance. ARMS is an annual survey, with focused dairy versions (providing greater dairy-related detail) in 2000, 2005, 2010, and 2016. The report also uses annual data, through 2018 and 2019, drawn from other USDA surveys. See Appendix A for more information on each data source, and on the development of measures of farm costs and returns that are based on ARMS.

Milk Production, Prices, and Costs

To set the stage for this report, we first summarize several important long-term features of the industry. Figure 1 shows monthly milk prices since 1980, and monthly composite feed costs since 2000. Each is based on data developed at the U.S. Department of Agriculture, primarily from its National Agricultural Statistics Service (NASS).[1]

Figure 1
Monthly milk prices and feed costs, 1980-2019



Note: cwt = hundredweight.

Sources: USDA, Economic Research Service calculations of feed cost index using soybean meal component from USDA, Agricultural Marketing Service; alfalfa and corn price components and the all-milk price from USDA, National Agricultural Statistics Service (NASS).

[1]The milk price is the average monthly "all-milk" price received by farmers and reported by USDA, National Agricultural Statistics Service (NASS). The feed cost measure is FC=1.0728*Pc + 0.0137*Pa + 0.00735*Ps. Pc and Pa are monthly corn and alfalfa prices received by farmers (as reported by NASS), while Ps is the average price of soybean meal reported for Central Illinois rail shipments by USDA's Agricultural Marketing Service (AMS). The weights were specified in legislation in 2014 and reflect the amount of each feed component used to produce a hundred pounds of milk. We extended the series back to 2000 using the specified weights and the NASS and AMS prices. The feed cost formula was revised by USDA in 2019 to account for two types of alfalfa; we have retained the original formula.

Milk prices showed little trend from 1980 through 2004; the monthly price averaged $13.10 per cwt during the 1980s, and $13.60 from 1990 through 2004. Average prices then rose after 2004, in line with increases in feed costs, with average milk prices of $15.70/cwt from 2005 through 2009 and $19.70 from 2010 through 2014, before falling back to $16.60 from 2015 through 2019.[2]

However, month-to-month *variations* in prices clearly rose over time. During the 1980s, monthly prices ranged from a low of $11.30/cwt to a high of $14.30/cwt. In the 1990s, that range expanded to $11.30 to $19.30—and in the 2000s, the range expanded again to $11.00 to $21.90. Prices showed very sharp changes over several short periods: from $17.10/cwt in September 2001 to $11.10 by the following July, and from $11.00 in June 2003 to $19.30 11 months later. Alternatively, compare the average July price over four consecutive years: from $11.60 in 2006 to $21.60 in 2007 and $19.30 in 2008, before falling to $11.30 in July 2009.

Farmers face considerable income risk from milk price fluctuations and have faced widening income risks from feed cost fluctuations since 2004. The composite average feed cost rose from $4.90 per hundredweight of milk produced in August 2006 to $11.11 by July 2008. The price fell back to $7.40 in March 2010, before spiking to $15.12 in August 2012. Moreover, milk prices and feed costs have not always moved in concert: the margin between the two narrowed sharply in 2006, 2009, 2012, 2016, and in 2018. Thus, dairy farmers operate in an environment of significant price risks for both their milk sales and their feed purchases (MacDonald, Cessna, and Mosheim, 2016). When those risks break in favorable ways (such as when high milk prices coincide with low feed costs), dairy farms can generate high earnings, as in 2007 and 2014. When the risks break in unfavorable ways, as they did in 2009 and 2012, farms face severe financial pressures.

Why are milk prices so volatile? Dairy markets, like other commodity markets, have certain features that make them prone to price volatility. Milk supply varies little, in the short to medium term, in response to changes in price. Moreover, dairy product demand responds only weakly to price changes; consequently, shifts in demand for dairy products require substantial changes in price to equate quantities demanded with quantities supplied in dairy markets.[3]

Dairy product demand may shift unexpectedly in response to changes in U.S. incomes and population. Changes in incomes associated with business cycles—recessions and expansions—can lead to unanticipated but noticeable changes in demand. For example, the 3.8 percent decline in U.S. per capita disposable incomes during the 2008–2009 recession led to declines in dairy product demand during those years and contributed to the fall in milk prices in 2009 (MacDonald, Cessna, and Mosheim, 2016).

[2]A cwt is 100 pounds of milk (11.63 gallons) and is a standard unit of account in the dairy industry.

[3]See MacDonald, Cessna, and Mosheim (2016) and references therein for a more detailed analysis of price fluctuations and dairy demand.

Dairy product demand may also shift because of changes in foreign demand for U.S. dairy products. Commercial exports of U.S. dairy products have increased substantially since 2003, due to improved U.S. competitiveness in global markets, increased global demand for dairy products in importing countries, and changes in U.S. policies.[4] Increased export demand has supported greater U.S. milk production and has expanded cow inventories, and it is likely that that expansion has facilitated the entry of more large operations.

However, export sales of U.S. dairy products can change sharply due to economic factors or revisions to the dairy policies of other countries, due to weather-related changes in domestic or foreign milk production, or because of changes in exchange rates. For example, U.S. dairy exports fell sharply during the global recession in 2008–09, placing additional pressure on domestic prices. Since then, exports rose to a new peak in 2014, before falling sharply in 2015–2016. Export markets add an important source of demand for U.S. producers, but also add an additional source of volatility in prices.

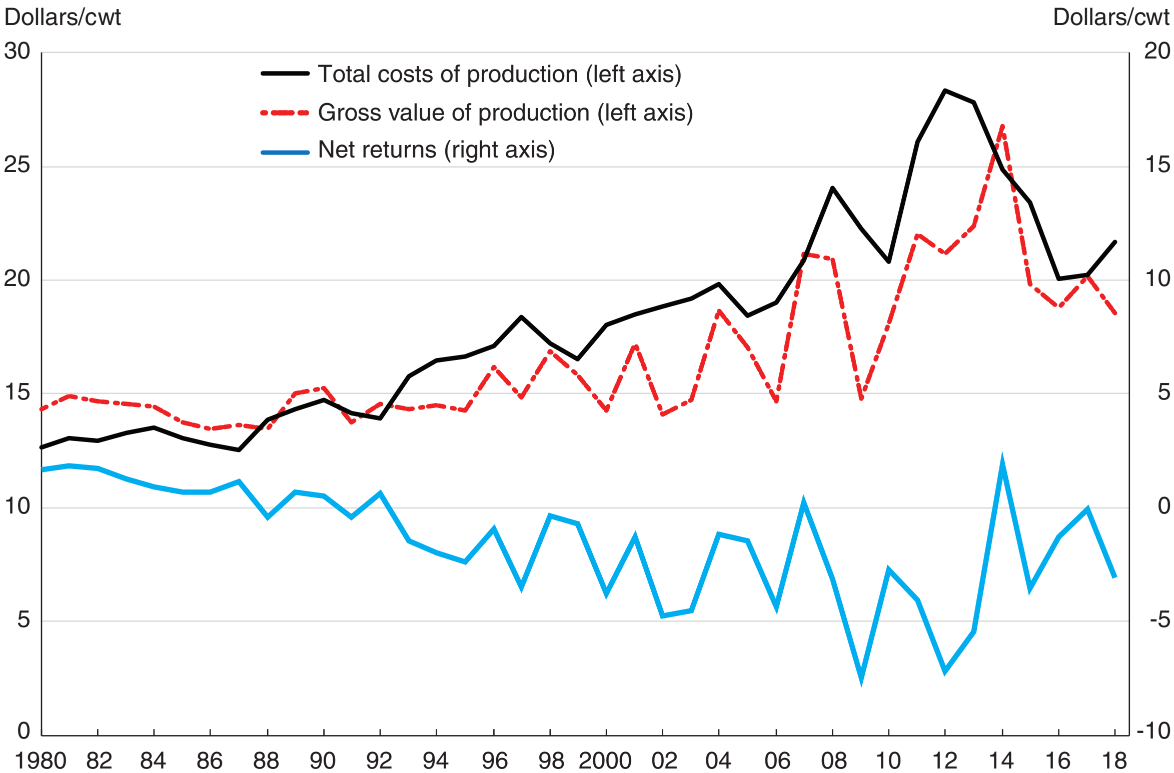
Trends in Net Returns

Industry average net returns show a declining trend since 1980, as well as wider fluctuations (figure 2). Net returns measure the difference between the gross value and the total cost of milk production, with that difference expressed on a per-cwt basis.[5] ERS estimates annual milk costs and returns as part of its commodity costs and returns (CAR) program.

[4]Some of that improved competitiveness on world markets derives from consolidation, as the shift of U.S. production toward larger and lower-cost farms placed downward pressure on industry-average costs and prices (MacDonald, Cessna, and Mosheim, 2016).

[5]Milk sales comprise about 90 percent of the gross value, which also includes revenue from selling culled milk cows and young calves, as well as the fertilizer value of manure produced by the dairy herd. Total costs include cash operating expenses, the annualized replacement costs of the farm's capital, the costs of hired and family labor, and a share of farm overhead expenses.

Figure 2
Milk costs and returns, 1980-2018



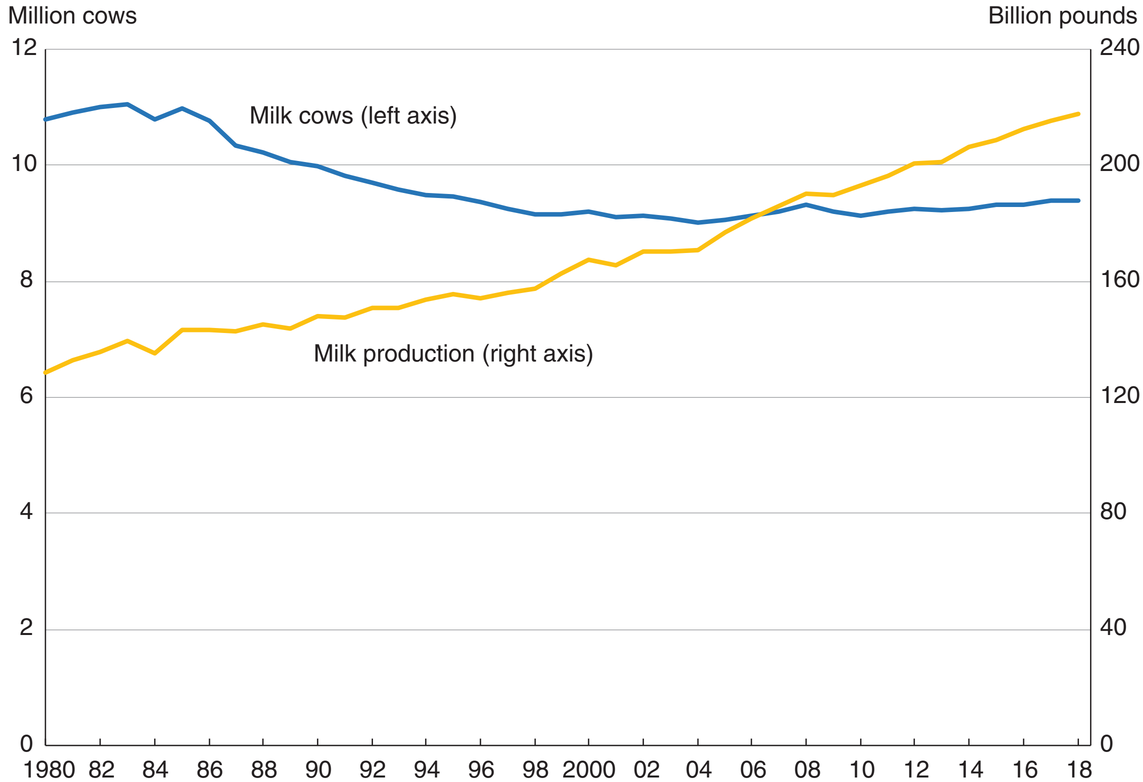
Note: cwt = hundredweight.

Source: USDA, Economic Research Service, Milk Costs and Returns Estimates.

During the 1980s, the sector's net returns were positive, on average, due to a dairy policy aimed at supporting milk prices. However, positive returns induced an expansion of herds and production, necessitating additional policy steps and public expenditures geared toward controlling production (MacDonald, Cessna, and Mosheim, 2016). Figure 2 shows clearly the impact of fluctuating milk prices on gross and net returns during the 1990s, and especially after 2000, as policy shifted from supporting prices. The impact of the sharp movements in feed prices on total production costs after 2006 can also be seen clearly in figure 2. Finally, notice the steady average decline in net returns per hundredweight over time, with deep troughs reached in 2009 and in 2012.

Despite negative net returns in many years and growing price risks, milk production has continued to expand at a steady annual rate: 1.4 percent per year since 1980, with particularly steady growth since 2002 (figure 3). Those gains reflect steady improvements in milk yields (production per cow). The cow herd, which was 10.8 million cows in 1980, fell to 9.0 million by 2004, before recovering to 9.4 million cows by 2018. In turn, improvements in milk yields reflect steady improvements in dairy cow genetics, feed formulations, and on-farm practices.

Figure 3
U.S. milk cows and milk production, 1980-2018



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Milk Production*.

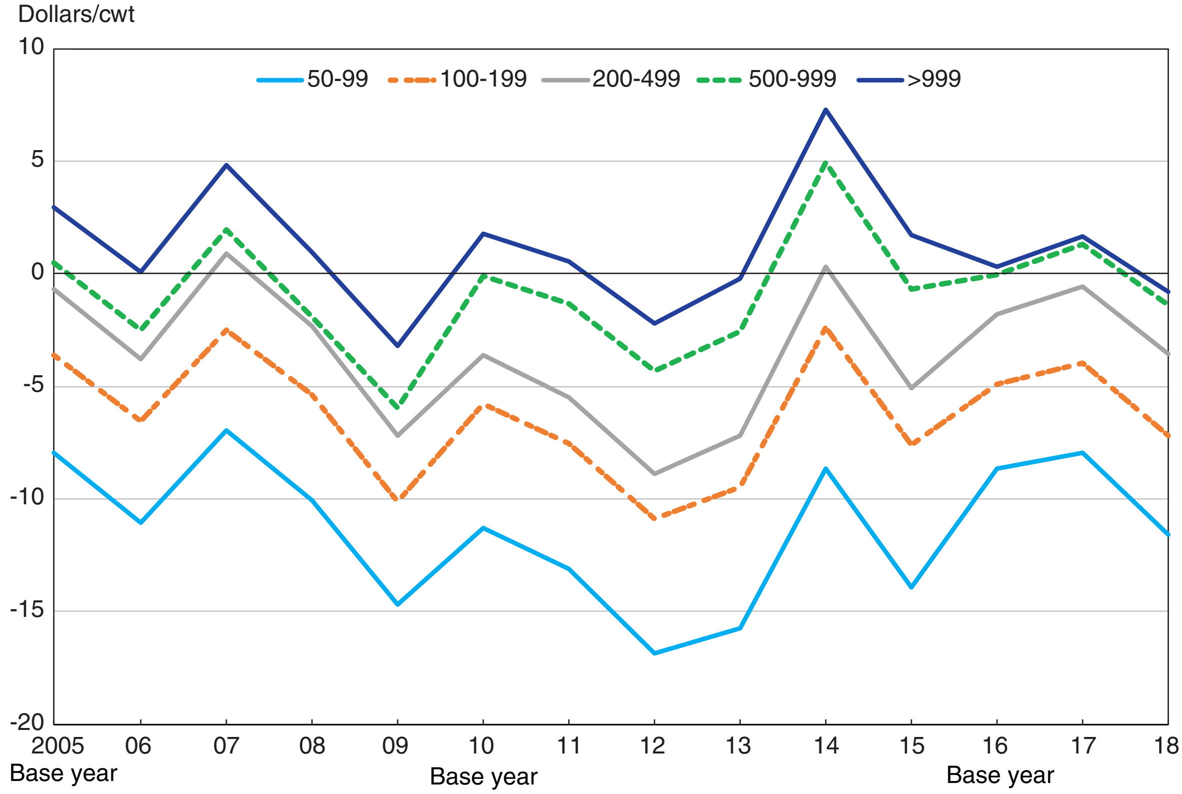
Why do we see expanded production when average industry-wide net returns are persistently negative? Net returns vary widely across farms. Some groups of dairy farms appear to earn consistently high returns, even as others lose money and gradually contract. Figure 4 tracks net returns from 2005 through 2018 for five different herd size classes: farms with 50 to 99 cows, farms with 100 to 199 cows, farms with 200 to 499 cows, farms with 500 to 999, and farms with 1,000 or more cows.[6]

The patterns in figure 4 are quite striking. Notice that net returns increase with herd size in every year—that is, larger herd size classes earned higher net returns. The difference between large and small herds is quite substantial. Notice that for farms in the smallest herd size class, net returns are negative in every year, while for farms in the largest herd size class, net returns are positive in 10 of the 14 years shown. Farms in the largest herd size class had average net returns of $1.12/cwt between 2005 and 2018.[7]

[6]ERS develops milk costs and returns estimates for base years (2005, 2010, and 2016 in figure 4) based on detailed dairy enterprise information collected in ARMS dairy surveys in those years. Between base years, ERS adjusts costs and returns estimates based on changes in input and product prices and production. See Appendix A for details.

[7]For a dairy enterprise of a large farm, we can convert returns per cwt to total net returns. If, for example, a farm operates a herd of 2,000 cows, with average milk production per cow of 25,000 pounds (250 cwt), then a return of $1.12 per cwt would generate total net milk returns for the farm of $560,000. Farms in small size classes produce less milk per cow (closer to 150 cwt for herds of 50 or less), so a 50-cow herd with a net return of -$10.00 would generate a farm-level net return of -$75,000.

Figure 4
Net returns by herd size, 2005-2018



Note: cwt = hundredweight.

Source: USDA, Economic Research Service, Milk Costs and Returns Estimates.

The ERS measure of the cost of milk production aims to include all economic costs. For example, the measure accounts for opportunity costs of farm labor and of home-grown feed (that is, what the farmer could have earned from working off the farm or from selling the feed). It also accounts for the costs of livestock and physical capital to the farm. In the ERS measure, positive net returns are equivalent to economic profits—returns on the capital invested in the farm business that exceed what investors could make elsewhere, on average, in the economy. Positive net returns should induce expanded investment, since they signal relatively high returns to that investment. This is the case, too, with the largest class of farms, as new farms enter and smaller farms invest in expansion to larger sizes. We should not see expanded investment into classes with persistent negative returns. Disinvestment and exit in those classes, however, has been gradual.

The persistent differences in net returns have led to powerful and ongoing structural changes in the industry, with shifts of cows and production away from smaller farms and toward larger ones. The structural changes also encompass regional shifts in production.

We turn next to a closer examination of the structural changes affecting the industry, and then return to a more detailed analysis of the ERS costs and returns estimates for dairy farms.

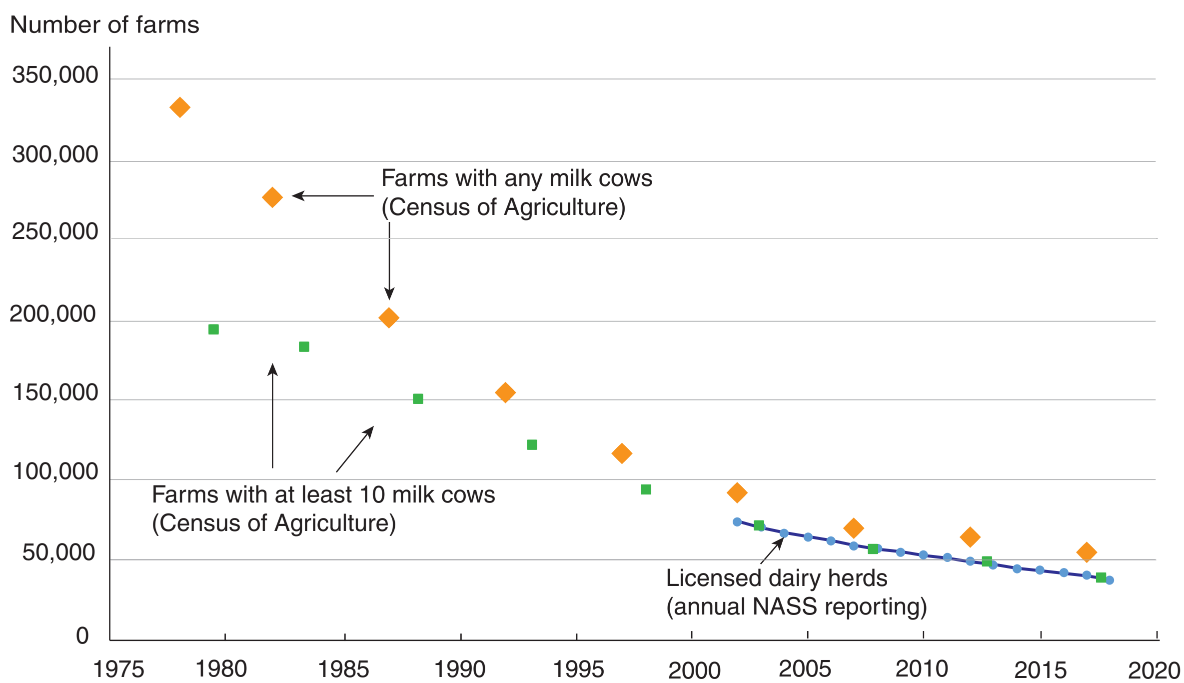
Dairy Farm Structure: Farms, Herds, and Production

The number of U.S. dairy farms has been shrinking, even as milk production continues to increase. There were 74,100 licensed dairy herds in the United States in 2002. The number of herds fell to 34,187 by 2019 (figure 5).[8]

The number of licensed dairy herds fell in each year between 2002 and 2017, at an average annual rate of 4.0 percent. However, that rate of decline accelerated in 2018 and 2019. The number of licensed herds fell by 2,731 farms in 2018 alone, or 6.8 percent of the 2017 total, and then fell another 8.8 percent in 2019 as the total fell by 3,281 farms.

The nationwide estimate of licensed herds is based on the average number of herds during a year. More detailed monthly counts from the State of Wisconsin show increasing rates of exit from 2017, to the nearly end of 2019 (figure 6). Wisconsin licensed herds declined at an average annual rate of about 4 percent in 2014–2016, in line with national trends. However, the rate of dairy farm exit in increased again in 2018, and in 2019 rose again to an annualized rate of over 10 percent through most of 2019, before falling off in late 2019 and early 2020.[9]

Figure 5
Dairy farm numbers have been declining for many years

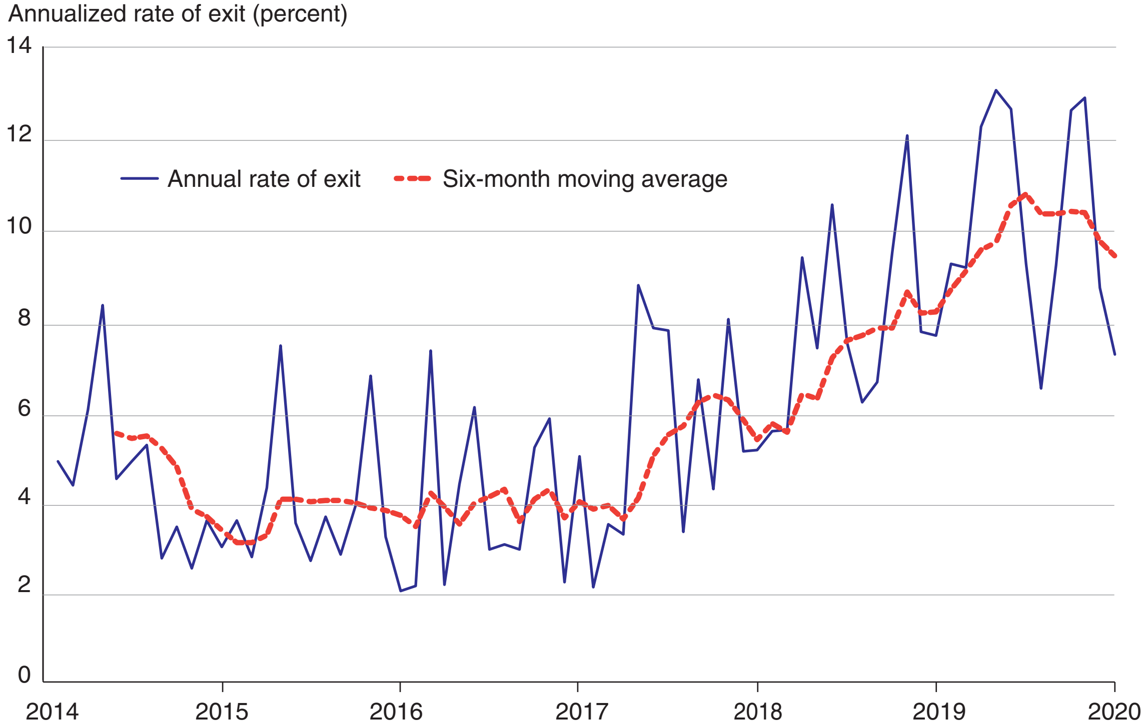


Sources: USDA, Economic Research Service using data for licensed dairy herds from USDA, National Agricultural Statistics Service (NASS), *Milk Production* February Issues, 2002-19; and for farms with milk cows from NASS, Census of Agriculture.

[8]To sell milk, dairy farmers must be licensed by State governments, in a process focused on sanitary standards. USDA, National Agricultural Statistics Service has tracked the number of licensed herds since 2002 and reports them in February issues of *Milk Production*.

[9]Wisconsin, the second-largest dairy State, accounts for over one-fifth of all U.S. licensed dairy herds. Developments in Wisconsin directly affect national trends because of the importance of the State's small and midsized herds, and likely signal developments in other States with similar farm structures (that is, in the Northeast and Upper Midwest). See Appendix B for more detail on farm structure in Wisconsin and other major dairy States.

Figure 6
Monthly exit rates, Wisconsin licensed dairy farms



Source: USDA, Economic Research Service using data for licensed dairy herds from USDA, National Agricultural Statistics Service.

Structural change was occurring before 2002, when NASS began publishing estimates of the number of licensed dairy herds. For a longer timespan, we can track the number of farms with milk cows, as reported in the Census of Agriculture.[10] This number has been declining for many years, from over 333,000 in 1978 to 54,599 in 2017.

Note, however, an important difference between the two sources. The number of farms with milk cows, as reported in the census, exceeds the number of licensed dairy herds. For example, the census reported 54,599 farms with milk cows in 2017, while NASS reported 40,199 licensed dairy herds (figure 5). The difference lies in farms that produce milk for their own consumption but do not sell milk. These farms tend to own just one or two cows.[11]

The distinction matters when assessing structural change. The financial pressures facing small commercial dairy farmers—those who sell milk, and for whom dairy production provides a livelihood—do not necessarily apply to operations that produce milk only for home consumption. We need to distinguish between these types of operations when evaluating consolidation in the industry.

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[10]The Census of Agriculture has been conducted in 5-year intervals, for years ending in 2 or 7, since 1982, and at 4-, 5-, or 10-year intervals before then, back to 1840.

[11]The census reports the number of farms with 1–9 cows. In 2017, there were 16,932 farms in that class, 30.7 percent of all farms with milk cows, and not much more than the difference between farms with cows and licensed dairy herds (14,580 farms). The average herd size among those farms was 2.3 cows, and it is likely that most did not sell milk. By way of comparison, over 137,000 farms had 1–9 cows in 1978. The census reported finer herd size breakdowns then, and 104,880 of those farms had 1–2 cows. Part of the long-term decline in farms with milk cows reflects farmer decisions to forego milking only for home consumption.

Developments among these very small noncommercial producers affect the census series, as we can see when we track the number of farms with at least 10 cows (figure 5). From 1978 through 2007, the number of farms with any cows substantially exceeds the number of farms with at least 10 cows, and also clearly declines more rapidly. This is because farms with fewer than 10 cows exited at a relatively rapid rate (7.5 percent per year) over the period, as many farm families stopped producing milk for their own consumption. After 2007, however, the trend reversed, and the number of herds with 1–9 cows began to rise, reflecting a modest increase in the number of farmers who keep cows for their own consumption.

If we focus on farms with at least 10 cows—which corresponds closely to farms that sell milk—the census series declines at an average annual rate of 4.2 percent from 1978 through 2017, and at 4.1 percent annually from 2002 to 2017, closely matching the 4.0 percent annual rate of decline of licensed dairy herds over 2002 to 2017. When assessing structural change, we account for trends in commercial herds, and distinguish them from farms that keep cows only for home consumption. The number of commercial dairy farms has been declining for many years, at a persistent average rate of just about 4 percent per year. Given the persistent long trend of decline, there is good reason to expect continued exit in the future.

Consolidation Into Larger Farms

With fewer dairy farms, average farm size has increased, measured either by milk production or herd size. The average number of cows per herd, according to census estimates, increased from 50 in 1987, to 99 in 2002, and finally to 175 in 2017. (This average includes all farms with milk cows.) Over the same 1987–2017 period, average milk production per farm rose more than five-fold, reflecting more cows per farm and more milk per cow. However, these simple averages understate the striking nature of consolidation that has occurred in the industry, as much larger farms—with herds of 5,000 cows, and some with 10,000 or more—have entered the industry.

In table 1, we sort farms with milk cows into 7 herd size categories, from the smallest class, with 1–9 cows, to the largest class, with more than 999 cows in the herd. We summarize Census of Agriculture data from six successive censuses (1992 through 2017) and report the number of farms and the share of the U.S. milk cow inventory by herd size class in each year. Several developments stand out:

- The number of farms in the smallest herd size class (1–9 cows) fell from 1992 to 2007, and so did the share of cow inventory for farms of that size class. The decline was not as rapid as that in other small and midsize classes, and it stopped after 2007. Farm numbers in this class actually grew in 2007–2012 and grew again in 2012–2017. Since most of these farms do not sell milk, their decisions are likely based on considerations that differ from farms that do sell milk.

- There were large and persistent declines in the number of farms with 10–99 cows—a decline of over 80 percent in 1992–2017 for farms with 10–49 cows and over 70 percent for those with 50–99 cows. These were typical dairy farms in 1992, when they accounted for nearly half (48.5 percent) of all U.S. milk cows. By 2017, that share had fallen to 12.6 percent.

- In 1992, a dairy farm with 100–199 cows was a relatively large farm. Over the next 25 years, farms in that class saw their numbers, and their share of inventory, fall by more than half.

- These three classes of small commercial farms (10–199 cows) collectively accounted for over 68 percent of all U.S. milk cows in 1992, but just 22 percent in 2017. Even by 2017, there were still 30,373 of these small commercial operations, three-quarters of all licensed dairy herds. It is among these classes that exit has been concentrated, primarily through closures of existing operations and as some farms have expanded to larger sizes. Many of those remaining face increasing financial pressures.

- Inventory has shifted to the largest size class. In 1992, the census counted 564 farms with at least 1,000 cows, and those farms accounted for less than 10 percent of all cows. Twenty-five years later, nearly 2,000 farms had herds of that size, and they accounted for 55 percent of U.S. inventory.

The pace of consolidation in dairy exceeds that in most of U.S. agriculture (MacDonald, Hoppe, and Newton, 2018). Consolidation in U.S. crop production was widespread across crops and was persistent over time; over 30 years, consolidation in crops doubled. The equivalent measure in dairy shows a 16-fold increase in 30 years. In livestock, consolidation in hogs and in eggs occurred at a pace similar to the pace of dairy, but consolidation in other livestock sectors lagged far behind.[12]

The largest size class reported in table 1 (1,000 or more cows) encompasses a wide range of actual herd sizes, with production moving to much larger farms over time. We use a cut-off of 1,000 or more in table 1 because that was the largest class reported in census publications in 1992–2002. As the frontiers of herd size expanded, NASS split that class into two classes, beginning with the 2007 census—1,000–2,499 head and 2,500 or more—and then split the largest class again in the 2017 census, with categories for 2,500–4,999 and 5,000 or more cows. The 189 farms with 5,000 or more cows in 2017 accounted for over 1.5 million milk cows (16.4 percent of the total). They have multiplied rapidly: MacDonald, Cessna, and Mosheim (2016) identified 8 such farms in 1992 census records, compared with 47 in 2002 and 142 in 2012. Today, the largest dairy farms in the country milk more than 25,000 cows, usually organized into a series of pods comprised of cow barns or lots, manure storage units, feed bunkers, and milking facilities.

[12]MacDonald, Hoppe, and Newton (2018) relied on a midpoint farm size—the size of farm at which half of all acres (or animals, in livestock measures) was on larger farms, and half on smaller. Census of Agriculture records allow researchers to measure midpoints precisely, over many years. Many commodities displayed a doubling or tripling in midpoint farm sizes over 1987–2012. For example, the midpoint for harvested corn acreage increased from 200 acres in 1987 to 633 in 2012, while the wheat midpoint increased from 404 acres in 1987 to 1,000 in 2012. The 1987 midpoint size for broilers was 300,000 removed in a year, compared with 680,000 in 2012. By contrast, the midpoint dairy herd was 80 milk cows in 1987, and 900 in 2012. More recent 2017 census data puts the dairy midpoint at 1,300 cows, a 16-fold increase over 1987.

Table 1
The changing size structure of U.S. dairy farms, 1992–2017

Herd size (Milk cows)	1992	1997	2002	2007	2012	2017
	Number of farms with milk cows					
1–9	32,803	22,824	21,016	14,426	16,463	16,932
10–49	60,315	40,833	27,244	19,912	17,869	11,479
50–99	41,813	33,477	25,465	18,986	15,351	12,137
100–199	14,062	12,602	10,816	8,975	7,359	6,757
200–499	4,652	4,881	4,546	4,307	3,712	3,830
500–999	1,130	1,379	1,646	1,702	1,537	1,511
>999	564	878	1,256	1,582	1,807	1,953
Total	**155,339**	**116,874**	**91,989**	**69,890**	**64,098**	**54,599**
	Share (percent) of U.S. milk cow inventory					
1–9	0.9	0.7	0.6	0.4	0.4	0.4
10–49	19.5	13.8	9.2	6.8	5.9	3.6
50–99	29.0	24.5	19.1	13.8	11.1	8.6
100–199	19.0	18.0	15.4	12.8	10.6	9.4
200–499	13.7	15.3	14.7	13.8	12.0	12.0
500–999	8.0	10.2	12.2	12.5	11.3	10.7
>999	9.9	17.5	28.8	39.9	48.7	55.2
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture.

Consolidation in Milk Production

The Census of Agriculture reports on cows but does not track milk production. Milk production is highly correlated with the number of cows in a herd, but the correlation is not exact because milk yields (milk per cow) are generally higher in larger herds.

USDA's Agricultural Resource Management Survey (ARMS), jointly administered by ERS and NASS, elicits information on milk production as well as cow inventories. This annual survey of all U.S. farms includes specialized questionnaire versions aimed at representative samples of producers of target commodities in certain years. ARMS targeted dairy producers in 2000, 2005, 2010, and 2016. Those four Dairy Versions of ARMS also provide the baseline information for the ERS milk costs and returns estimates, used throughout this report, and they provide information on the location, organization, and production practices used on dairy farms, and so allow for deeper analyses of consolidation. More detailed information on ARMS can be found in Appendix A.

The ARMS Dairy Version targets a population that differs from that covered by the Census of Agriculture. It targets farms with at least 10 milk cows, while the census covers all farms with milk cows. ARMS also focuses on major dairy States (28 in 2016), while the census covers all States.

And ARMS is carried out in different years than the census. Nevertheless, ARMS data provide a useful complement to census findings.

We first compare ARMS and census inventory shares by size class, and then show how ARMS cow inventories relate to ARMS milk production estimates (table 2). Generally, the ARMS and census inventory shares for each herd size class are close to one another for nearby years. ARMS shares exceed census shares among smaller size classes—as they should since the ARMS estimates predate the census estimates—and structural change means that small-farm shares will shrink over time. There is one significant discrepancy: farms with at least 1,000 cows accounted for 30 percent of the ARMS inventory in 2005, and 39.9 percent of the 2007 census inventory. That's a large jump in a 2-year period, and it suggests that ARMS may have underrepresented large farms in 2005.

Now compare ARMS production shares to inventory shares. Cows on larger farms tend to produce higher annual milk yields than those on smaller farms, because larger farms are more likely to milk three times a day instead of two, and are more likely to aim for yield in herd selection and breeding decisions (MacDonald, Cessna, and Mosheim, 2016). As a result, small-herd inventory shares exceed their production shares, while large-farm milk production shares exceed their inventory shares.

Table 2

Cow inventories and milk production

Source	2007 Census	2005 ARMS		2017 Census	2016 ARMS	
Base	Cows	Cows	Production	Cows	Cows	Production
Herd size	Share (percent) of total U.S. inventory or production					
1–9	0.4	x	x	0.4	x	x
10–49	6.7	6.9	5.4	3.6	3.8	2.7
50–99	13.8	15.7	14.0	8.6	9.7	8.1
100–199	12.7	16.4	15.7	9.4	9.9	8.9
200–499	13.8	17.7	18.2	12.0	11.8	11.9
500–999	12.5	13.3	14.5	10.7	13.3	14.5
>999	39.9	30.0	32.2	55.2	51.5	53.9

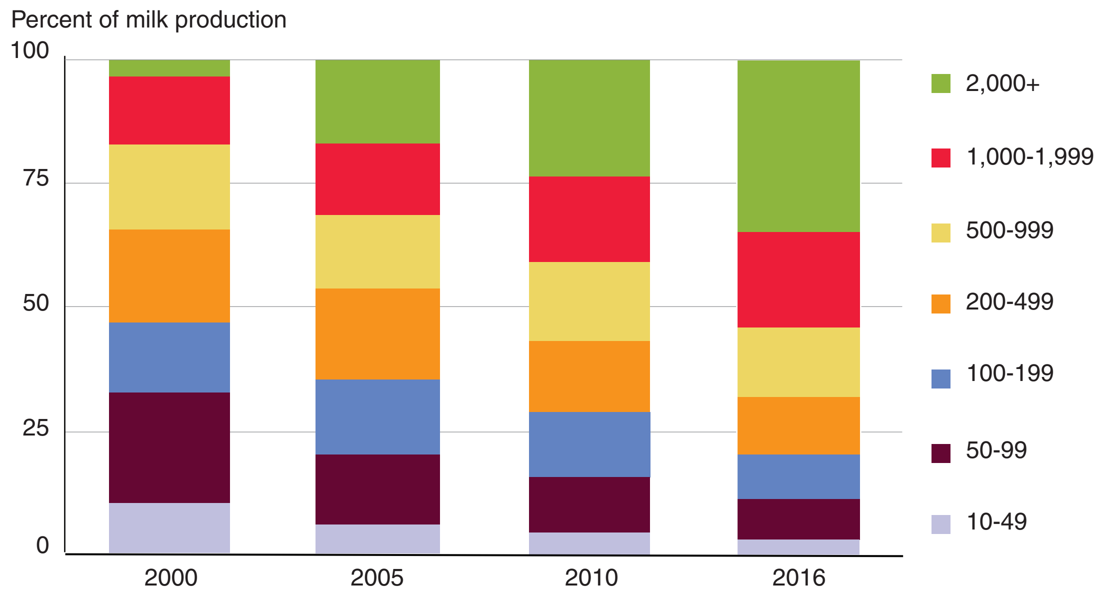
Note: x = not surveyed. The ARMS Dairy Version only surveys farms with at least 10 cows.

Source: USDA, Economic Research Service (ERS) using data from USDA, National Agricultural Statistics Service (NASS), 2007 and 2017 Census of Agriculture; and ERS and NASS, Agricultural Resource Management Survey, Dairy Version (2005 and 2016).

Production has been shifting to larger herds in the ARMS data, where we break large dairy farms into two classes: those with 1,000–1,999 head, and those with 2,000 head or more (figure 7). Note that production steadily shifted to both size classes between 2000 and 2016, but that the major expansion occurred in the larger class. In 2016, farms with at least 2,000 cows handled 35.2 percent of milk production, up from 4.5 percent in 2000. Farms in the next-largest class (1,000–1,999) head also expanded their share of production, from 13.4 percent in 2000 to 18.7 percent in 2016. Combined, these two classes accounted for 53.9 percent of U.S. milk production in 2016. Thus, the shift of production to farms with at least 1,000 head mirrored the movement of cows to those farms, and that movement is continuing.

The shift to farms with at least 2,000 head is largely a 21st Century phenomenon. MacDonald, Cessna, and Mosheim (2016) showed that such farms were appearing, primarily in Western States, during the 1990s, and that by the time of the 1997 census, there were just over 200. However, the total number of farms with at least 2,000 cows doubled between the 1997 and 2002 censuses, and then nearly doubled again between the 2002 and 2012 censuses, with continuing increases since. The frontier—the size of a dairy farm that we would call "large"—keeps expanding.

Figure 7
Milk production has shifted to larger herds



Source: USDA, National Agricultural Statistics Service, and USDA, Economic Research Service, Agricultural Resource Management Survey, Dairy Versions, 2000, 2005, 2010, 2016.

Location and Dairy Consolidation

Dairy production is concentrated in a relatively small number of States (table 3). California and Wisconsin—the largest and the second-largest milk production States—together accounted for nearly 33 percent of U.S. milk production in 2018, while the next six States—Idaho, New York, Texas, Michigan, Pennsylvania, and Minnesota—combined for 34 percent. Production has become more geographically concentrated as well: those top eight States accounted for 61 percent of total production in 1992. Geographic consolidation, too, extends to finer levels. In 1982, it took 50 U.S. counties to encompass 25 percent of all dairy cows, and 174 counties to capture 50 percent. By 2007, the corresponding numbers were 17 and 80 counties as cows were concentrated into fewer counties (O'Donoghue, et al. 2011).

There are important regional differences in dairy production (Sumner and Wolf, 2002). Farms in dairy production areas in the Northeast and Midwest have been smaller, more likely to have combined milk and feed production on the farm, have been more likely to graze their cows on pasture, and have relied primarily on family labor in the dairy enterprise. In contrast, farms in the West have been larger; are more likely to purchase most or even all of their feed and to confine cows in barns and lots instead of grazing them; and are more likely to rely heavily on hired labor for the dairy enterprise.

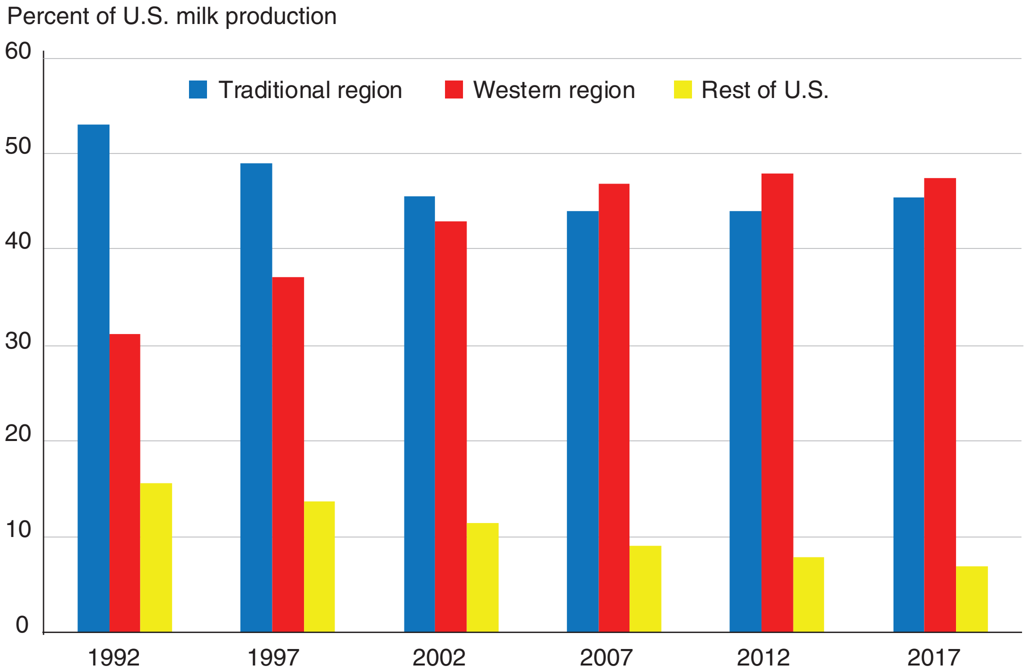
Table 3

Leading dairy States, 2018

Rank	State	Production (Million pounds)	Cows (1,000 head)
1	California	40,413	1,734
2	Wisconsin	30,579	1,274
3	Idaho	15,149	609
4	New York	14,882	623
5	Texas	12,852	537
6	Michigan	11,168	424
7	Pennsylvania	10,665	519
8	Minnesota	9,868	453
9	New Mexico	8,285	330
10	Washington	6,736	277
11	Ohio	5,532	259
12	Iowa	5,268	220
13	Arizona	4,978	208
14	Colorado	4,557	176
15	Indiana	4,161	184
16	Kansas	3,708	159
17	South Dakota	2,705	121
18	Vermont	2,680	127
19	Oregon	2,531	123
20	Florida	2,381	120
21	Utah	2,322	100
22	Illinois	1,878	90
23	Georgia	1,766	82
24	Virginia	1,635	83
25	Nebraska	1,440	60
	United States	**217,575**	**9,399**

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Milk Production* (March 12, 2019).

Figure 8
Milk production has shifted to Western States



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture.

To detail these regional patterns, we focus on two groupings of States: an Eastern region consisting of 10 major dairy production States, and a Western region of 11 major dairy States.[13] Together, the 21 States account for over 90 percent of U.S. milk cows and production. The Eastern Dairy States encompassed 45 percent of cows and 46 percent of milk production in 2017, while the Western Dairy States contained 46 percent of cows and 48 percent of production.

Over time, milk production has shifted to Western Dairy States (figure 8), which held 31 percent of U.S. production in 1992. That share rose to 47 percent by 2007, before stabilizing in 2012 and 2017 at about 48 percent. The share held by Eastern Dairy States fell by nine percentage points between 1992 and 2007, but has since risen, reaching 46 percent in 2017. Dairy production has declined steadily in the rest of the country, falling from nearly 16 percent of production in 1992 to 7 percent in 2017.

Eastern and Western Dairy States feature much different farm size distributions (table 4; see Appendix B for detailed State-by-State comparisons). While the Western States had more cows and higher production, the Eastern States had far more dairy farms in 2017: 35,153 farms, compared with 6,962 in the Western States. About 84 percent of milk cows in the Western States were in herds of 1,000 cows or more, compared with 30 percent of cows in the Eastern States. Each region had significant, and growing, numbers of very small herds (1–9 cows).

[13]The Eastern Dairy States are Illinois, Indiana, Iowa, Michigan, Minnesota, New York, Ohio, Pennsylvania, Vermont, and Wisconsin. The Western Dairy States are Arizona, California, Colorado, Idaho, Kansas New Mexico, Oregon, South Dakota, Texas, Utah, and Washington. We focus on census years (1992–2017) because the census reports data by herd size classes.

However, the Eastern Dairy States include far more small commercial dairy farms (those with 10–49, 50–99, and 100–199 cows): almost 25,000 in 2017, compared with 1,349 in Western States. That is, 80 percent of small commercial dairy farms are in the 10 Eastern Dairy States, while only 4 percent are in the 11 Western Dairy States. Moreover, 60 percent of small commercial dairy farms were in just four of the Eastern Dairy States—Minnesota, New York, Pennsylvania, and Wisconsin—and those States accounted for almost 10,000 of the 17,500 small commercial farms that disappeared from 2007 to 2017.

Table 4
Dairy farms and cow inventory by herd size and region, 2007 and 2017

Herd size	Eastern Dairy States		Western Dairy States	
	2007	2017	2007	2017
	Number of farms with milk cows			
1–9	5,067	6,502	3,033	3,142
10–49	16,083	9,448	759	444
50–99	15,678	10,222	714	455
100–199	6,172	5,004	822	450
200–499	2,505	2,579	1,071	688
500–999	649	798	898	555
>999	314	600	1,170	1,288
Total	**46,468**	**35,153**	**8,467**	**6,962**
	Share (percent) of milk cow inventory			
1–9	0.4	0.4	0.2	0.2
10–49	12.6	6.6	0.5	0.3
50–99	25.4	16.3	1.2	0.7
100–199	19.5	15.5	2.8	1.4
200–499	17.6	18.1	8.5	5.0
500–999	10.5	12.7	15.4	8.8
>999	14.0	30.4	71.4	83.6
Total	**100.0**	**100.0**	**100.0**	**100.0**

Note: Eastern dairy States are Illinois, Indiana, Iowa, Michigan, Minnesota, New York, Ohio, Pennsylvania, Vermont, and Wisconsin. Western dairy States are Arizona, California, Colorado, Idaho, Kansas, New Mexico, Oregon, South Dakota, Texas, Utah, and Washington.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture.

Dairy farm consolidation, in the form of shifts to much larger farms, proceeded in each region. Among Eastern Dairy States, the number of farms with at least 1,000 milk cows nearly doubled between 2007 and 2017, with a concomitant movement of cows (table 4). Consolidation came largely at the expense of small commercial dairy farms (10–199 cows), where farm numbers fell by more than one-third between 2007 and 2017.

The two regions are not monolithic. Within the group of Western Dairy States, production and cow inventories fell in California over 2007–2017 while rising noticeably in Idaho and in the Plains States of Texas, Kansas, and South Dakota. The shift from California likely reflects urbanization pressures and environmental regulations in the Nation's most populous State (Ash, 2018; Sneeringer, 2011). Among the Eastern Dairy States, there were substantial production increases in Wisconsin and New York over 2007–2017, driven by relatively large increases in milk yields, and increased inventories and production in Michigan and Indiana, reflecting investments in large-scale operations (Appendix B).

Dairy farm consolidation, and associated changes in production practices, has had important impacts on land use in Eastern Dairy States. In particular, the total amount of land used for pasture in the 10 Eastern Dairy States fell by nearly half from 1987 through 2017, from 21.6 million acres to 11.2 million, as fewer cows grazed on pasture. In contrast, total land used for pasture in the rest of the United States fell by only 15 percent during that period.

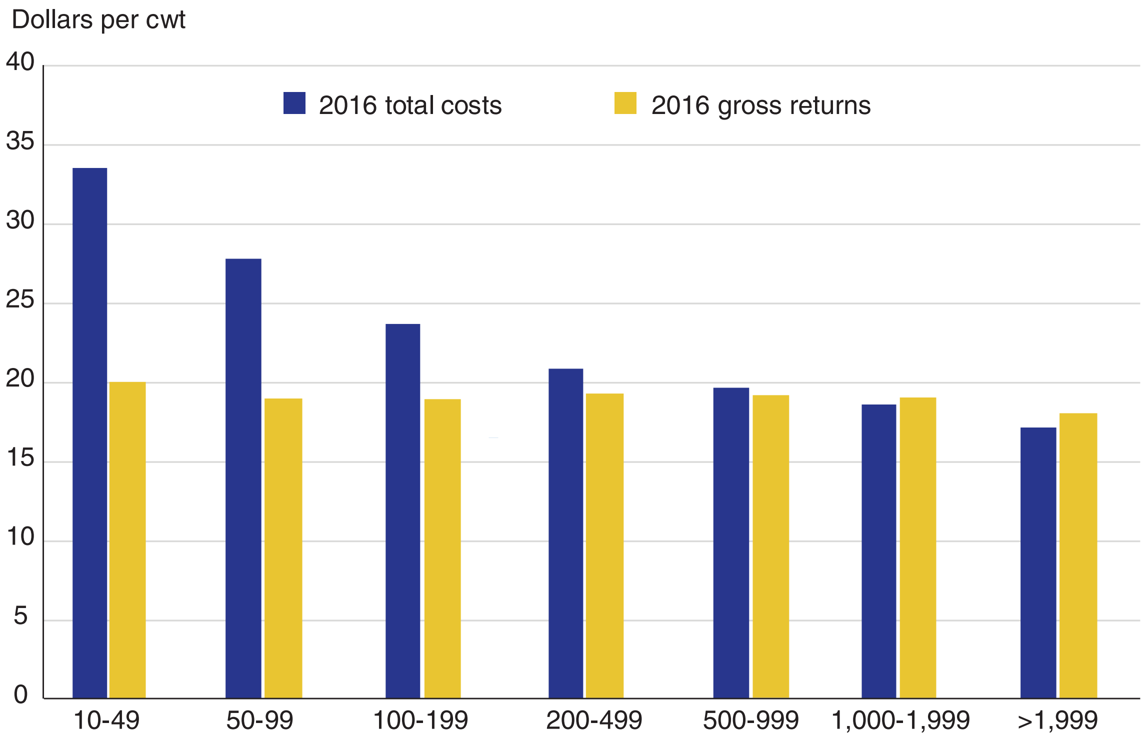
Large farms already accounted for most cows and production in Western Dairy States in 2007, but in the 10 years that followed, each region continued to shift to farms with at least 1,000 head. The number of small commercial farms in the Western States fell by 41 percent from 2007 to 2017, a larger proportional decline than in the Eastern States. However, the numbers affected are much smaller in the West: 936 fewer small commercial dairy farms, compared with a decline of 17,500 farms in Eastern States.

Farm Size, Farm Costs, and Financial Performance

The number of U.S. dairy farms, measured either as licensed dairy herds or as farms with milk cows, has been declining steadily for many years. The long-term trend appears to be quite powerful—for example, figure 5 shows a near-linear decline in licensed dairy herds over 2002–2018. Dairy farm numbers declined in every year, whether average industry financial returns were weak or strong, and annual declines fell within a narrow range, from 2.7 to 6.8 percent. In turn, that pattern suggests that long-term factors are important in driving farm consolidation.

Indeed, powerful longstanding financial incentives are driving dairy farm consolidation (figure 9). We report estimates of total costs of milk production, per hundredweight of milk produced, for seven herd size classes, and then compare total costs to gross returns to milk production. The estimates are based on ERS milk costs and returns estimates drawn from the 2016 ARMS survey of dairy producers. We show estimates for conventional production only, excluding operations with certified organic milk production.[14]

Figure 9
Milk costs and returns, by herd size, 2016



Note: cwt = hundredweight.

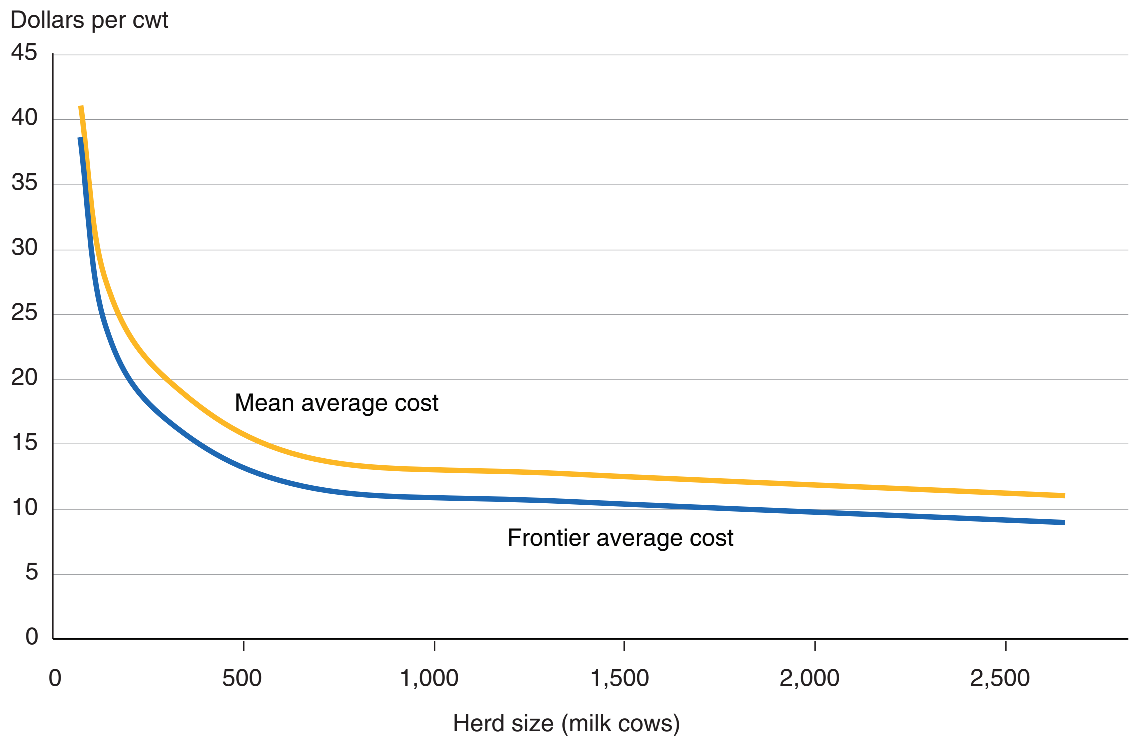
Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

[14]Organic milk costs and returns are evaluated separately in this report because organic costs and prices are much higher than those for conventional production.

In 2016, total costs of production fell steadily as herd size increased, from $33.54/cwt in the smallest herds (10–49 cows) to $17.16/cwt in the largest herds (2,000 or more cows). Gross returns per cwt—which includes revenues from milk sales, livestock sales of culled cows and calves, and other sources—were lower for the largest operations but did not vary nearly as widely as costs. In 2016, gross returns exceeded total production costs for farms with the largest herds, while falling well short of total costs among farms with fewer than 500 cows. The gap between total costs and gross returns was particularly wide among small commercial operations—those with fewer than 200 head.

This finding is not new and has been cited in earlier ERS research (MacDonald, Cessna, and Mosheim, 2016; MacDonald et al., 2007; Mosheim and Lovell, 2009). For example, Mosheim and Lovell (2009) estimated that production costs in 2000 fell sharply as herd size increased from 10 to around 750 head, and that costs continued to decline more gradually throughout the range of their data, which extended out to a few farms with just over 2,500 head (figure 10). While average costs in figure 10 fall at a modest rate as one goes from 1,000 to 2,000 to 2,500 head, the full reduction in estimated costs is meaningful. At 2,700 head, estimated costs were about 13 percent below estimated costs for herds half that size.

Figure 10
Estimated scale economies in dairy in 2000



Note: Data includes only conventional producers. Organic operations were excluded.

Source: USDA, Economic Research Service using data from the 2000 Agricultural Resource Management Survey, Dairy Version (Mosheim & Lovell, 2009).

The sample in the Mosheim and Lovell (2009) study did not have many large operations in it, so the large-farm estimates in figure 10 are based on a thin sample. Moreover, one could certainly quibble with some of the ways in which costs were estimated (we discuss cost estimates in more detail below and in Appendix A). However, later experience provided strong validation for their analysis: cows and production moved to much larger farms after 2000, indicating that producers believed that there were substantial cost advantages to larger operations.

Understanding Milk Costs and Returns

Larger dairy operations persistently show lower costs and higher net returns, on average, than smaller operations in the ERS costs and returns (CAR) accounts. Costs and returns estimation is complex. It requires detailed data as well as steps to estimate costs that are not explicitly reported. We go into some estimation details in this section.

ERS estimates the CAR associated with commodity enterprises on the farm—in this case, the farm's dairy enterprise. If the farm also raises crops, whether as feed for the dairy or for commercial sale, ERS treats that activity as a separate enterprise and focuses on CAR for the dairy enterprise. ERS estimates the value of the feed produced on the farm (including pasture) and treats that value as a cost to the dairy enterprise. The agency aims to account for all the products generated by the dairy enterprise, including milk, dairy cows and calves sold by the farms, and the manure produced by the dairy herd, which can be used as fertilizer for cropping enterprises.

Large and small dairy farms use different production practices, and it is important to account for those differences in assessing costs and returns (table 5). Large farms rely heavily on hired labor, while small farms use little hired labor, relying instead on family-provided labor. While almost all dairy farms purchase at least some of the feed used for their cows, large farms rely more heavily on purchased feed (on average, 80 percent of feed expenses for the largest farms). Since most farms also rely heavily on homegrown feed, it is important to properly account for the cost of homegrown feed to the dairy enterprise.[15] While some large farms graze their cows on pasture for at least some of the year, most do not; their cows are confined within barns or lots on the farm. Most small operations, in contrast, graze their cows for at least part of the year.

[15]The ARMS is used to elicit information from respondents on the quantities of different homegrown feeds fed to their cows. ERS then values those quantities using annual average market prices received by farmers for those crops in the respondent's State. In short, the ERS milk CAR accounts value homegrown feed at its opportunity cost, or what the farmer could have gotten by selling it.

Table 5
Production practices on dairy farms, 2016

	Farm production practices			
	Hired share of labor	Purchased share of feed	Farms that purchase all feed	Farms that do not graze cows
	Percent of expenses		Percent of farms	
All farms	22.7	53.6	3.1	47.0
All cows	67.1	70.6	13.7	80.0
Herd size class				
10–49	3.0	44.3	0.2	22.6
50–99	7.5	50.4	0.2	38.2
100–199	25.0	51.7	4.2	53.9
200–499	59.0	63.9	6.8	75.3
500–999	76.0	74.3	8.2	82.0
1,000–1,999	88.5	80.1	15.1	89.9
>1,999	94.7	82.7	21.1	96.1

Note: Conventional operations only (organic excluded). USDA, Economic Research Service estimates opportunity costs for self-employed and unpaid family labor, and for homegrown feed, and includes them with hired labor and purchased feed in estimates of labor and feed expenses.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Differences in production practices matter when analyzing costs and competition in the industry. Changes in hired-labor wage rates and availability affect large farms much more than small because small farms use little hired labor, and for the same reason changes in purchased feed expenses have greater impacts on large farm costs than on small. Because farms use differing practices and technologies, it is also important to fully capture all practices and technologies in order to properly estimate costs.

We look more closely at estimated milk costs and returns in table 6, where all cost and revenue figures are expressed in dollars per hundredweight of milk sold. Gross returns are reported in the top row. Note that, in the next row, revenue from milk sales accounts for about 89 percent of gross returns (a slightly lower share for the smallest class). The sale of dairy animals, milk dividends from cooperative ownership, and the value of manure accounts for most of the rest.

In 2016, average milk returns ranged from $16.37 to $16.88/cwt for all herd size classes except the largest ($15.67). Milk prices vary across the country and across farms, reflecting regional differences in end use (such as fluid milk versus manufactured products) as well as differences in milk attributes. Larger operations are more likely to be in areas with lower milk prices.

Table 6
Milk costs and returns by herd size class, 2016

Item	Herd size (milk cows)						
	10–49	50–99	100–199	200–499	500–999	1,000–1,999	>1,999
	Dollars per cwt						
Gross returns	19.53	18.53	18.39	18.78	19.00	18.49	17.54
Milk returns	16.88	16.53	16.48	16.75	16.93	16.37	15.67
Other returns	2.65	2.00	1.91	2.03	2.07	2.12	1.97
Operating costs							
Total feed costs	10.03	9.95	9.55	8.85	8.80	8.97	9.20
Purchased	4.44	5.01	4.94	5.66	6.54	7.18	7.61
Homegrown	5.19	4.80	4.52	3.13	2.23	1.78	1.59
Grazed	0.40	0.14	0.10	0.07	0.03	0.01	0.00
Other operating costs	4.32	4.00	3.77	3.50	2.94	2.71	2.32
Total operating costs	14.36	13.95	13.32	12.35	11.74	11.68	11.52
Gross minus operating	5.17	4.58	5.07	6.43	7.26	6.81	6.02
Allocated overhead							
Hired labor	0.40	0.61	1.28	2.08	2.18	2.30	1.75
Unpaid labor	12.78	7.53	3.84	1.45	0.69	0.30	0.10
Capital recovery	4.72	4.47	4.23	4.11	3.82	3.60	3.37
Other overhead costs	1.30	1.21	1.01	0.86	0.70	0.66	0.41
Total allocated costs	19.18	13.81	10.35	8.49	7.39	6.86	5.64
Total costs	33.54	27.77	23.68	20.85	19.13	18.54	17.16
Net returns	-14.01	-9.24	-5.29	-2.07	-0.13	-0.05	0.38

Note. cwt = hundredweight. Conventional producers only.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

In the ERS accounts, costs are sorted into two major categories: operating costs and allocated overhead. Feed costs account for 70 to 80 percent of operating costs. Although larger herds rely more on purchased feed than smaller herds do, total feed costs per hundredweight do not vary markedly for herds of 200 cows or more. “Other operating costs” include veterinary services, bedding and litter, energy (such as fuels and electricity), repair expenses, and interest payments on operating capital. On a per-hundredweight basis, those other costs are lower in larger herds, suggesting that larger operations can use such inputs more intensively.

Allocated overhead costs are an important source of large-herd advantages in the ERS CAR accounts, with labor and capital recovery costs being particularly important (table 6). Dairy farms rely on hired labor and unpaid family labor.[16] Even though most family labor is unpaid, there is still a cost associated, in that family members could have worked off the farm and earned income from that labor. The true cost of unpaid labor to the farm operation is therefore the opportunity cost—what farmers and their families could have earned by working elsewhere instead of on the dairy enterprise.

ERS calculates that the costs of unpaid labor are substantial for smaller farms, but are negligible (as a share of production) for larger farms that rely more heavily on hired labor (table 6).[17] Overall, labor costs (including hired as well as unpaid labor) range from $13.18/cwt of milk produced for the smallest farms—those with 10–49 head—to $5.12/cwt for farms with 100–199 head, to $1.85/cwt on the largest farms.

Differences in labor costs do not arise from differences in hourly wage rates, whether explicit (hired labor) or implicit (imputed wages for unpaid family labor), because hourly wages for hired labor and imputed wage rates for unpaid family labor are higher on larger farms (MacDonald, Cessna, and Mosheim, 2016). Larger farms realize lower labor costs per hundredweight of milk produced because they realize much higher labor productivity—that is, greater output (more milk produced) per hour of labor.

ERS also aims to account for capital costs. Farmers do not pay a cash expense for capital use each year. Capital includes structures for housing the herd and for storing feed, for milking and milk storage equipment, for the herd itself, and equipment for manure storage and handling and for feed distribution. ERS relies on information gathered in ARMS to estimate the value of the capital used on the farm. ERS analysts then calculate an annualized replacement value of the capital and use that annualized replacement value as the cost of capital recovery in CAR accounts.

While the differences in capital recovery costs between large and small farms are not as stark as the differences in labor costs, they are nevertheless important (table 6). Among the largest operations, capital recovery costs average $3.37/cwt, about 20 percent of total costs among those farms. Capital recovery costs are systematically higher among smaller farms and reach $4.23 (100–199 cows), $4.47 (50–99 cows), and $4.72 (10–49 cows) for small commercial farm classes.

Larger operations appear to realize lower average costs in part because they are able to use their labor and capital more intensively and realize greater output per hour of labor or per dollar of capital. Differences in the use of technology and production practices underlie differences seen in input use (table 7). For example, farms with at least 200 cows realize substantially higher yields of milk per cow than do small commercial farms. This is at least partly due to differences in milking: the largest farms are more likely to milk three times a day, which requires hired milking crews, instead of the twice-a-day milking common among smaller farms.[18] Larger farms are also

[16]Most U.S. farms are family-owned and operated businesses. Unless the business is incorporated, owner-operators are not allowed to pay themselves a salary (and to record those salaries as expenses for tax purposes). Most farms are not incorporated, and most owner-operators do not draw salaries or wages—they are "unpaid" and draw their compensation from the business' net income.

[17]See Appendix A, MacDonald, Cessna, and Mosheim (2016), and MacDonald et al. (2007) for more detailed summary data on labor cost estimations.

[18] Notice that the largest farms realize lower milk yields, on average, than those with 500–999 cows (table 7). Location and climate play a role in that disparity. The largest farms are more likely to be located in Arizona, Texas, or Southern California—areas that experience extreme summer temperatures, which limit milk production.

more likely to use computerized feed delivery systems—designed to generate feed mixes that are tailored to the cow's age and place in a lactation cycle—as well as computerized milking systems that generate information about each milking for each cow. These systems should allow farms to generate higher milk yields, with desired milk attributes, while controlling feed costs.

The cost advantages held by larger dairy operations persist over time. ERS reports baseline estimates for milk costs and returns for 2000, 2005, 2010, and 2016, and in each of those years larger operations realize lower costs than smaller operations. The differences are consistently substantial and provide powerful economic incentives behind dairy consolidation (USDA, Economic Research Service, 2019; MacDonald, Cessna, and Mosheim, 2016; MacDonald, et al., 2007; Mosheim and Lovell, 2009).

Table 7

Technology use on dairy farms, 2016

	Annual milk yields	Milk three times daily	Feed delivery computerized	Milking systems computerized	Artificial insemination
Herd size	Pounds/cow	Percent of farms			
10–49	16,161	0.0	0.4	0.3	64.3
50–99	18,728	2.4	5.0	3.6	83.3
100–199	19,797	8.7	9.7	11.6	82.9
200–499	22,255	38.6	20.3	24.9	82.9
500–999	23,702	51.6	29.2	48.2	88.7
1,000–1,999	22,747	60.5	42.4	52.4	86.6
>1,999	22,901	61.5	67.8	41.3	95.1
All farms	19,000	13.0	10.6	11.7	79.4

Note: Data included conventional operations only.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

The Organization of U.S. Dairy Farms

Most farms in the United States are small—over 90 percent, according to the ERS farm typology, which classes small farms as those with less than $350,000 in sales (Burns and MacDonald, 2018). By that standard, dairy farms are different: just over half are small. Most dairy farmers draw their livelihood from the farm, and they work full-time on it. Farms with 100–199 cows, which we have been referring to as small commercial farms, generated an average of $603,000 in sales in 2016, which qualifies them as midsize farms in the ERS farm typology (table 8). Farms in the next-largest herd size class (200–499 head) generated average sales of $1,489,000, enough to put them in the large farm category of the ERS typology. Dairy farms with 2,000 or more cows generated average sales of over $15 million.[19]

Dairy farms are major investments. A farm with a herd of 350 milk cows and 800 acres of cropland could have $500,000 invested in livestock (cows and replacement heifers) and another $4 million in cropland at 2019 NASS price estimates.[20] Equipment, vehicles, structures, and working capital add more. Farms may rent land, equipment, or even livestock in order to limit their capital exposure, but dairy farms usually invest a substantial amount in farm assets. Farms in the smallest herd size class own average business assets in excess of $1 million, while large-scale operations have average farm business assets of $14 million (farms with 1,000–1,999 cows), and $28 million (the largest size class). Dairy farms often take on substantial debt in order to finance the assets needed to operate efficiently, leaving some exposed to liquidity risks arising from cash flows insufficient to cover interest payments when margins between milk and feed prices narrow (Ifft, Novini, and Patrick, 2014; MacDonald, Cessna, and Mosheim, 2016).

Even though many dairy farms are large farms, almost all are still relatively small family businesses. While a dairy farm with $15 million in sales counts as a very large farm, it is not a particularly large business, as there are tens of thousands of U.S. businesses with higher sales. Moreover, despite the investment required, most dairy farms, even large ones, remain family farms. ERS defines a family farm according to ownership and operation. Specifically, the principal operator, and people related to the principal operator by blood, adoption, or marriage, own more than 50 percent of the business assets of a family farm. In turn, the principal operator is the person most responsible for day-to-day decisions on the farm. By this definition, almost all small commercial dairy farms are family farms (table 8). But over 90 percent of farms with 1,000 to 1,999 cows are family farms, as are almost 88 percent of farms with 2,000 or more cows.[21]

Family farms may incorporate for tax purposes, to limit the liability that they may face, or to facilitate intergenerational transfers. Nearly half of dairy farms with at least 1,000 cows are registered as limited liability corporations (LLCs) under the laws of the States in which they are located. LLCs

[19]Sales are measured by gross cash farm income, which includes revenue from commodity sales (milk, as well as revenue from sales of other commodities produced on the farm); fees from production contracts; Government payments from conservation or commodity programs; leases of land or hunting rights; insurance indemnities; income from custom services; and other farm-related income.

[20] USDA, National Agricultural Statistics Service reports prices paid for milk cows and heifers in the monthly *Agricultural Prices*, and reports average State-wide cropland and pastureland values in *Land Values*.

[21]Some large dairy farms are operated by hired managers on behalf of a family that owns the farm. These would be non-family farms, according to the ERS definition, because the operator does not own the farm. Many large dairy farms are operated by several partners. If those partners are related (siblings, or cousins, or parents and children), they would be classified as family farms. If the partners are unrelated, and no partner owns more than half of the operation, it would be a non-family farm. While some poultry and hog farms are owned by large diversified corporations, and would be classed as non-family farms, few dairy farms have such ownership links.

retain the tax pass-through status of sole proprietorships or partnerships, with the limited liability of a corporation. Farms with any kind of legal status may register as LLCs. While many operators of dairy farms choose to incorporate, it is more common that large operations are organized as partnerships (table 8).

Table 8
Organization of U.S. dairy farms, 2016

	Herd size (milk cows)						
Item	10–49	50–99	100–199	200–499	500–999	1,000–1,999	>1,999
Farm size	Dollars (thousands) per farm						
Average sales	147	271	603	1,489	3,252	5,827	15,241
Average assets	1,348	1,783	3,077	5,015	8,551	14,311	28,107
Farm organization	Percent of farms						
Family farm	99.5	99.4	97.1	96.9	96.0	91.7	87.8
Organized as LLC	1.2	6.9	20.9	37.9	36.7	47.1	48.7
Farm legal status	Percent of farms						
Partnership	2.3	11.9	25.0	34.3	33.0	41.3	47.0
Corporation	0.3	0.8	7.0	22.1	27.9	14.1	13.4
Sole proprietor	97.4	86.6	68.0	43.2	38.0	43.3	38.3

Note: Data included 1,145 conventional operations. Organic operations were excluded. A limited liability corporation (LLC) can assume any legal status. Family farms can also assume any legal status, since the principal operator and relatives by blood or marriage own more than half of the assets of the farm business. Sales are gross cash farm income, which includes commodity sales, contract fees, and farm-related income (such as income from government payments, land rentals, custom services, or asset sales).

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Farm Size Matters, But It Isn't Everything

While scale is important, there are significant variations in production costs and net returns within size classes, so that well-run smaller farms can achieve positive net returns, and poorly run larger farms can realize net losses. Those differences affect the pace of structural change.

Production costs vary widely, even after accounting for herd size.[22] In table 9, we report production costs (per hundredweight of milk sold) for the median farm in each herd size class, and for a low-cost producer and a high-cost producer. We define the low-cost producer as the farm at the 25th percentile of production costs, such that 75 percent of farms in the herd size class have higher costs and 25 percent have lower costs. Symmetrically, we define the high-cost producer as the farm at the 75th percentile of production costs, such that 75 percent of farms in the class have lower costs and 25 percent have higher costs.[23]

Size advantages are still quite clear when the estimates are reported in this way: costs of production at the median farm fall as herd sizes get larger, and the differences are large (table 9). Similarly, costs of production at the 25th and 75th percentiles fall as herd size increases, and the largest low- and high-cost operations have noticeably lower costs than those corresponding farms in smaller herd size classes.

However, production costs also vary widely within size classes. High-cost producers realize costs that exceed those of low-cost producers by 25 to 30 percent among all size classes with 200 or more cows, and by 40 to 60 percent among small commercial operations. The difference in production costs between high- and low-cost farms with more than 2,000 cows amounts to $4.61/cwt (the high-cost producer realizes production costs that are 30 percent greater than the low-cost producer). This gap exceeds the difference in average costs of production between farms with more than 2,000 cows and those with 200–499 cows.

[22]See the statistical analysis reported in Appendix C. While herd size accounts for nearly a third of the total variation in average production costs across farms, there is still a wide variation in costs after accounting for herd size, location, and specified farm production practices and herd attributes. See also Stephenson (2019) for analysis of the wide range of milk production costs within herd size classes.

[23] The median splits the farms in the class: half have higher costs than the median farm and half have lower. We could have chosen the 10th and 90th percentile operations for our low- and high-cost farms, which would show an even wider range of costs, but our samples are small enough that we fear that some of those farms are more likely to reflect extreme and unusual circumstances.

Table 9
Production costs varied widely within size classes, 2016

Herd size (milk cows)	Percentiles of total costs of production		
	25th (low cost)	50th (average cost)	75th (high cost)
	Dollars per cwt		
10–49	26.95	34.29	42.48
50–99	22.40	26.69	34.23
100–199	19.76	22.86	27.51
200–499	18.08	20.74	23.76
500–999	16.96	18.80	21.21
1,000–1,999	16.27	18.02	20.54
2,000 or more	15.02	16.62	19.63

Note: cwt = hundredweight. Data included 1,145 conventional operations. Organic operations were excluded.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Now compare high-cost large producers to low-cost smaller producers. The production cost of the high-cost producer in the largest size class (2,000 or more cows) was $19.63 per cwt, exceeding the costs incurred by the low-cost producer in three smaller classes (200 to 499, 500 to 999, and 1,000 to 1,999 cows), and only barely below the cost of a low-cost producer with 100 to 199 cows. Low-cost producers with 100 to 199 cows realize production costs that are below those of most producers in the next-largest class (200 to 499 cows).

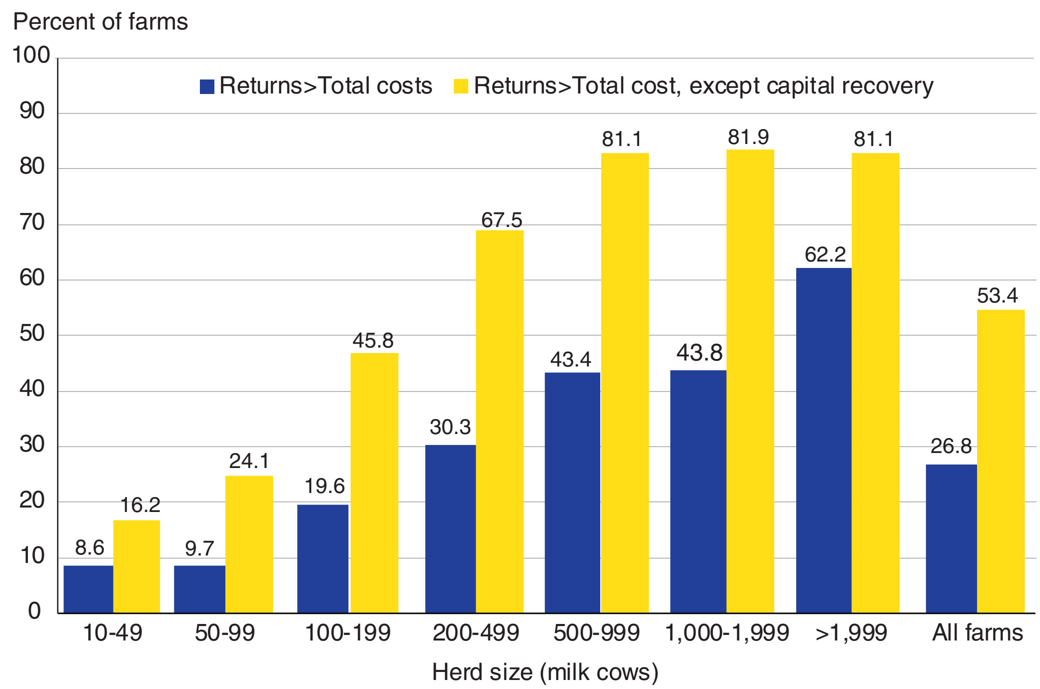
Why do costs vary across producers of a given size? Some may pay different prices for inputs, such as feed, labor, and energy. Accounting can also play a role: the ARMS survey collects information on expenses incurred during a calendar year, and if expenses were actually incurred in a different year, then per-unit costs will be unusually low in one year and high in another.

Weather differences may also play a role, since dairy farms cover a wide range of climate zones. For example, excessive heat can reduce milk yields for any given level of expenses, while increasing energy costs for cooling, thus creating higher production costs per cwt of milk. Similarly, outbreaks of disease may reduce milk yields (Key and Sneeringer, 2014). Machinery breakdowns can create new expenses and may unsettle herds, leading to lower yields. The physical configuration of farms can also affect expenses and production. Older operations, with less than ideal layouts of facilities and equipment, may not be able to realize the efficiencies of operations newly designed for the current use. Each of these factors may be outside of the farmers' control, but there are also substantial differences among dairy farmers in their management experience and skills, whether related to breeding and herd management, to labor force management, to cropping decisions, or to milk marketing and input purchasing.

Cost differences translate to differences in financial performance, even among similarly sized farm operations. In 2016, farms with at least 2,000 milk cows earned positive net returns in 2016, on average, while total costs exceeded gross returns, on average, in all other size classes. However, there is a wide range of financial performance around the average, and some farms in each size class earned positive net returns.

In 2016, 62 percent of farms with at least 2,000 cows generated gross returns that exceeded total costs (figure 11), compared with 43 to 44 percent of farms in the two next-largest classes (500 to 999 cows and 1,000 to 1,999 cows). Even among the smallest classes (10 to 99 cows) almost 10 percent of farms generated positive net returns. Given the range of estimated production costs in table 9, it should not be surprising to see a wide range of net returns.

Figure 11
Net returns by farm size class, 2016



Note: Conventional producers only.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Some farms in each size class earn positive net returns, but in 2016, most farms in most size classes did not. Why do they continue to operate? Farmers may view adverse finances as temporary, as 2016 was a relatively poor year for the industry—the average all-milk price reported by NASS hit $14.50 per hundredweight in May, the lowest since 2009. Many operations could reasonably look ahead to better days. Even if negative net returns persist, however, a farm may operate economically for as long as gross returns cover some costs, even if not covering all of them. Specifically, as long as gross returns cover operating expenses and provide the farm family with earnings at least equal to what they could earn elsewhere, the family would be better off financially by continuing to operate the farm. Such farms can operate successfully for a long time, until cash expenses (including those associated with maintaining and repairing aging equipment) rise enough to keep the family from earning a reasonable income from the farm.[24] Hence, even if the farm does not generate enough income to cover capital recovery costs, continued operation is in the farmer's financial interest if the farmer is not planning to reinvest in the farm's capital stock.

[24]This is equivalent to the shutdown decision in economic theory: one operates a plant as long as revenues exceed variable costs, even if revenues fall short of total costs.

In 2016, over 80 percent of farms with at least 500 cows earned gross income that covered all expenses except for capital recovery (figure 11). Even among smaller farms, many covered all costs except for capital recovery. These farms were able to cover all cash operating expenses, and provide a reasonable living for their operators, while still retaining funds to cover some (though not all) capital needs. They will likely continue to operate.

However, many farms were not able to cover their noncapital costs: 84 percent of farms with 10 to 49 cows and 76 percent of those with 50 to 99 cows failed to generate enough income to cover cash expenses and the opportunity cost of their labor. These farmers could have earned a higher income by leaving dairy farming. However, many people decide to stay in dairy farming, earning less than they might elsewhere, because they prefer the life of a dairy farmer, are reluctant to give up a life they have known, or hope that the volatility of milk prices may lead to better days.

Operator Age, Farm Exit Decisions, and Consolidation

Since most dairy farms are family businesses, the age of the operators also plays a role in decisions regarding continued operation of a business. Dairy farmers as a group are getting older. The average age of dairy farmers was 54 in 2016, compared with an average age of 49 in 2000. Moreover, 30 percent were 60 or older in 2016, compared with 20 percent in 2000.[25]

Older operators are more likely than younger operators to shut down farm operations. As dairy farmers age and retire without successors, we expect to see more farm closures. We can use data from ARMS to assess the impacts of farm size, operator age, and other farm and operator attributes. Though ARMS does not provide information on actual farm closures, it does ask farmers about their plans to end milk production. The 2010 ARMS dairy questionnaire, for example, asked respondents how long they expected their operations to continue producing milk. Respondents could choose among six responses: less than 1 year, 1 year, 2 to 5 years, 6 to 10 years, 11 to 19 years, and 20 or more years.[26]

We combined the first three responses into one, identifying respondents who expected their operations to stop producing milk within 5 years. The question's focus in whether the *operation* will continue to produce milk encompasses several actions. For a respondent who expects to retire within 5 years, the response also implies that the respondent does not expect anyone else to take over the operation.

Twenty-three percent of respondents to the 2010 survey (responding in 2011) expected to stop milk production within 5 years. The total number of licensed dairy herds fell by 19 percent over the 5 years between 2011 and 2016, and by 22 percent over 6 years. Some farms entered dairy farming during this period, so this forward-looking survey expectation was close to what actually happened.

Farmers' expectations were closely related to certain farm and farmer attributes. We estimated a statistical model that related expected exit to the farm's herd size class; the farm's production costs; whether the operator was 60 or older; whether the operator was a hired manager (signaling that the

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[25]These estimates are based on the 2016 and 2000 ARMS Dairy Versions. Specifically, we are referring to "principal farm operators," the person with primary responsibility for day-to-day decision-making on the farm.

[26] The 2016 ARMS dairy questionnaire was shortened for budget considerations, and we were unable to continue using the prospective exit question in 2016.

farm could hire another manager when the operator retired); and whether the farm had multiple operators (again suggesting that someone else might take over). The detailed results are presented in Appendix D, and we report summary results in table 10.

Table 10
Smaller farms and older operators more likely to end milk production, 2010

Herd size	Base case	Operator is 60 or older
	Probability (percent) of exit within 5 years	
10–49	28.1	59.6
50–99	22.9	53.0
100–199	13.4	37.9
200–499	8.6	26.3
500–999	4.0	13.6
>999	6.3	20.7

Note: For details of the estimation, see Appendix C. The base case is a farm with production costs equal to the average for its size class, with a single operator less than 60 years old, who is not a hired manager. The estimate for older operators assumes costs equal to the average for the size class, with a single operator who is not a hired manager.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2010 Dairy Version.

We start with the predicted likelihood of planned exit in a base case: the farm's production costs match the average for its size class, the operator is younger than 60, is the sole operator, and is not a hired manager. In that case, predicted 5-year exit probabilities fall sharply with herd size. Within 5 years, 28 percent of farms with 10 to 49 cows, 23 percent of farms with 50 to 99 cows, and less than 10 percent of farms with 200 or more cows expected to end milk production.

However, the age of the operator matters. Predicted 5-year exit probabilities jump if the operator is 60 or older, to nearly 60 percent in the smallest size class, and to 14 to 20 percent among the two largest classes. Other factors, discussed in Appendix D, also matter: higher-cost farms are more likely to be planning exit, and exit is less likely if there are other operators or if the principal operator is a hired manager.[27]

These findings can help us think about likely dairy farm closures in the near future. Compared with 2010, small commercial dairy farms constitute a smaller fraction of the industry, and there are more large operations. That factor should lead to lower rates of exit in the future. However, offsetting the effect of recent structural change, the share of dairy farmers who are 60 or older has increased since 2010, and that should raise exit probabilities, especially among smaller farms with no successors. If we use the model estimated in Appendix D and apply it to data from the 2016 ARMS (regarding herd sizes, operator age, production costs, and other attributes), then we would predict that 21.4 percent of the dairy farms in the 2016 ARMS would expect to close within 5 years. That's an annual rate of 4 percent per year, in line with the long-term trend shown for licensed dairy herds (figure 5). That estimate suggests the number of licensed dairy herds would fall by almost 9,000 herds, to under 33,000 by 2021, 5 years after the 2016 ARMS dairy survey.

[27]Ifft and Yi (2019) analyzed the factors driving actual exit decisions among dairy farms in New York over 1993–2016 and found that operator age and the farm's return on equity were important factors in exit. In our data, net returns are strongly associated with production costs (inversely), and with herd size (positively).

Dairy farm consolidation has played out over several decades. The adjustment is gradual because many farms with gross returns less than total costs may continue to operate if they are covering all non-capital costs, and their operators are therefore better off operating the farm than leaving dairy farming. The economics of the matter indicate that farm operators who cannot consistently cover their noncapital costs should consider exit. However, those are difficult decisions to make, and factors other than financial performance play a role. For each reason, dairy farm exit is a gradual process, playing out over years, and so consolidation is also a gradual process.

Value-Added Activities

Some small dairy farms earn positive net returns, while others can provide a reasonable income for a family, even without covering all capital costs. What lies behind good financial performance in a difficult overall environment? Some farms combine a value-added business, such as agritourism or cheese-making, with the dairy operation. Even if the dairy operation alone is not profitable, an agri-tourism business that relies on guests' interest in dairy may generate enough additional income to make the combined activity viable.

Other small dairies generate additional income by breeding and selling high-quality heifers and calves. About 10 percent of the conventional dairy farms analyzed in tables 5–9 earned at least 80 cents in calf sales for every hundredweight of milk sold, and half of those farms earned at least $1.35. In contrast, the median farm earned 14 cents—calf sales were not an important source of revenue for most farms. In short, some farms realize significant additional revenues from breeding and selling higher-quality calves, and those farms were also considerably more likely to generate positive net returns than were other farms in the sample.

Organic Dairies

Some small and midsize dairies have also found certified organic production to be viable. According to a 2014 NASS survey of organic producers (a follow-on to the 2012 Census of Agriculture), 2,262 farms had organic milk production, about 5 percent of licensed dairy herds in 2014. Those farms were relatively small; certified organic milk cows accounted for about 2.5 percent of all U.S. milk cows that year (228,116 certified organic cows in inventory at the end of 2014, or an average of 101 cows per farm).[28]

The 2016 ARMS dairy survey included a sample of 381 organic dairy farms. While there are very large organic operations, most are small. We group organic producers in the survey into four herd size classes: 10 to 49 cows, 50 to 99 cows, 100 to 199 cows, and 200 or more milk cows. That is, we cover the three classes that we have been referring to as small commercial farms, and then placed all others into a single larger class (table 11).

[28]Organic producers accounted for a larger share of milk revenues, since organic milk fetched higher prices (an average of $31.82/cwt in 2014).

Table 11
Milk costs and returns for organic producers by herd size class, 2016

	Herd size (milk cows)			
	10–49	50–99	100–199	>199
	Dollars per cwt			
Gross returns	37.10	37.93	38.27	37.45
Milk returns	34.37	35.17	36.07	34.87
Other returns	2.73	2.76	2.20	2.58
Operating costs				
Total feed costs	17.09	16.37	17.00	14.05
Purchased	6.87	6.65	8.23	8.79
Homegrown	9.26	8.94	8.02	4.23
Grazed	0.96	0.78	0.76	1.03
Other operating costs	5.12	5.53	4.85	4.70
Total operating costs	22.21	21.90	21.86	18.75
Gross minus operating	14.89	16.03	16.41	18.70
Allocated overhead				
Hired labor	0.66	1.91	2.71	4.40
Unpaid labor	18.22	9.47	5.09	1.66
Capital recovery	5.23	4.70	4.49	3.84
Other overhead costs	2.55	2.47	1.68	2.25
Total allocated costs	26.66	18.56	13.96	12.14
Total costs	48.87	40.45	35.82	30.89
Net returns	-11.77	-2.52	2.45	6.56

Note: cwt = hundredweight. Data included 381 organic operations. Conventional operations were excluded.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

In 2016, total production costs at organic operations were noticeably higher, on a per- hundredweight basis, than costs at conventional operations—by 46 percent among farms with herds of 10 to 99 head and by over 50 percent among herds of 100 to 199 head. However, with higher prices for organic milk, the gap in gross returns between conventional and organic producers was even greater. Gross returns for organic farms with 50 to 199 cows were more than double those at conventional operations in 2016, and the gap for farms with 10 to 49 cows was almost as great.

As a result, financial performance among small commercial organic producers was much better than among small commercial conventional producers (table 11 and table 6). While the smallest organic producers—those with 10 to 49 cows—displayed substantial losses (-$11.77/cwt), organic producers with 50 to 99 cows earned net returns of -$2.52, compared with -$9.24 for conventional producers in that herd size class. Producers with 100 to 199 cows earned positive net returns of $2.45/cwt, compared with -$5.29 among comparable conventional producers—and those with more than 199 cows also earned positive net returns. These findings agree with earlier findings for field crops: certified organic corn and soybean producers showed higher costs of production than matched conventional producers, but they were also able to generate higher net returns (McBride, et al. 2015).

Two cautions should be kept in mind when making these comparisons. First, the comparison between table 6 and table 11 is for a single year (2016). Both organic and conventional milk prices and feed costs can fluctuate widely from year to year. As a result, there is no assurance that the performance gap will hold over time. Second, the costs listed for organic producers in 2016 do not include the costs of making the transition from conventional to organic production.

Conventional farms that aim to make a transition to organic production must follow a regulated process. Organic certification requires that crops not receive any synthetic chemicals for 3 years prior to the harvest of crops designated as certified organic. Dairy animals require a 12-month transition of receiving organic feed. During this transition phase, farms incur the costs of organic production without being able to realize organic prices. In 2016, farms that were making a transition to organic production realized production costs that were 25 to 30 percent above comparably sized conventional operations (see Appendix B for this comparison). Transition costs place a significant barrier on farms that are considering shifting from conventional to organic production.

Federal Agricultural Program Support for Dairy Farmers

The Federal Government provides financial support for farmers through several programs. Some of these programs direct support specifically to dairy farmers, while others provide support to a range of farmers that includes dairy farmers. In recent years, Congress has expanded support for dairy farmers, with a focus on small and midsized dairy operations.

As with many other types of farmers, dairy farmers may be eligible for support under Federal conservation programs, such as the Conservation Reserve Program (CRP) or the Environmental Quality Incentive Program (EQIP). Those who grow field crops covered under Federal commodity programs may also be eligible for support under those programs. In each case, those with cropland are most likely to be eligible for support, and ARMS data indicate that conventional dairy operations with cropland received an estimated $210 million in Federal conservation and nondairy commodity program payments in 2016. That amounted to 0.6 percent of farm sales (gross cash farm income) for dairy operations. Small commercial operations with 10 to 199 cows received $90.6 million of that support, amounting to 1.2 percent of their sales.[29]

Certain other Federal programs have been directed specifically to dairy farmers. In 2014, Congress introduced the Margin Protection Program (MPP-Dairy) as part of the Agricultural Act of 2014. The Bipartisan Budget Act of 2018 (BBA of 2018) and the Agriculture Improvement Act of 2018 revised the program and it was renamed as Dairy Margin Coverage (DMC).

[29]These estimates are derived from the 2016 ARMS Dairy Version, allowing for comparisons of program payments and gross cash farm income for different categories of dairy farms. The ARMS focuses on payments received by farmers, and as reported by farmers, on a calendar-year basis. In contrast, USDA administrative sources report total program payments, made to farmers and to non-operator landlords who qualify for payments, on a fiscal-year basis (12 months, beginning on October 1). Administrative source data cannot be decomposed into farm types. See McFadden and Hoppe (2017) for a comparison of the strengths and weaknesses of ARMS and administrative sources.

DMC is a voluntary risk-management initiative that offers payments to dairy producers when the milk-feed margin—the difference between a national average milk price and a national average feed cost (as defined by a statutory formula)—falls below a certain dollar amount.[30] The program is voluntary in that producers choose whether to participate, and they choose the level of coverage that they wish to purchase.

Enrollees in MPP-Dairy paid a $100 annual administrative fee. For that fee, enrollees received base catastrophic coverage. As originally designed under the 2014 Act, whenever the margin fell below $4/cwt for a 2-month period (January–February, March–April, etc.), enrollees at the catastrophic level of coverage received payments equal to the difference between the national margin and $4, applied to 90 percent of their milk production history. An enrollee's milk production history was defined as the highest annual quantity of milk marketed during 2011–13, and it was adjusted each year based on the percentage change in national milk production.

Enrollees could purchase additional buy-up coverage for a premium. Buy-up coverage allowed enrollees to cover higher margin thresholds in 50-cent increments from $4.50 to $8/cwt, such that payout would be made in the event of national margins falling below those levels (table 12). Premiums varied across two tiers of production: one set of premiums applied to the first 4 million pounds of covered production, while a second, higher set of premiums applied to production in excess of 4 million pounds. Finally, enrollees could also choose how much of the registered production history they wished to cover, in increments from 25 to 90 percent of production history

In the initial signup for 2015 coverage under MPP-Dairy, 44 percent of enrollees—with 62 percent of covered production—chose catastrophic coverage. MPP-Dairy premiums were scheduled to increase after 2015, and in subsequent years more farms opted to enroll at minimal coverage, with no premiums and coverage limited to margins at the catastrophic level. By 2017, 93 percent of enrollees and 98 percent of covered production were enrolled at that minimal level, according to summary data from USDA's Farm Service Agency, which administers the program. Those choices ensured that total premium payments by enrollees would also be minimal (limited to the annual $100 fee), but so would government payouts under the program. While the margin between milk and feed prices fell below $4/cwt for several months in 2009 and 2012, it has not breached the catastrophic level since then, so farmers enrolled at the catastrophic coverage level would have received no payments since the program's introduction. Total MPP-Dairy payments to farmers amounted to $10 million in 2016, but only $19,000 in 2017.[31]

[30]The feed cost and milk price measures specified in the 2014 legislation are tracked in figure 1 and defined in footnote 1. USDA changed the feed cost measure in 2019 to include two types of alfalfa.

[31]Milk production in 2016 came to 212 billion pounds, so $10 million in payments amounted to less than a penny per cwt. These estimates are for calendar years, as reported in ERS farm sector income estimates. For the Farm Sector accounts, ERS obtains program payment data from administrative sources (in this case, USDA's Farm Service Agency) and converts fiscal year flows to calendar years.

Table 12
MPP-Dairy and DMC premiums

Margin coverage threshold	Tier 1		Tier 2	
	MPP-Dairy 2016–17	DMC	MPP-Dairy 2016–18	DMC
	<4 million pounds	<5 million pounds	>4 million pounds	>5 million pounds
$4.00	0.000	0.000	0.000	0.000
$4.50	0.010	0.0025	0.200	0.0025
$5.00	0.025	0.005	0.040	0.005
$5.50	0.040	0.030	0.100	0.100
$6.00	0.055	0.050	0.155	0.310
$6.50	0.090	0.070	0.290	0.650
$7.00	0.217	0.080	0.830	1.107
$7.50	0.300	0.090	1.060	1.413
$8.00	0.475	0.100	1.360	1.813
$8.50	NA	0.105	NA	NA
$9.00	NA	0.110	NA	NA
$9.50	NA	0.150	NA	NA

Note: In the 2014 Farm Bill, the threshold for Tier 2 Margin Protection Program for Dairy (MPP-Dairy) premiums was 4 million pounds of production. That was changed to 5 million pounds in the 2018 legislation, and was retained in the Dairy Margin Coverage (DMC) legislation. The 2018 legislation also extended Tier 1 coverage to margins in excess of $8.00.

NA = not available.

Source: USDA, Economic Research Service.

Under the BBA of 2018, the demarcation between the two premium tiers was adjusted from 4 million to 5 million pounds for Tier 1 coverage (with catastrophic coverage available for the administrative fee of $100). The margin calculation was also made monthly, rather than for every 2 months. Tier 1 premiums were reduced, while Tier 2 premiums remained unchanged.

With widening concern over dairy farm finances and closures, Congress made some significant changes to the program with passage of the 2018 Farm Act. In addition to changing the name to Dairy Margin Coverage (DMC), the following significant changes were made:[32]

- Catastrophic coverage for both Tier 1 and Tier 2 was set at $4/cwt, but it was made available on 95 percent of a farm's production history, compared with 90 percent under MPP-Dairy, and remained available for a $100 enrollment fee.
- Farms could elect to cover between 5 and 95 percent of their milk production history with buy-up premiums, compared with 25 to 90 percent under MPP-Dairy.
- Tier 1 premiums were charged for up to 5 million pounds of covered production history, compared with 4 million pounds under the 2014 Farm Act.

[32]A more complete discussion of the legislative changes can be found at the ERS 2018 Farm Act page.

- Farms could purchase buy-up coverage for margin thresholds ranging from $4.00/cwt to $9.50/cwt under Tier 1 coverage, compared with a range of $4.00 to $8.00 under MPP-Dairy. Tier 2 premiums applied to coverage exceeding 5 million pounds of covered production history, and still provided coverage for margin thresholds ranging from $4.00 to $8.00/cwt.

- Buy-up premiums were restructured under DMC; Tier 1 premiums were reduced from levels in MPP-Dairy, while Tier 2 premiums were reduced at lower margin coverage levels and increased at higher margin coverage levels (table 12).

- The average national margin continued to be calculated monthly, as it had been calculated under the BBA of 2018.

- Registration fees were waived for certain classes of producers, and refunds of MPP premiums were to be paid retroactively to most enrollees.

- An operation's milk production history in the 2014 Act was based on the highest annual volume of milk marketed over 2011–2013 and adjusted upward each year through 2018 to reflect changes in national milk production. The 2018 Act made no adjustments for years subsequent to 2018.

ERS estimates that MPP payments amounted to $250 million in calendar year 2018, and $279 million in calendar year 2019.[33] Direct payments to farmers—such as those received through commodity and conservation programs—do not enter calculated gross returns in the ERS CAR accounts, and so do not affect estimated net returns.[34] However, current programs do provide financial support to dairy farms. With milk production likely to reach close to 220 billion pounds in 2019, $279 million in payments would amount to an additional 13 cents per hundredweight. The DMC is structured to ensure that a substantial amount of that support would flow to smaller operations, such that smaller operations could receive greater support on a per-hundredweight basis. The exact amount would depend on the enrollment choices that farmers make.

Other Federal insurance programs also provide support for dairy farmers. USDA's Risk Management Agency (RMA) offers a Livestock Gross Margin insurance policy for dairy (LGM-Dairy), which insures the margin between milk prices and feed costs. Because the 2014 Farm Act prohibited concurrent enrollment in MPP and LGM-Dairy, and because Federal expenditures on livestock insurance policies were capped at $20 million, participation in the LGM-Dairy program was limited. However, Congress eased those restrictions in 2018 legislation (Congressional Research Service, 2018).

In October of 2018, RMA introduced another program, Dairy Revenue Protection (Dairy-RP), which insures against unexpected declines in quarterly revenues from milk sales relative to a guaranteed coverage level. Expected revenue is based upon future prices for milk and dairy commodities and the amount of covered milk production elected by the producer. Producers may cover 80 to 95 percent of their expected quarterly revenue, and if actual milk revenue falls below the revenue guarantee, the producer can receive an indemnity payment. Producers can tailor a policy to their individual needs by declaring the amount of milk they want to cover in each quarterly policy and

[33]These estimates are drawn from ERS farm sector income estimates.

[34]Earlier dairy price support programs aimed to benefit farmers by affecting prices paid for milk. Because they worked through prices received for milk, those programs did affect estimates of net returns to dairy production (as seen in figure 3).

a range of pricing options. Participants have covered 30 billion pounds of milk production with Dairy-RP insurance policies in 2019, amounting to 13 to 14 percent of production.

While dairy producers pay premiums for insurance under Dairy-RP and LGM-Dairy, the Federal Government provides subsidies to insurance providers to cover administrative costs and to support premium subsidies under Dairy-RP. Premium subsidies in support of Dairy-RP and LGM-Dairy amounted to $41.4 million through the first 8 months of 2019.

In addition to direct payments resulting from the previously discussed programs, dairy producers can apply for USDA direct or guaranteed loans. Dairy farmers unable to obtain credit from commercial lenders at reasonable rates and terms despite being creditworthy can receive credit through USDA's Farm Service Agency. In 2017, 22 percent of indebted dairy farms had either a direct or guaranteed USDA farm loan.[35]

Congress has provided support to dairy farmers through different types of programs for many years. Through the BBA and the Agriculture Improvement Act, Congress has substantially expanded Federal support for dairy farmers.

[35]This estimate is drawn from USDA administrative data. Direct loans are provided to borrowers by USDA, while guaranteed loans are provided by private lenders but guaranteed by USDA.

Conclusions

Dairy consolidation has had wide-ranging impacts, as described in greater detail in our earlier reports (MacDonald et al., 2007; MacDonald, Cessna, and Mosheim, 2016). Consolidation has led to lower prices for milk and for dairy products. Lower dairy product prices benefit consumers and have made U.S. dairy products more competitive in international markets, leading to more commercial dairy exports. However, lower prices for farm milk have placed financial pressures on higher-cost (and usually smaller) dairy producers.

Dairy consolidation has also had environmental impacts. It has substantially reduced the use of pastureland for grazing and thereby led to noticeable changes in land use, particularly in Eastern and Midwestern Dairy States. By consolidating cows into fewer but larger farms in a narrowing range of geographic areas, manure production has become concentrated—creating water and air risks from excess nutrients and leading to expanded local, State, and Federal regulatory interventions. Most large dairy operations now come under Federal regulations aimed at management of manure effluents under the Clean Water Act, and they are further subject to State regulations regarding facility siting and manure management. Through Federal conservation programs, dairy operations also receive cost-sharing support for manure management structures and practices.

Dairy production has been shifting to larger farms for several decades, and at a pace that exceeds the pace of consolidation in most of U.S. agriculture. The scale of what constitutes "larger" has continued to increase, so that nearly 200 farms now milk 5,000 or more cows, and the very largest farms milk more than 25,000 cows. Large dairy operations continue to show substantial cost advantages, on average, over smaller operations. What's more, many operators of smaller dairy farms are nearing or reaching retirement, and the added support provided in recent years—while substantial in the aggregate—remains a fraction of the average cost differences between small and large operations. The disappearance of smaller dairy farms—particularly those with fewer than 200 cows—is likely to continue in years to come.

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Appendix A: Data Sources Used in This Report

The Census of Agriculture, administered by USDA's National Agricultural Statistics Service (NASS) and updated every 5 years, provides comprehensive data on the number, size, and location of U.S. dairy farms. We use it to assess farm structure. Data on U.S. milk production and prices are drawn from monthly, quarterly, and annual NASS surveys.

NASS is also the source of data on licensed dairy herds, as reported in February issues of the NASS publication *Milk Production*. Farms must be licensed by State agencies to sell milk, with the licensing process focused on sanitary procedures on farms, and NASS collects the data from those State agencies.

Our analysis also relies heavily on data drawn from an annual large-scale survey of U.S. farms, the Agricultural Resource Management Survey (ARMS), which is jointly administered by NASS and the Economic Research Service (ERS). ARMS links measures of farm financial performance to farm production and production practices and to farm household resources and finances. The survey is designed to be comprehensive, covering all types of farms in the 48 contiguous States, and to be representative of U.S. agriculture. Phase III of the survey, conducted in the winter months following the reference year, focuses on farm production and financial outcomes.[36]

We rely primarily on a dataset drawn from Phase III of ARMS, the dairy costs and returns (CAR) dataset. The 2000, 2005, 2010 and 2016 Phase III surveys included an expanded set of questions on dairy costs, production, and practices aimed at a sample designed to be representative of all dairy producers with at least 10 milk cows in major dairy States. The dataset derived from this questionnaire is called the Costs and Returns dataset because its primary use is to provide baseline estimates of milk costs and returns.[37] Finally, the ARMS Dairy Versions are also the source of data on farm production practices in table 7 and farm organization in table 8.

Appendix table A1

Agricultural Resource Management Survey (ARMS) Costs and Returns (CAR) coverage of milk cows

ARMS year	Number of ARMS States covered	ARMS milk cows (inventory)	NASS milk cows (U.S. inventory)	ARMS inventory / NASS inventory
2000	22	7,987,441	9,210,000	0.867
2005	24	8,100,910	9,040,000	0.896
2010	26	8,513,161	9,117,000	0.934
2016	28	8,946,854	9,325,000	0.959

Note: ARMS samples among herds in survey States with at least 10 milk cows. NASS samples from all known milk producers in all States.

Source: USDA, Economic Research Service (ERS) using data from ERS and USDA, National Agricultural Statistics Service (NASS), Agricultural Resource Management Survey (ARMS), 2000–2016; and NASS *Milk Production*, February.

[36]Phase II of the survey focuses on production practices and resource use for selected field crops. Phase I is a screening survey, used to identify farms for selection into Phases II and III.

[37] Congress requires USDA to provide annual estimates on milk costs of production. Economic Research Service (ERS) provides estimates for baseline years from the Agricultural Resource Management Survey, and updates baseline data with National Agricultural Statistics Service data on changes in input and product prices to estimate costs of production for non-baseline years. For more information, please see the Milk Cost of Production Estimates data set on the ERS website.

The Dairy CAR survey has covered a growing number of States over time, and by 2016 covered the 28 largest dairy States, including 96 percent of U.S. milk cows.

ARMS sample farms are stratified into classes sorted by farm location, major commodity, and sales class. Sampling probabilities vary across strata. Each sample farm represents a number of like farms, and carries a sampling weight that allows us to generate population estimates for the measures of interest. Farms in the dairy CAR version each carry weights that allow us to generate population estimates for the CAR version's universe (dairy producers with more than 10 cows in major States). All of our analyses use the relevant sample weights to realize population estimates.

The CAR measures focus on the costs and returns to the farm's dairy enterprise, and not the financial performance of the whole farm (although CAR datasets also include whole-farm financial estimates derived from other questions in ARMS). CAR accounting therefore has to take account of transactions between the dairy enterprise and the rest of the farm. For example, the dairy enterprise may generate manure that is used as fertilizer, and that allows the farm's crop enterprise to reduce purchases of commercial fertilizer. The CAR accounts estimate a value for the manure generated by the cows, and include that value as part of the gross value of dairy production (that is, noncash income to the dairy enterprise). Similarly, the CAR accounts estimate a value for feed grown on the farm and provided to the dairy enterprise and include that value as a cost to the dairy enterprise (since it could have been sold off-farm).

CAR estimates are reported as unit values for class and industry aggregates. For example, the estimates of total cost and the gross value of production, per cwt, reported in table 6 are the sum of total costs in each category divided by the sum of production in each category.[38]

[38]The unit values reported in tables 5, 6, and 10 and figures 2, 4, and 9 are not simple averages across farms, adjusted for sampling weights. Instead, to reflect industry outcomes, these values are weighted by sampling weights and by production. By comparison, tables 5 and 7 are simple averages across farms, adjusted for sampling weights, because we want to represent the average farm in those tables—not the average unit of output.

Labor Costs in ARMS and CAR Accounts

Labor costs form an important component of milk costs of production for smaller farms, and differences in labor costs of production form an important element in overall production cost differences across different herd sizes. Because of the importance of labor in comparisons of production costs, we provide more detail on ERS procedures here.

The CAR accounts use data from the ARMS Dairy Version to estimate the labor component of milk costs of production. Specifically, the survey elicits information from farmers on hours worked on the whole farm as well information about hours worked on the dairy enterprise of the farm. Information is collected separately for the principal operator (the person most responsible for making day-to-day operating decisions on the farm), other operators, other unpaid workers (who are usually family members related to operators), and all other hired workers.

The ARMS also elicits data on expenses for hired labor, and ERS imputes an hourly cost for unpaid labor (unless the farm is incorporated, operators and their families cannot be paid a wage or salary by the farm business, but instead share in the net income of the business). ERS estimates a cost to unpaid labor with data from ARMS on farm operator off-farm work hours and earnings, as well as farm operator attributes such as age and education, and the location of the farm. ERS uses statistical analyses to estimate the average hourly earnings from off-farm work for farmers with specific attributes (age, marital status, education, and location). The agency then uses those findings to estimate what a dairy farmer with a specific set of attributes likely could have earned by working off the farm. That estimate forms the basis of the cost of unpaid labor for each farm operator.

Average labor costs, per hundredweight of milk produced, vary from $13.18/cwt among farms with 10 to 49 cows to $1.85/cwt among farms with at least 2,000 cows (Appendix table A2). Since farms with fewer than 200 cows heavily rely on labor provided by operators and family members, unpaid labor costs are most of total labor costs for those farms, and unpaid labor costs (per hundredweight) fall sharply as herd sizes increase.

Appendix table A2

Mean hours, costs, and wages by herd size

Herd size (milk cows)	Labor costs, milk production ($/cwt)		Imputed wage for unpaid labor ($/hour)	Annual hours, paid & unpaid, whole farm	Annual hours, principal operator	
	Total	Unpaid			Whole farm	Dairy enterprise
10–49	$13.18	$12.78	$21.74	6,166	3,522	2,387
50–99	$8.14	$7.53	$22.18	8,207	3,977	2,762
100–199	$5.12	$3.84	$23.16	11,903	3,879	2,701
200–499	$3.53	$1.45	$23.71	22,460	3,683	2,428
500–999	$2.87	$0.69	$25.03	34,805	3,427	2,560
1,000–1,999	$2.60	$0.30	$25.09	64,962	3,103	2,526
>1,999	$1.85	$0.10	$25.81	101,477	2,916	2,553

Note: cwt = hundredweight.

Source: USDA, Economic Research Service (ERS) using accounts on milk cost of production from ERS and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Small-herd labor costs are not higher because of higher imputed wages. The average imputed wage is higher for larger herds mainly because operators of those farms have higher levels of education, on average. Instead, labor costs differ because of substantial differences in milk output per labor hour.[39]

Note that principal operators with at least 500 cows report working just over 2,500 hours per year on the dairy enterprise, while those with 50 to 199 cows report working over 2,700 hours per year. In the ARMS questionnaires, ERS asks respondents to distinguish between hours worked in the dairy enterprise and hours worked for the whole farm business (including, for example, any cropping operations that the farm may run). Farmers do make that separation in their reporting: on average, farmers with fewer than 500 cows report 1,100 to 1,200 hours worked on farm operations aside from the dairy enterprise.

However, as appendix table A2 shows, principal operators do report very high levels of hours worked: nearly 4,000 hours per year for operations with herds of 50–199 cows, over 3,600 hours per year for farms with 200–499 cows, and over 3,400 hours for herds of 500–999. At the highest reported average, those estimates work out to 11 hours per day, every day, for farms with 50–99 cows. Operators do most of the milking on such farms, and cows are milked every day, so dairy farmers almost certainly work more days than other workers.

The hours reported are consistent across years, and they consistently distinguish between dairy hours and other farm hours. The questionnaires, which are personally enumerated, ask about whole farm hours first, and then dairy hours, to avoid double-counting. However, if farmers overestimate their hours worked, then we likely also overestimate farm labor costs. Because operator labor accounts for most labor hours on smaller farms, an overestimate of operator labor would also lead to an overestimate of the cost gap between small and large herds.

[39]See MacDonald, Cessna, and Mosheim (2016) for more analysis using 2010 ARMS data, which included more detail on labor hours.

Appendix B: Dairy Herd Size Distributions in Major Dairy States

The Agriculture Improvement Act of 2018 (the Farm Act) included the following directive:

SEC. 7607. COLLECTION OF DATA RELATING TO THE SIZE AND LOCATION OF DAIRY FARMS.

(a) IN GENERAL.—Not later than 60 days after the date on which the 2017 Census of Agriculture is released, the Secretary, acting through the Administrator of the Economic Research Service, shall update the report entitled “Changes in the Size and Location of US Dairy Farms” contained in the report of the Economic Research Service entitled “Profits, Costs, and the Changing Structure of Dairy Farming” and published in September 2007.

(b) REQUIREMENT.—In updating the report described in sub-section (a), the Secretary shall, to the maximum extent practicable, use the same unit of measurement for reporting the full range of herd sizes in Table 1 and Table 2 of the report while maintaining confidentiality of individual producers.

ERS prepared a report for Congress in 2019, updating the information on dairy farm structure included in the earlier report noted above (MacDonald et al., 2007). Table 1 of this report updates table 1 of the 2007 report. In order to report the full range of herd sizes in table 2 as in table 1, as requested in the Farm Act, we needed to greatly expand the original (2007) table 2 into 4 tables. Those tables provide additional detail on changes in dairy herd structure in each of 21 major dairy States (major Eastern and major Western Dairy States as denoted in the text of this report). We report that detail in the following appendix tables B1–B4, providing counts of the number of farms in each herd size class in 2007 and 2017 in tables B1 and B2, as well as the total number of cows in each State. Tables B3 and B4 provide estimates of the share of each herd size class in each State’s cow inventory.

Appendix table B1

Farms with milk cows in major Eastern Dairy States, 2007 and 2017

State	Year	All farms	Herd size (milk cows)						
			1–9	10–49	50–99	100–199	200–499	500–999	>999
		Number of farms with milk cows							
All 10 States	2007	46,468	5,067	16,083	15,678	6,172	2,505	649	314
All 10 States	2017	35,153	6,502	9,448	10,222	5,004	2,579	798	600
Illinois	2007	1,217	238	302	363	218	83	11	2
Illinois	2017	924	228	174	237	179	80	17	9
Indiana	2007	2,023	635	671	396	206	78	17	20
Indiana	2017	2,049	857	579	292	199	73	20	29
Iowa	2007	2,390	290	878	712	346	114	28	22
Iowa	2017	1,592	397	302	383	293	153	33	31
Michigan	2007	2,647	555	781	454	479	262	68	48
Michigan	2017	2,158	582	462	353	303	270	102	86
Minnesota	2007	5,148	279	1,757	1,965	775	284	60	28
Minnesota	2017	3,644	483	999	1,160	612	275	63	52
New York	2007	5,683	683	1,683	1,854	872	375	145	71
New York	2017	4,648	844	1,495	1,295	453	278	141	142
Ohio	2007	3,650	574	1,471	989	420	145	33	18
Ohio	2017	3,346	1,111	960	665	356	179	41	34
Pennsylvania	2007	8,333	1,049	2,986	2,996	980	255	55	12
Pennsylvania	2017	6,914	960	1,953	2,674	956	255	62	24
Vermont	2007	1,219	166	316	382	191	111	38	15
Vermont	2017	841	136	181	255	124	86	38	21
Wisconsin	2007	14,158	598	5,238	5,567	1,685	798	194	78
Wisconsin	2017	9,037	874	2,343	2,908	1,529	930	281	172

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture, 2007 and 2017.

Appendix table B2

Farms with milk cows in major Western Dairy States, 2007 and 2017

State	Year	All farms	Herd size (milk cows)						
			1–9	10–49	50–99	100–199	200–499	500–999	>999
		Number of farms with milk cows							
All 11 States	2007	8,467	3,033	759	714	822	1,071	898	1,170
All 11 States	2017	6,962	3,142	444	455	450	688	555	1,228
Arizona	2007	182	103	1	1	4	6	10	57
Arizona	2017	186	108	9	0	0	8	9	52
California	2007	2,165	433	58	43	101	427	510	593
California	2017	1,653	380	58	20	62	249	296	588
Colorado	2007	449	258	61	15	20	35	22	38
Colorado	2017	583	478	10	8	6	15	19	47
Idaho	2007	811	198	82	103	94	108	101	125
Idaho	2017	785	337	47	79	62	79	58	123
Kansas	2007	776	290	187	161	86	30	2	20
Kansas	2017	639	313	113	115	46	23	4	25
New Mexico	2007	272	116	10	1	3	6	18	118
New Mexico	2017	389	270	1	2	3	3	10	100
Oregon	2007	596	305	39	40	84	82	24	22
Oregon	2017	645	437	34	16	39	68	22	29
South Dakota	2007	656	147	182	161	86	45	16	19
South Dakota	2017	509	246	53	80	44	43	10	33
Texas	2007	1,293	685	54	69	147	146	90	102
Texas	2017	467	42	63	46	59	73	51	133
Utah	2007	450	174	30	53	92	59	26	16
Utah	2017	445	218	22	69	53	39	24	20
Washington	2007	817	324	55	67	105	127	79	60
Washington	2017	661	313	34	20	76	88	52	78

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture, 2007 and 2017.

Appendix table B3

Cow inventory by herd sizes in major Eastern Dairy States, 2007 and 2017

State	Year	Milk cows	Herd size (milk cows)						
			1–9	10–49	50–99	100–199	200–499	500–999	>999
			Share of cow inventory (percent)						
10 States	2007	4,125,944	0.4	12.6	25.4	19.5	17.6	10.5	14.0
10 States	2017	4,239,856	0.4	6.6	16.3	15.5	18.1	12.7	30.4
Illinois	2007	99,677	0.7	9.2	25.0	28.6	23.9	d	d
Illinois	2017	93,341	0.6	5.3	18.5	24.8	24.7	11.8	14.3
Indiana	2007	166,149	1.0	11.7	15.9	16.3	12.4	7.5	35.3
Indiana	2017	189,035	1.0	9.1	10.6	13.9	10.9	7.5	47.0
Iowa	2007	215,391	0.7	9.2	25.0	28.6	23.9	8.0	4.5
Iowa	2017	223,579	0.4	4.1	11.8	18.1	18.7	9.9	37.0
Michigan	2007	344,233	0.5	6.1	9.2	18.8	22.0	13.6	29.7
Michigan	2017	442,032	0.3	2.9	5.4	9.5	18.5	15.7	47.7
Minnesota	2007	459,752	0.2	12.3	28.8	21.6	17.3	8.4	11.4
Minnesota	2017	457,801	0.3	6.7	17.2	16.8	18.5	9.0	31.5
New York	2007	626,455	0.3	8.8	20.1	18.5	18.4	15.8	18.1
New York	2017	628,245	0.4	7.1	13.6	9.7	13.4	15.6	40.2
Ohio	2007	271,938	0.7	16.3	26.7	20.1	15.9	8.6	11.7
Ohio	2017	269,069	1.0	10.0	16.8	17.8	18.5	9.6	26.3
Pennsylvania	2007	553,321	0.5	19.0	35.3	22.6	12.8	6.3	3.6
Pennsylvania	2017	527,617	0.4	13.3	33.9	23.1	13.8	7.9	7.5
Vermont	2007	139,719	0.3	7.6	19.0	18.7	22.4	17.5	14.4
Vermont	2017	128,742	0.3	4.6	13.9	13.1	20.6	20.8	26.7
Wisconsin	2007	1,249,309	0.2	13.8	29.4	17.5	18.6	10.2	10.4
Wisconsin	2017	1,280,395	0.2	4.5	15.4	15.6	21.8	14.3	27.2

Note: Values have been suppressed in cells labeled with a “d” to preserve respondent confidentiality.
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture, 2007 and 2017.

Appendix table B4

Cow inventory by herd size in Western Dairy States, 2007 and 2017

State	Year	Milk cows	Herd size (milk cows)						
			1–9	10–49	50–99	100–199	200–499	500–999	1,000+
			Share of cow inventory (percent)						
11 States	2007	4,065,739	0.2	0.5	1.2	2.8	8.5	15.4	71.4
11 States	2017	4,396,826	0.1	0.3	0.8	1.4	5	8.8	83.6
Arizona	2007	183,744	d	d	d	0.3	1.3	4.0	94.2
Arizona	2017	211,937	d	d	0.0	0.0	1.0	3.2	95.7
California	2007	1,840,730	0.1	0.1	0.2	0.8	7.8	19.3	71.9
California	2017	1,750,329	0.0	0.1	0.1	0.5	4.7	12	82.6
Colorado	2007	126,944	0.4	1.1	0.8	2.3	9.8	12.6	72.9
Colorado	2017	169,423	0.6	d	d	0.5	3.6	7.7	86.7
Idaho	2007	536,643	0.1	0.5	1.3	2.3	6.4	13.6	75.8
Idaho	2017	603,817	0.1	0.2	1	1.3	3.9	6.8	86.7
Kansas	2007	115,634	0.7	4.6	9.8	9.5	7.1	d	d
Kansas	2017	160,671	0.4	1.9	5.2	3.6	4.3	1.4	83.2
New Mexico	2007	326,400	0.1	d	d	D	0.7	4.2	94.8
New Mexico	2017	337,888	0.2	d	d	0.2	0.3	1.9	97.4
Oregon	2007	116,788	0.6	0.9	2.5	10.6	22.2	14.4	48.8
Oregon	2017	128,284	0.7	0.6	0.9	4.4	16.4	11.3	65.7
South Dakota	2007	86,243	0.5	6.4	12.8	12.4	15.5	d	d
South Dakota	2017	127,325	0.4	1.3	4.4	4.8	10.2	5.8	73.1
Texas	2007	404,399	0.4	0.3	1.2	5.2	11.2	14.9	66.8
Texas	2017	531,849	0	0.3	0.6	1.5	4.2	6.2	87.2
Utah	2007	85,262	0.5	1.0	4.5	15.0	21.4	20.6	37.0
Utah	2017	98,389	0.4	0.6	5	7.4	11.1	15.9	59.6
Washington	2007	243,132	0.3	0.5	2.1	6.0	16.5	22.0	52.6
Washington	2017	276,914	0.2	0.3	0.5	3.9	11.1	13.5	70.5

Note: Values have been suppressed in cells labeled with a “d” to preserve respondent confidentiality.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Census of Agriculture, 2007 and 2017.

Appendix C: Analyzing Cost Differences Among Conventional Dairy Farms

We performed a statistical analysis of production costs among conventional dairy farms, in order to (a) identify the association of herd size with costs; (b) establish the substantial variation in production costs, even after controlling for herd size; and (c) identify the impact of certain farm attributes, such as making a transition to organic production, on costs.

We drew on individual dairy farm data from the 2016 Agricultural Resource Management Survey (ARMS). The analysis assessed those 1,145 respondent farms focused on conventional production. The dependent variable was total production costs per hundredweight of milk sold, expressed in natural logarithms (so that coefficients can be interpreted as elasticities). In the statistical analysis, we related costs to herd size (milk cows, and milk cows squared, to account for nonlinearities in the relationship), also expressed in natural logarithms.

We added several attributes of the farms, expressed as dichotomous (0-1) variables, each equal to 1 if the farm: was making a transition to organic production during the year; produced milk for only part of the year; used computerized record-keeping systems for feeding or for milking; used artificial insemination or sexed semen for breeding; milked cows three times day (normal is twice a day); or used recombinant bovine somatropin (Rbst) in feed. We also entered the percent of the herd consisting of Holstein cows. Holsteins generally produce more milk per cow and per unit of feed. Finally, we also added State fixed effects, to account for persistent cross-State differences in average costs.

We first regressed average costs on herd size and size squared (equation 1). Coefficient values were as expected, with costs declining at a decreasing rate as herd size increased. Herd size alone accounts for 31 percent of the variation in average costs, but that also indicates a wide range of average costs for any given herd size. Adding State fixed effects (equation 2) reduced the variation only modestly (an R-squared of 35 percent), while showing little effect on the coefficients for size.

In equation (3), we added measures for an organic transition, and for operating part of the year. Each had substantial estimated effects on costs. Average production costs for farms making a transition to organic were 31.7 percent higher than other farms, holding herd size and State constant. The effect of part-year operation is not statistically significant, but it is large: average costs at farms operating only part of the year are about 10 percent higher.

We added a set of farm practices in equation (4). It should be noted that these practices are often chosen jointly with the decision to operate at a certain volume of production and may enable farms to operate at that volume. That is, the practices are not necessarily exogenous. The percent of a herd that is Holsteins had an important association with costs. Average production costs, per hundredweight of milk produced, for a herd with 100 percent Holsteins are 18 percent lower than a herd with no Holsteins. Holsteins produce more milk, but other breeds, such as Jerseys, produce milk with a higher fat content and may generate higher prices. The inclusion of the Holstein variable also reduces the coefficient on organic transition, with farms making a transition now estimated to have costs that are 25.6 percent higher than farms not making a transition. Finally, we should note that the estimated effects of herd size on average costs remain robust to the inclusion of other variables.

Appendix table C1

Regression analysis of average costs among conventional dairy producers

Variables	(1)	(2)	(3)	(4)
	–Coefficients and t statistics–			
Intercept	5.261 (0.154)	5.233 (0.160)	5.108 (0.160)	4.949 (0.167)
Milk cows (number)	-0.629 (0.060)	-0.651 (0.063)	-0.640 (0.063)	-0.521 (0.063)
Milk cows squared	0.041 (0.0055)	0.043 (0.006)	0.043 (0.0061)	0.032 (0.0063)
Making a transition to organic			0.275 (0.075)	0.228 (0.074)
Operating part-year			0.097 (0.061)	0.140 (0.060)
Percent Holsteins in herd				-0.002 (0.00024)
Uses AI or sexed semen				0.021 (0.026)
Computerized feeding				0.011 (0.037)
Computerized milking				-0.069 (0.035)
Milks three times/day				0.083 (0.037)
Uses Rbst				-0.051 (0.044)
State fixed effects	No	Yes	Yes	Yes
R^2	0.314	0.352	0.363	0.398
N	1,145	1,145	1,145	1,145

Note: The dependent variable is the logarithm of total costs per cwt of milk sold. Continuous explanatory variables (milk cows and cows squared) are also specified in logarithms.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2016 Dairy Version.

Appendix D: Decisions to End Milk Production

Our analysis shows a substantial decline in the number of dairy farms over time. It also shows that many farms continue to operate despite relatively poor financial returns, and that decisions to end production can play out over a long period of time. We take a closer look at dairy farm exit decisions here, focusing on prospective plans to exit.

The 2010 ARMS Dairy Version asked respondents how long they expected their operations to continue producing milk, and gave six choices among which to select: less than 1 year, 1 year, 2–5 years, 6–10 years, 11–19 years, and 20 or more years. We combined the first three responses into one: the respondent expects the farm to stop producing milk within 5 years. We created a variable EXIT, set equal to 1 if the respondent expected to end milk production within 5 years, and set equal to 0 otherwise. We then analyzed variations in EXIT, using a logit model with a set of farm and operator attributes drawn from ARMS as explanatory variables.

We aimed to identify the association of exit with herd size by entering dummy variables for six different herd size classes (with 10–49 cows as the base). We also included production cost per cwt on the farm as an explanatory variable (with herd size variables also included, this amounts to using the difference in cost/cwt from the mean for the farm's herd size class).

One primary focus of the analysis is to estimate the association between farm exit and operator age. To that end, we also entered a dummy variable equal to 1 if the farm's principal operator was at least 60 years old, another dummy variable equal to 1 if the principal operator was a hired manager, and a final dummy variable equal to 1 if the farm had multiple operators. The last two reflect options for someone else to take over the farm in the event of the principal operator's retirement. The analysis used 1,351 observations on conventional dairy operations in the 2010 ARMS.

We report coefficients and standard errors in table D-1. All of the explanatory variables are of the expected sign; they are all precisely estimated; and the effects are large. Smaller farms, farms with relatively high production costs, farms whose operators are over age 59, and farms without other operators to take over are more likely to close. We report four different regression equations. The first includes production costs and operator age alone, and we then add other operator attributes in equation (2), and finally size variables in equations (3) and (4) without production costs (which are strongly correlated with herd size) and then with production costs added. The coefficient on operator age is robust to the inclusion of other variables and remains highly significant throughout.

Because logit models are highly nonlinear, the coefficient values do not have transparent implications. Predicted values from logit models are the logarithm of the odds ratio (p/1-p), where p is the probability of exit. We estimated predicted values for various combinations of explanatory variables, and then derived the predicted probability p. In table 10, we report those predicted exit probabilities for different values of the explanatory variables, and in that way show how a change in an explanatory variable affects the probability of exit.

Appendix table D1

Modeling exit from milk production

Variable	(1)	(2)	(3)	(4)
	–Coefficient and standard errors–			
Intercept	-2.4026 (0.293)	-2.1498 (0.0340)	-0.9311 (0.0247)	-0.9406 (0.0464)
50–99 cows			-0.2784 (0.0274)	-0.2707 (0.0276)
100–199 cows			-0.9387 (0.0365)	-0.9274 (0.0367)
200–499 cows			-1.4417 (0.0571)	-1.4201 (0.0570)
500–999 cows			-2.2612 (0.1138)	-2.2404 (0.1138)
>999 cows			-1.7517 (0.1036)	-1.7335 (0.1065)
Cost/cwt	0.0256 (0.0007)	0.0243 (0.0007)		0.0126 (0.0009)
Operator>59	1.1452 (0.0257)	1.2005 (0.0261)	1.3909 (0.0269)	1.3296 (0.0272)
Multiple operators		-0.3281 (0.0250)	-0.2945 (0.0252)	-0.2801 (0.0253)
Hired manager		-0.4841 (0.0998)	-0.3290 (0.1023)	-0.2626 (0.1018)

Note: Dependent variable EXIT equal to 1 if respondent expects operation to stop producing milk in 5 years or less, and equal to 0 otherwise. Cost/cwt is a continuous variable, measuring milk production costs per cwt on milk produced. Other explanatory variables are dichotomous, taking on values of 0 or 1, with 6 herd size classes (0–49 is excluded), a variable equal to 1 if the principal operator is 60 or older, another equal to 1 if the principal operator is a hired manager, and another equal to 1 if there are multiple operators. The model is estimated with the logit maximum likelihood technique.

Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, 2010.