Title

Dairy Farm Size Patterns and Women Dairy Farm Operators: Trends and Relationships in Six Major Dairy States

Author
Fraysse, Elizabeth

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Dairy Farm Size Patterns and Women Dairy Farm Operators: Trends and Relationships in Six Major Dairy States

Elizabeth Anne Fraysse
Department of Agricultural and Resource Economics

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Master of Science

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Approved:

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Professor Daniel Sumner, Chair

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Professor Richard Sexton

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Professor Bulat Gafarov

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Abstract

This thesis presents evidence on two related sets of patterns and relationships. First it show commercial dairy farm size distributions and related to farm management and operator characteristics. Second it shows how gender demographics of dairy farm operators have changed over time and relationships between farm size and farm operator characteristics related to gender and marriage between farm operators. The data draws on the four Census of Agriculture from 2002 through 2017 and the six major dairy states—California, Idaho, New Mexico, New York, Texas, and Wisconsin.

As the trend of farm consolidation continues within the dairy industry, it remains imperative to present evidence of ongoing farm size trends with geographic distinctions. There is a clear trend of increasing herd sizes across all states and a decrease in the number of commercial dairies. Herd size patterns and trends vary greatly by state and this research finds that none of the six states studies follow either of the two common skewed parametric densities often used for firm size. Moreover, there remains little evidence that the U.S. dairy industry is becoming bimodal. The diversification of sales has a positive relationship with farm size. Farm operator characteristics, such as age and off farm employment, tend to have either a slightly negative relationship with size or no relationship with size.

This research finds that the old assumption that dairy farms are traditionally run by men is shifting with increase representation of female dairy farm operators. Recent data shows an increase in the share of commercial dairy farm operators who are female and an increase in the share of commercial dairies with at least one female operator. Census of Agriculture data also show that the presence of female operators on a dairy farm and a spousal run dairy has negative correlation with the commercial dairy farm size. Commercial

dairy farms run by spouses and that include women may make management decisions that differ from those exclusively run by men.

Acknowledgement

I would like to sincerely thank Professor Daniel Sumner for his guidance and support of my research. His guidance and mentorship have shaped my research and inspired me, and I am incredibly grateful to have had to the opportunity to learn from him.

I would also like to thank my other committee members Richard Sexton and Bulat Gafarov for their time and consideration.

Last but certainly not least, I would like to thank my family: my parents Robert and Michelle Fraysse and my brother Matthew Fraysse, for supporting and helping me throughout my studies.

Chapter 1: Introduction

1.1 Relevance of Research

This thesis deals with two important trends in the U.S. dairy industry: 1) increases in farm size, and 2) the increases in prevalence of female dairy farm operators. This research explores detailed data on farm size changes in major U.S. dairy states and document consolidation and other trends in the patterns of dairy farm size distributions.

The dairy industry is of interest, not only because it is an important industry measured by production value, but also because of its environmental and social importance. Declines in the number of dairies have raised concerns based on their impact on rural communities, particularly movement of dairies out of local regions and, the potential fall in local employment opportunities.

New data on farm operator characteristics allow us to better analyze the trends of gender demographics and the influence of operators' ages relative to farm size. There has been very little economic research related to the increasing role of female operators in the dairy industry. Trends toward more women operators and fewer dairy farms suggests correlations between the role of women in the dairy industry and herd size per farm and other farm characteristics.

Looking overall at U.S. trend in operations with milk cows, Figure 1.1 shows that since 1982, the number of operations with milk cows has decreased rapidly and the average number of milk cows per farm has increased. This graph describes a trend of consolidation in the dairy industry, as defined as operations with milk cows. Despite the slight decrease in number of milk cows there has been an increase in the U.S. milk production (NASS[a]). These changes characterize the consolidation within the dairy industry.

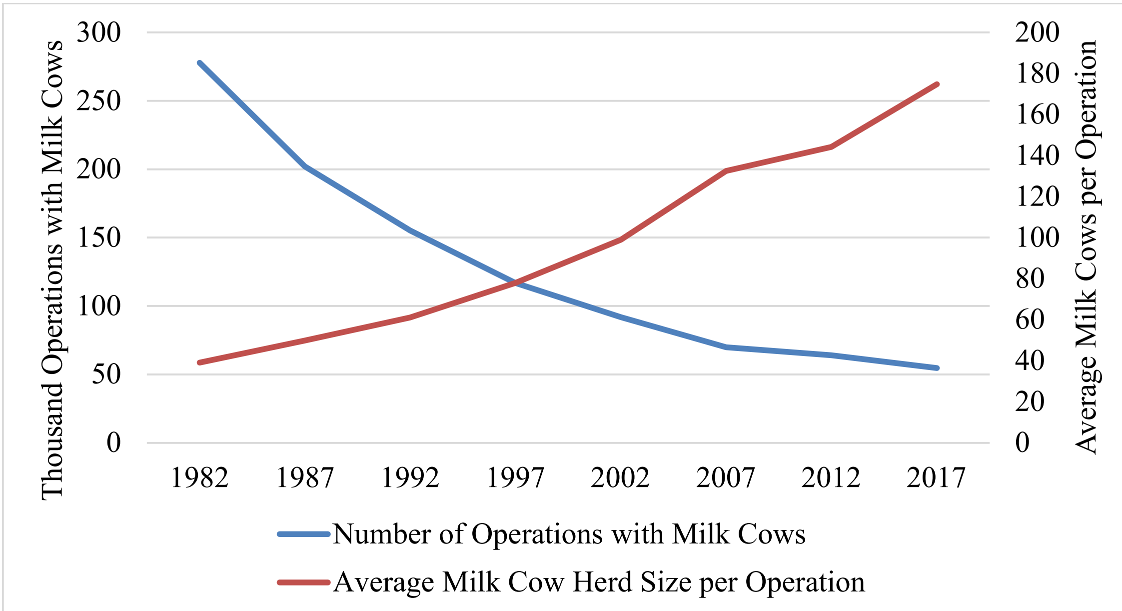
These national trends mask large differences by state. Some states, such as California, has seen growth of herd sizes into the range of 2,000 or more milk cows per farm. Other states, such as Wisconsin have experienced equally rapid increases in herd size per farm in percentage terms, but herd sizes of larger farms in Wisconsin are in the range of 500 cows per farm. Consolidation is common in other farm industries. An important contribution of this thesis is to document and characterizes this trend over time for an important industry, which is of significance to agricultural economic research.

Consolidation may have allowed dairies to capture improved productivity and efficiency on the farm. How dairy farm size changes in response to these and other factors are important in considering future trends in farm size and their impact on milk production in the United States. My research seeks to help explain recent patterns of farm size change in the dairy industry, considering trends in operator characteristics and management, while accounting for regional differences.

Farm operator characteristics have changed as dairy farm size has evolved. The share of women dairy farmers has increased. Historically, farming has been a stereotypically male occupation. Despite contributing to farm production and farm management, surveys, and censuses, have been limited in their collection of data on the contributions of women as farm operators. I hypothesize that some of growth in female contribution to farm operation is due to changes in social and gender norms in reporting. One contribution of my research is to attempt to separate, to the extent possible, changes in management and operations on dairy farms from how such activities are reported.

Demographic trends in farm operation and management are important because they help researchers and policy makers get a better sense of who runs the operations in an industry by age, gender, and other characteristics. The dairy industry remains predominately male. However, since 2002, there has been a substantial increase in the share of women dairy farm operators and an increase in the absolute number of dairy farms with at least one female operator in many places. The share of commercial dairies with at least one female core operator has increased across all states, except New Mexico. New York saw the largest increase in the share of commercial dairies with at least one female core operator from 36% to 55%. California saw a 40% increase in the share of commercial dairies with at least one female core operator. This trend, which has occurred while dairy farm consolidation has proceeded at a similar pace suggests that the participation of female dairy farm operators may positively affect dairy farm herd size and economic viability.

Figure 1.1 Numbers of U.S. operations with milk cows and average milk cows per farm



Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 1982, 1987, 1992, 1997, 2002, 2007, 2012, and 2017 Link: (https://quickstats.nass.usda.gov/)

Chapter 2: Census of Agriculture Data and Sample Observation Utilized

This chapter presents the reader with an overview of the data and sample used in Chapters 4 and 5, detailing the specific definitions used and changes to the Census of Agriculture (COA) overtime, as is relevant to this research.

2.1 GENERAL DATA DESCRIPTION

As noted in the previous chapter, for the statistical estimation in the thesis I will utilize data for the USDA COA. Under "Census of Agriculture Act of 1997", The COA is a federally mandated Census of all U.S. farms and ranches every five years, and it captures individual farm-level data on production costs, operators' characteristics, land use, number of milk cows, revenue, etc. The data and statistics resulting from this Census are reported at the county or state level and research using the individual level data is restricted to USDA research or special request for non-USDA entities. I was given special permission to have access to individual farm-level data for census years of 2002, 2007, 2012, and 2017 from the following specified states: California, Idaho, New Mexico, New York, Texas, and Wisconsin.

The National Agricultural Statistics Service (NASS), which conducts the Census, attempts to gather responses from every farm in the United States, where a farm is defined as, "is any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year." (NASS[b])

NASS uses a complex sampling procedure that starts with the Census Mail List (CML). The CML is a mailing list of all potential U.S. farms, as defined by UDSA, The CML is built and improved upon using outside sources, from government lists or different agricultural producer lists. When new names, of potential farms, are discovered they are then treated as a potential farm and added to the CML until the farm is found to not meet the USDA definition of a farm. From there Census data is collected by mail or Computer-Assisted Self Interview (CASI) on the Internet. The respondents submitted one of four different forms: general, short, Hawaii, or American Indian form.

The COA data that I use can be described as unbalanced panel data with both attrition and replacement and with occasional errors in recognizing continuing cross-section units. Although the data used is at the individual farm level, no data presented in this thesis reveals any information concerning an individual farm or person.

All present research has been subject to a disclosure review and all research using COA data follows the following guidelines, "In keeping with the provisions of Title 7 of the United States Code, no data are published that would disclose information about the operations of an individual farm or ranch. All tabulated data are subjected to an extensive disclosure review prior to publication. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived, was suppressed, and coded with a 'D'. However, the number of farms reporting an item is not considered confidential information and is provided even though other information is withheld." (NASS[a])

2.2 EXPLANATION OF HOW CENSUS QUESTIONS VARY YEAR-TO-YEAR

The survey questions asked of farmers and ranchers by the COA change slightly every Census round, although most questions remain the same across rounds. Below are descriptions of questions changes for relevant variables to the analysis. First, in 2002 and 2007, farms were asked for the total amount of milk or dairy sales in that year, but in 2012 and 2017, this question was dropped and replaced with the total amount of milk sales.

Second, operator characteristic questions have become more detailed over the years and allowed more operators to be captured by the Census. In 2002, 2007, and 2012, the COA asked detailed operator characteristic questions about up to three operators, and only one operator was able to be identified as the principal operator. The COA defined a principal operator as "… the person most responsible for making day-to-day decisions on the farm, during the data collection process." (ERS Glossary)

Whereas an operator is defined as "A farm operator is a person who runs the farm, making day-to-day management decisions. An operator could be an owner, hired manager, cash tenant, share tenant, and/or a partner. If land is rented or worked on shares, the tenant or renter is an operator." (ERS Glossary)

However, in 2017, the COA expanded its detailed operator questions to include up to four operators and now allows for up to four operators to be identified as a principal operator. The definition of principal operator (producer, all principal) is "Demographic data were collected for up to four producers per farm. Each producer was asked if they were a principal operator or senior partner. A principal operator is a producer who indicated they were a principal operator. There may be multiple principal producers on a farm. Each farm has at least one principal producer." (NASS[c]) Whereas operators (producers, all non-principal) were defined as "A non-principal is a producer who did not indicate they were a principal operator. There may be no non-principal producers on a farm." (NASS[c]) Furthermore, in 2012, the COA started asking farmers and ranchers if the secondary operators (meaning those not labelled as the principal operator) were married to the principal operator. This question was then adapted in 2017 to reflect the increase in possible principal operators identified and asked if the operator (principal or secondary) was married to a principal operator.

2.3 WORKING SAMPLE OF USE IN THE ECONOMETRICS

In order to capture dairy farms with substantial dairy operation, I limit my statistical analysis to those farms that have engagement with the commercial milk business. To implement this, I needed to set an inclusion criterion:

The COA asks farmers and ranchers to answer two dairy specific questions:

(1) "Of the total number of cattle and calves on hand December 31," (Of the given Census year) "How many were – Milk cows kept for production of milk? Include dry milk cows and milk heifers that had calved." (NASS[a])

(2) Milk or dairy product sales:

(3) In 2012 and 2017, "Sales of milk from cows – Gross Value of Sales." (NASS[a])

   a. Or, in 2002 and 2007, "Value of Sales – Milk and other dairy products from cows." (NASS[a])

For our further data analysis, I consider farms that have substantial dairy operations. I want to leave aside those operations that meet the USDA definition of a farm but have minimal connection to commercial dairy production and revenue. To be included as a commercial dairy operation in our sample requires meeting two minimum criteria.

First, the farm must have dairy or milk sales revenue above the dollars of milk sale revenue that would have been generated by 30 milk cows. Second, at least 20 milk cows were on the farm as of December 31 in the Census year. This minimum was set to remove dairy farms that had "exited" and had already removed most of their cow from the farm but still had milk or dairy sales revenue for the year above our minimum criteria.

For this research I choose to analyze dairies from six states, California, Idaho, New Mexico, New York, Texas, and Wisconsin. These six states were chosen for my research because they capture the major the U.S. commercial dairy industry (both in number of milk cows and milk sales revenue) and therefore are a useful and representative characterization of

U.S. dairy farming. The following Chapter details the reasoning behind the selection of the six states and characterizing the U.S. dairy industry on the whole.

Chapter 3: Characterization of the U.S. Dairy Industry

This chapter gives a brief overview of the U.S. dairy industry in order to provide context to the reader of ongoing trends. Table 3.1 shows the number of farms that fit the definition of 1) the number of farms with any milk cows and milk and/or dairy sales (referred to as a dairy with milk and/or dairy sales), as well as 2) the number of farms with any milk cows and 3) a commercial dairy, as set by my criteria listed above. Across all definitions of a dairy each state has seen significant decreases in the number of dairies, except in New Mexico where the number of farms with milk cows remains relatively unchanged.

3.1 EXPLAINATION FOR THE SELECTION OF THE SIX STATES

The six states used in this research were selected because they capture a significant share of the U.S. dairy industry and reflect the overall trends. Figure 3.1 shows that these select six states make up the majority share of the total number of milk cows in the United States. These six states made up almost 55% of total U.S. number of milk cows in 2017 and demonstrated an increasing trend in share of U.S. number of milk cows since the 2002. Figure 3.2 shows that these six states also make up the majority share of milk sales revenue in the United States, with Texas and California making the largest shares in the group.

The six states are the leading milk producers in the United States. Although, there are significant differences between each state that I will discuss below, including differences in herd size trends. They represent the majority of the dairy industry, by multiple measures, and they are and representative of national distribution. As discussed in Sumner and Wolf (2002) the Eastern states are characterized with many smaller dairies than the other states, including New York and Wisconsin. Whereas, Pacific and Southern states such as, California, Idaho, and New Mexico (Pacific) and Texas (Southern), tend to have dairies with larger herd sizes.

3.2 THE NUMBER OF DAIRIES BY DIFFERENT DEFITIONS

From 2002 to 2017, California saw a 36% decrease in the number of commercial dairies and a slight larger percentage decrease for farms with milk and/or dairy sales and farms with milk cows. Idaho saw its largest decrease in the number of commercial dairies (37% decrease) with farms with milk or dairy sales close behind. However, farms with milk cows only decreased by 20% in Idaho. New Mexico had a very slight 3% increase in the number of farms with milk cows, but a 21% decrease in the number of farms with milk and/or dairy sales and a 26% decrease in the number of commercial dairies. New Mexico saw the smallest percent decrease in commercial dairies from 2002 to 2017 of any of the six select states. New York had about a 50% decrease in the number of commercial dairies and about a 40% decrease in the number of farms with milk cows and farms with milk and/or dairy sales. Texas had the largest percent decrease of across all definitions of dairies. Texas saw a 56% decrease in the number of commercial dairies and 60% decrease in the number of farms with milk and/or dairy sales. Interestingly, there was a 78% decrease in the number of farms with milk cows in Texas which is a significant decrease. Across all three definitions of a dairy Wisconsin had very similar trends with about 46-49% decrease in the number of dairies.

3.3 CHARACTERIZATION OF SIX SELECT STATES' DAIRY INDUSTRY

In California, there tends to be an increase in larger herd sizes. Figure 3.3 shows the number of farms with milk and/or dairy sales in California for the four Census years (2002, 2007, 2012, and 2017) and the share of farms with milk or dairy sales by herd size. California saw significant decreases in the smaller herd sizes.

Figure 3.4 shows the share of all milk or dairy sales and number of farms with milk or dairy sales by herd size for the state of California. From 2002 to 2017, the share of revenue generated by smaller herd sizes has decreased significantly. The majority of the share of milk or dairy sales revenue has come from dairies with 1,000 or more milk cows and this share has increased to over 80% in 2017.

Idaho follows a similar trend as California, Figure 3.5 shows a significant decrease in the smaller herd sizes and growth in the larger herd size groups. Furthermore, between 2002 and 2017 there was significant increase in the share of milk and/or dairy sales from farms with herd sizes greater than 1,000 milk cows (Figure 3.6). The share of sales revenue from farms with herd size smaller than 499 milk cows fell from about 15% in 2002 to less than 10% in 2017.

New Mexico saw an increase in the number of farms with milk and/or dairy sales between 2002 to 2007, but then subsequent decreases in 2012 and 2017 (Figure 3.7). Overall, there was a decrease in farms with herd sizes between 200-999 milk cows. Figure 3.8 show the relative decrease in farms with milk and/or milk sales in New York and the decrease in the share of dairies with 1-199 milk cow herd size. There was an increase in the number of farms with a herd size greater than 1,000 milk cows.

Figure 3.9 shows a decrease in the number of dairies with milk and/or dairy sales with significant decrease in the share of farms with a 1-199 milk cow herd size between 2002 to 2017 in Texas. There was also an increase in the number of farms with herd sizes greater 1,000 milk cows. Figure 3.10 shows that between 2002 and 2017 Texas farms with a herd size greater than 1,000 milk cows saw a significant increase in the share of milk or dairy sales revenue, from about 40% in 2002 to almost 90% in 2017.

The majority of Wisconsin farms have a small (1-199 milk cow) herd size, although there has been a decrease from 2002 to 2017. There has been an increase in the number of farms with larger milk cow herd sizes (Figure 3.11). Figure 3.12 shows that the majority of milk and/or dairy revenue in Wisconsin used to come from farms with smaller milk cow herd size but has shifted overtime towards farms with larger milk cow herd sizes.

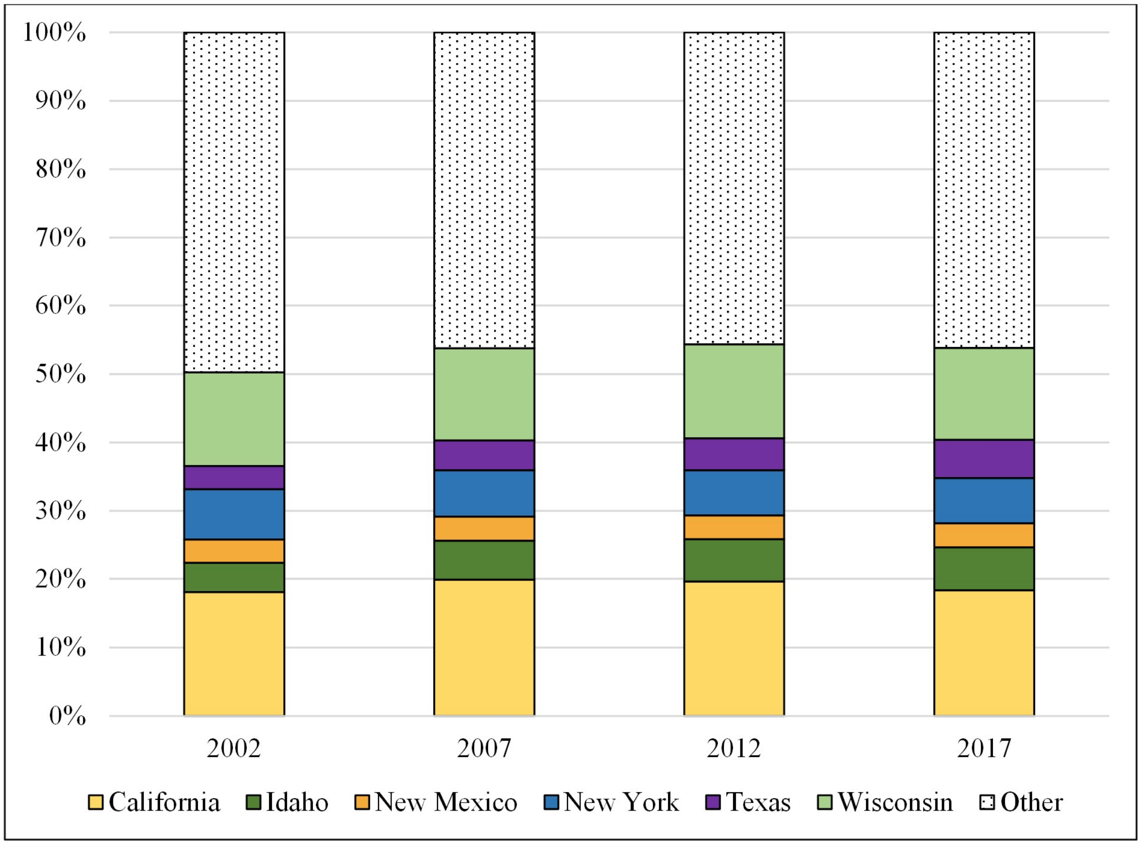
Table 3.1 Number of dairy farms using alternative definitions by state and census year

State	2002	2007	2012	2017
California				
Farms with Milk or Dairy Sales and at Least One Milk Cow	2,280	1,923	1,479	1,279
Farms with Milk Cows	2,793	2,165	1,931	1,653
Commercial Dairies	1,920	1,671	1,428	1,225
Idaho				
Farms with Milk or Dairy Sales and at Least One Milk Cow	738	796	625	490
Farms with Milk Cows	982	811	934	785
Commercial Dairies	625	521	496	393
New Mexico				
Farms with Milk or Dairy Sales and at Least One Milk Cow	182	245	157	143
Farms with Milk Cows	377	272	410	389
Commercial Dairies	161	146	119	119
New York				
Farms with Milk or Dairy Sales and at Least One Milk Cow	6,599	5,660	4,798	3,905
Farms with Milk Cows	7,388	5,683	5,427	4,648
Commercial Dairies	5,039	3,710	3,095	2,558
Texas				
Farms with Milk or Dairy Sales and at Least One Milk Cow	1,130	1,214	649	452
Farms with Milk Cows	2,080	1,293	985	467
Commercial Dairies	842	547	491	370
Wisconsin				
Farms with Milk or Dairy Sales and at Least One Milk Cow	16,465	13,888	11,063	8,327
Farms with Milk Cows	16,886	14,158	11,543	9,037
Commercial Dairies	11,641	9,564	7,586	6,165

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

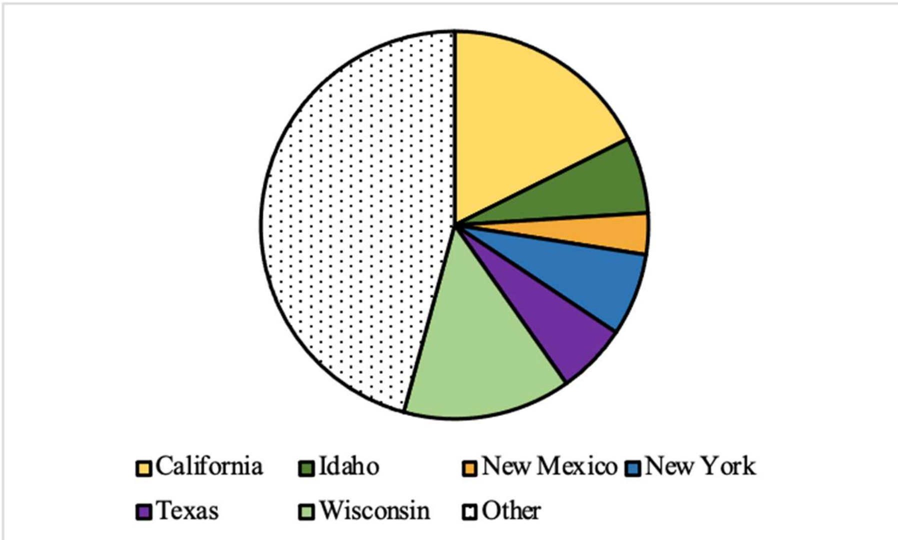
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 3.1 Milk cows as a share of national total, by state and census year, 2002 – 2017



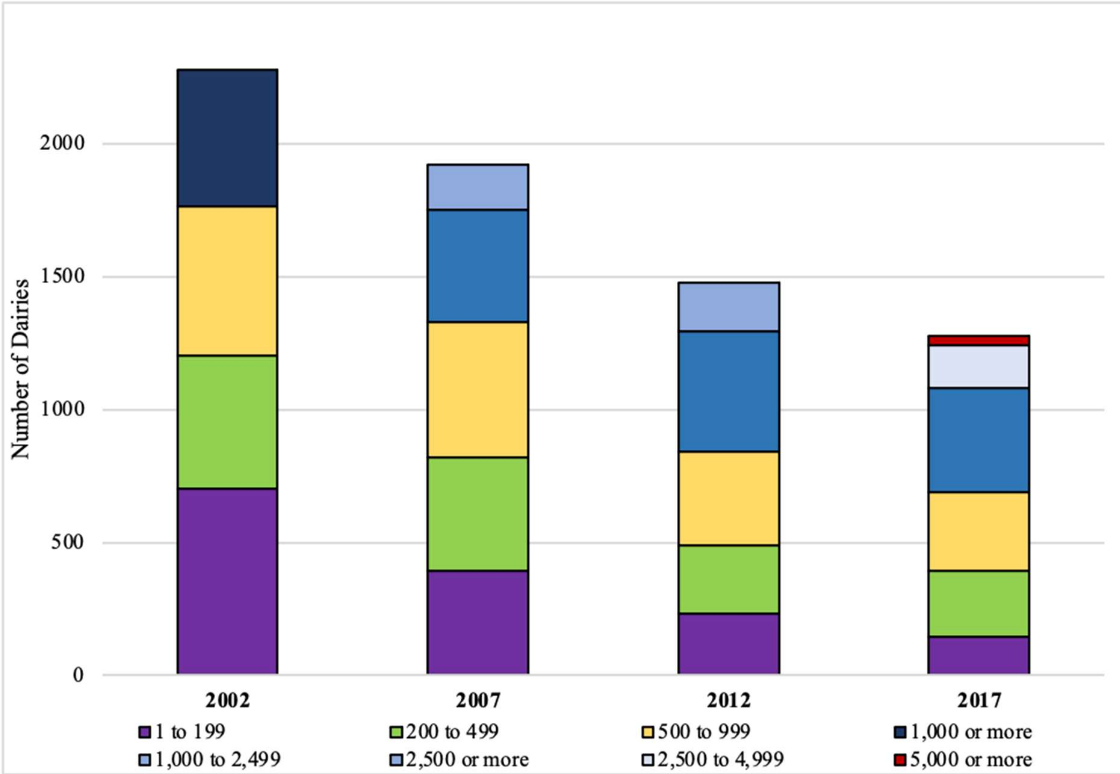
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017
Link: (https://quickstats.nass.usda.gov/)

Figure 3.2 Share of national milk revenue, by state in 2017



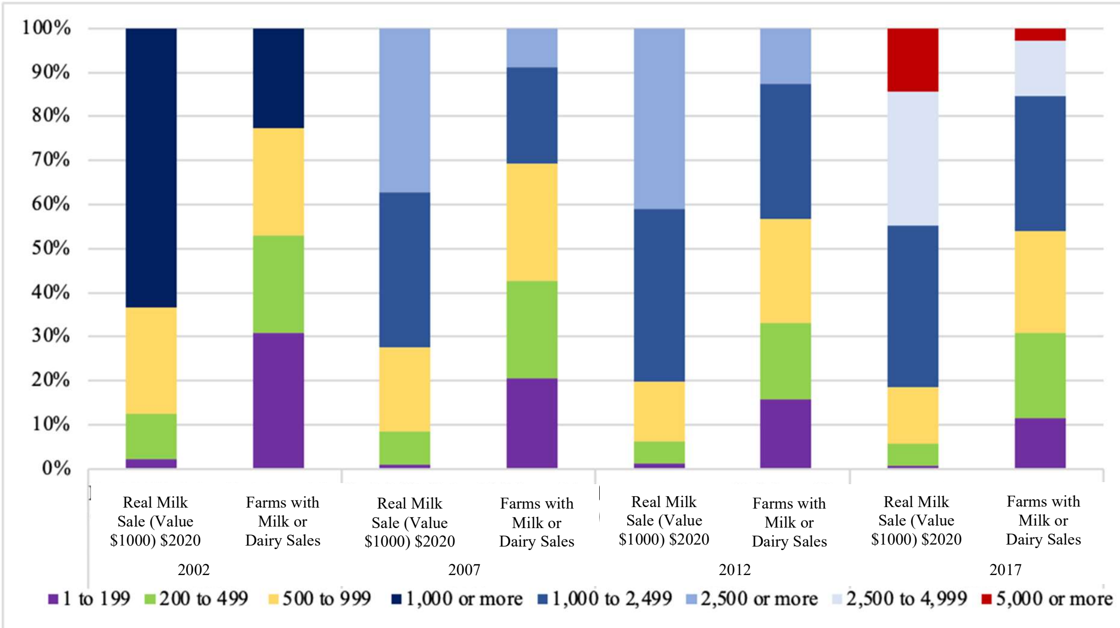
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2017, Link: (https://quickstats.nass.usda.gov/)

Figure 3.3 Distribution of farms with milk or dairy sales by herd size, California, 2002 – 2017



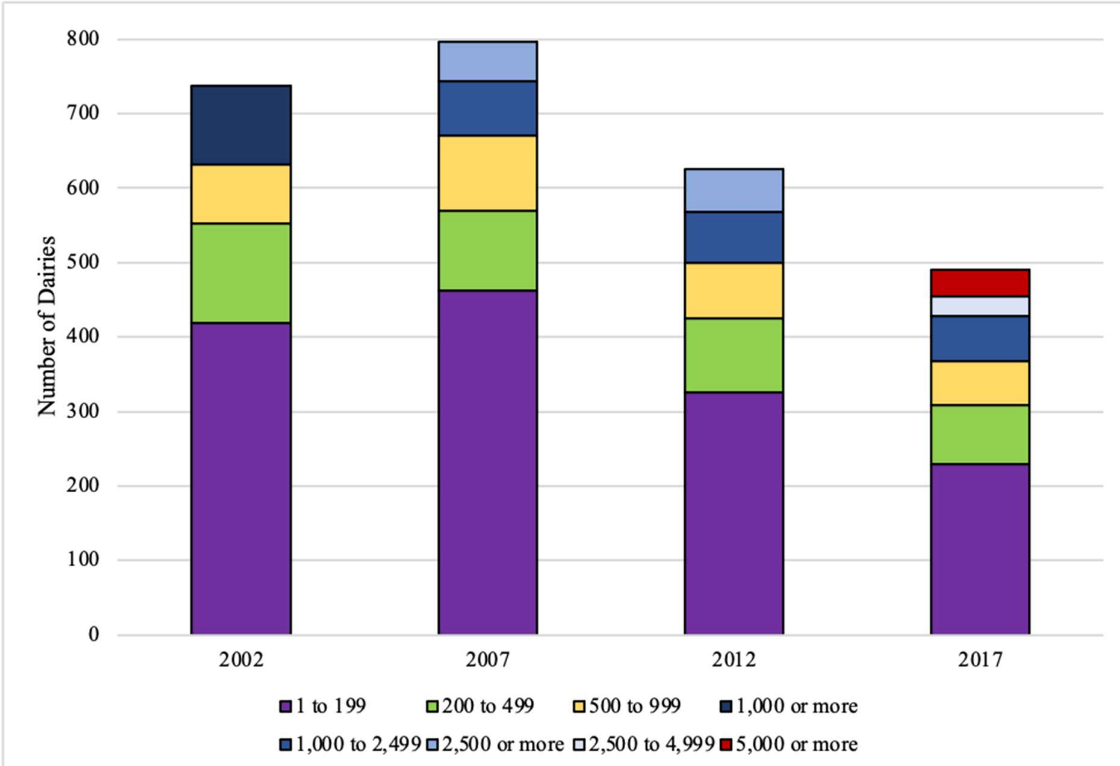
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 3.3 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.

Figure 3.4 California milk or dairy* revenue distribution and number of farms with milk or dairy sales (with at least one cow) by herd size, in 2020 GDP Prices



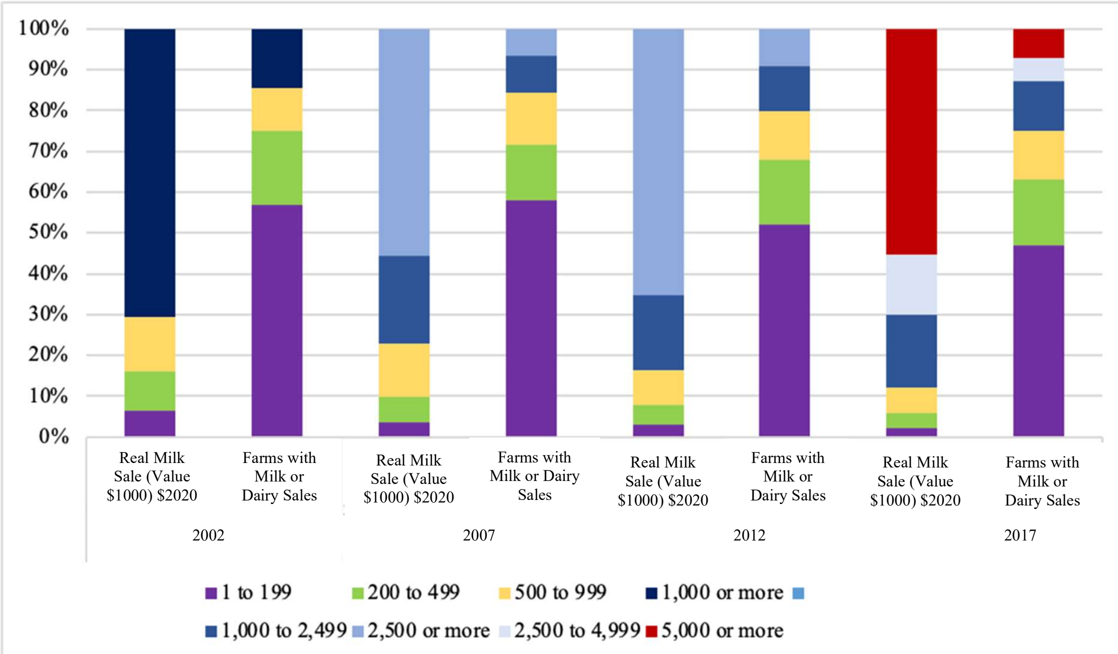
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)

Figure 3.5 Distribution of farms with milk or dairy sales by herd size, Idaho, 2002 – 2017



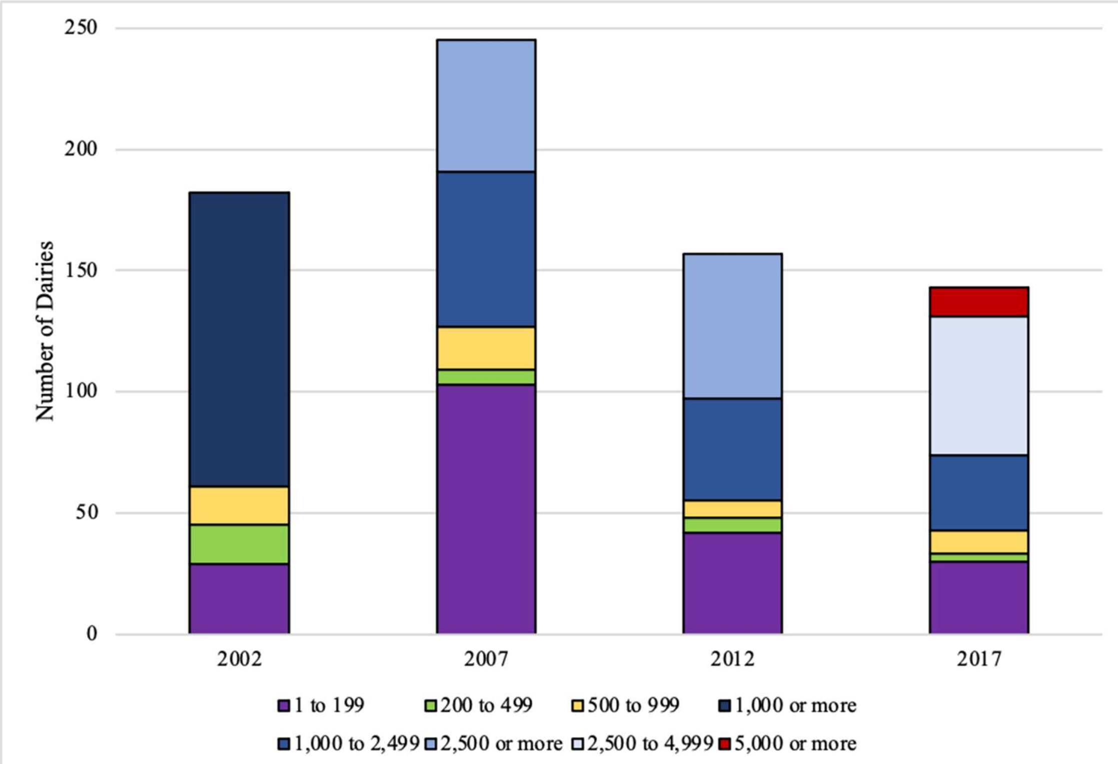
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 3.5 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.

Figure 3.6 Idaho revenue distribution by herd size ($2020)



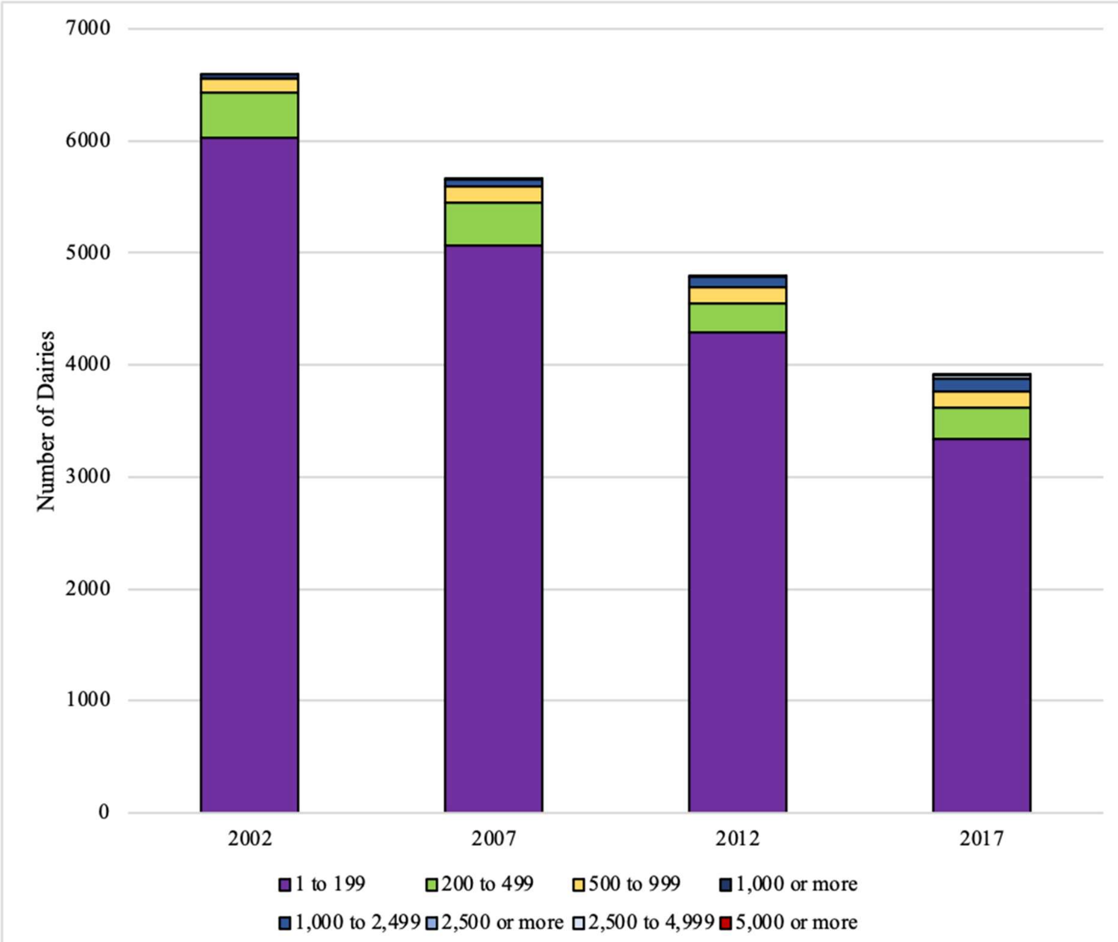
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)

Figure 3.7 Distribution of farms with milk or dairy sales by herd size, New Mexico, 2002 – 2017



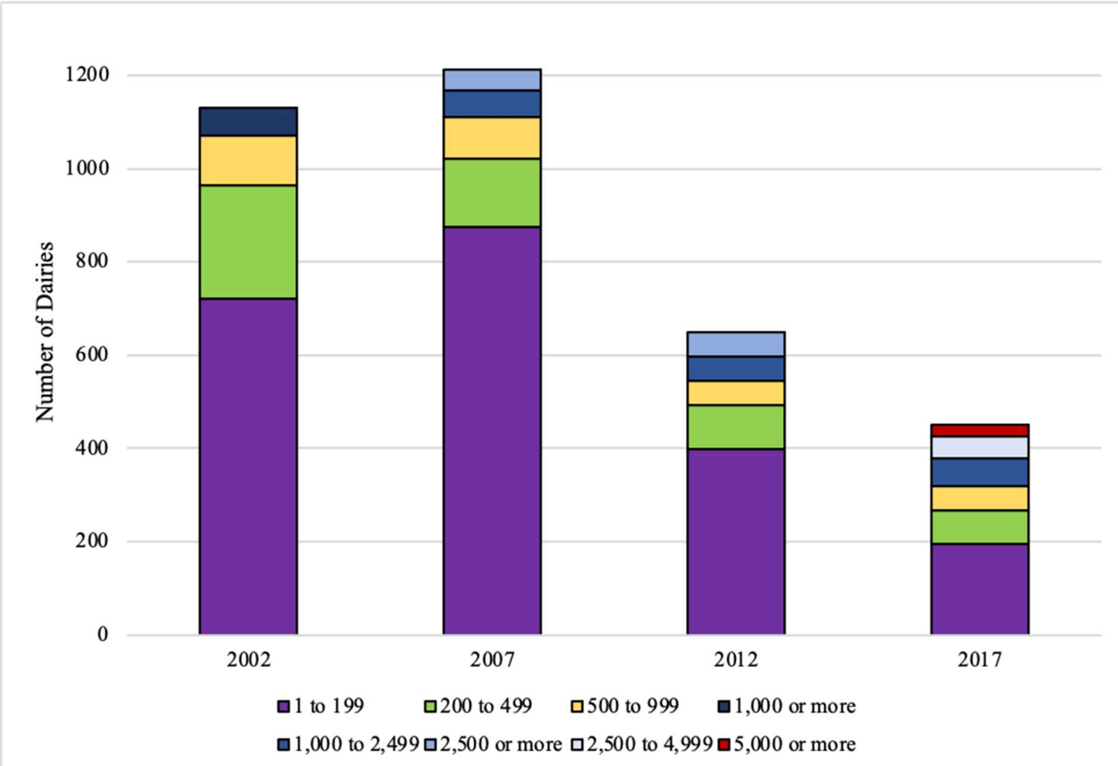
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 3.7 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.

Figure 3.8 Distribution of farms with milk or dairy sales by herd size, New York, 2002 – 2017



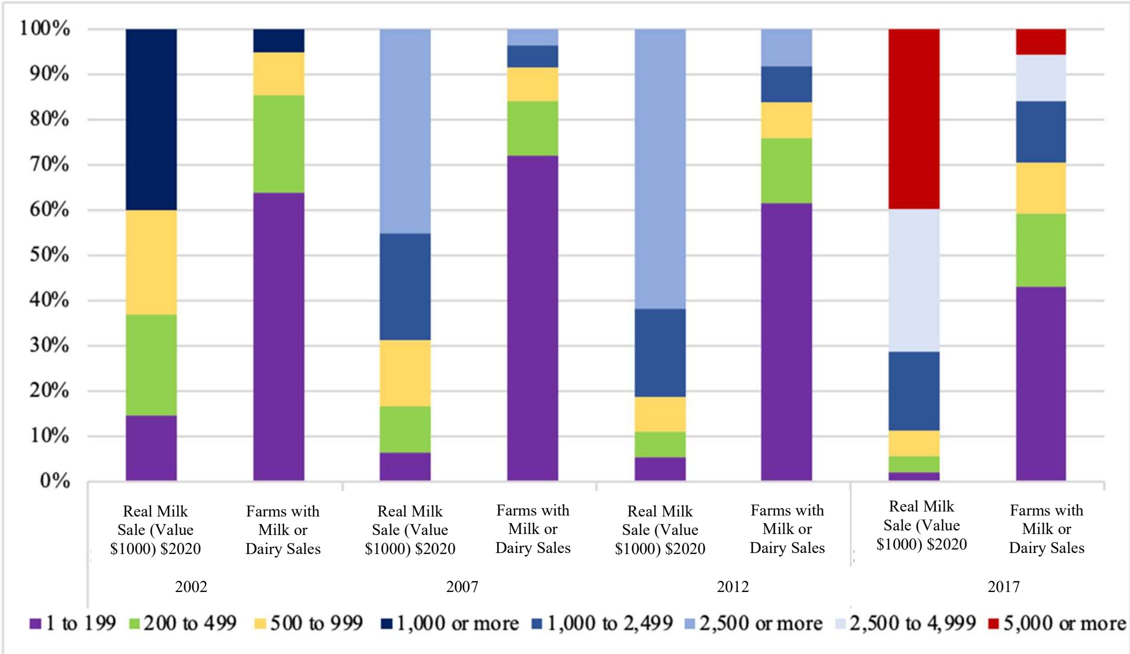
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 8 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.
The 5,000+ (2017) category is too small to see but contains only one farm with milk cows.

Figure 3.9 Distribution of farms with milk or dairy sales by herd size, Texas, 2002 – 2017



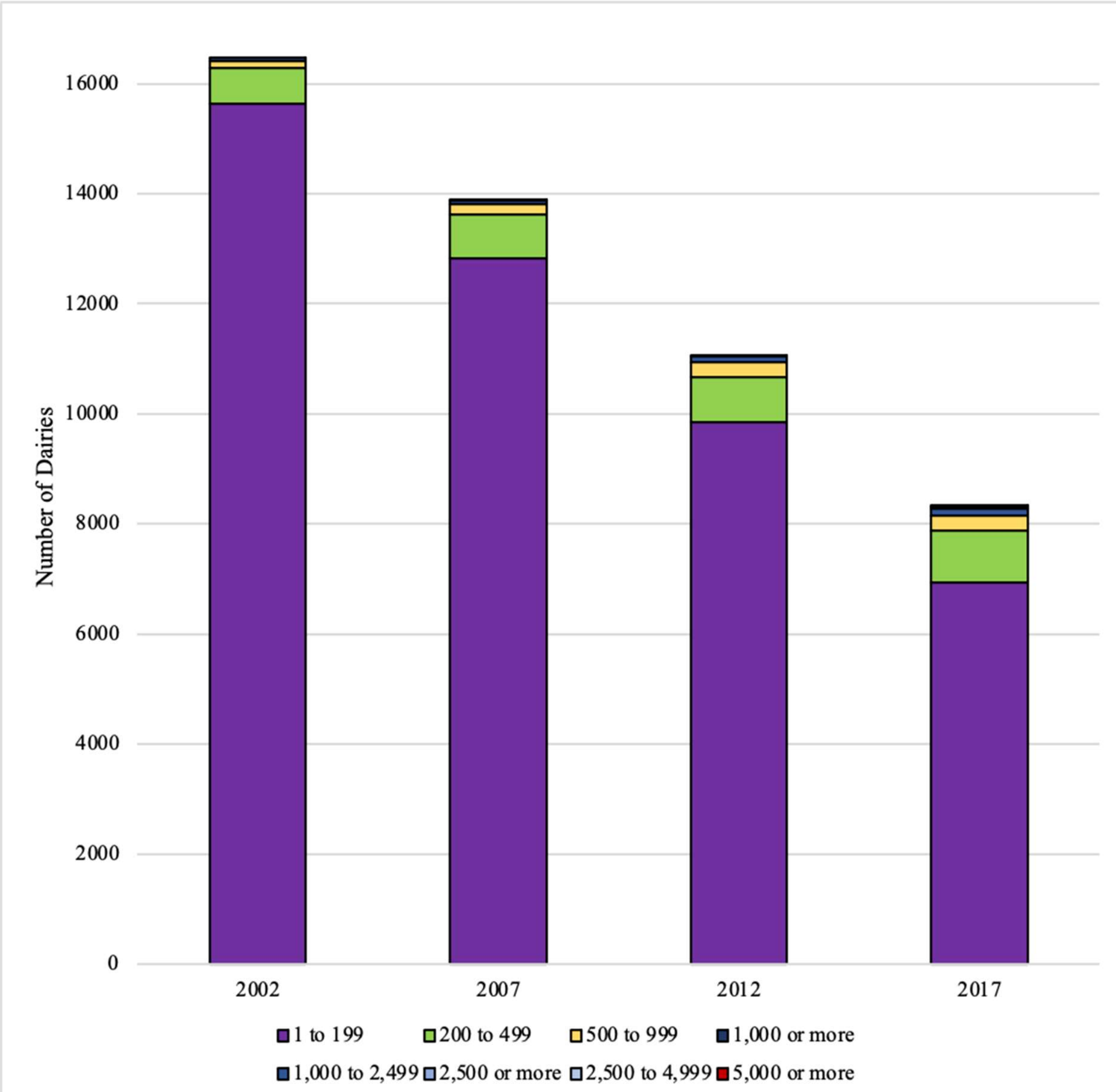
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 3.9 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.

Figure 3.10 Texas revenue distribution by herd size ($2020)



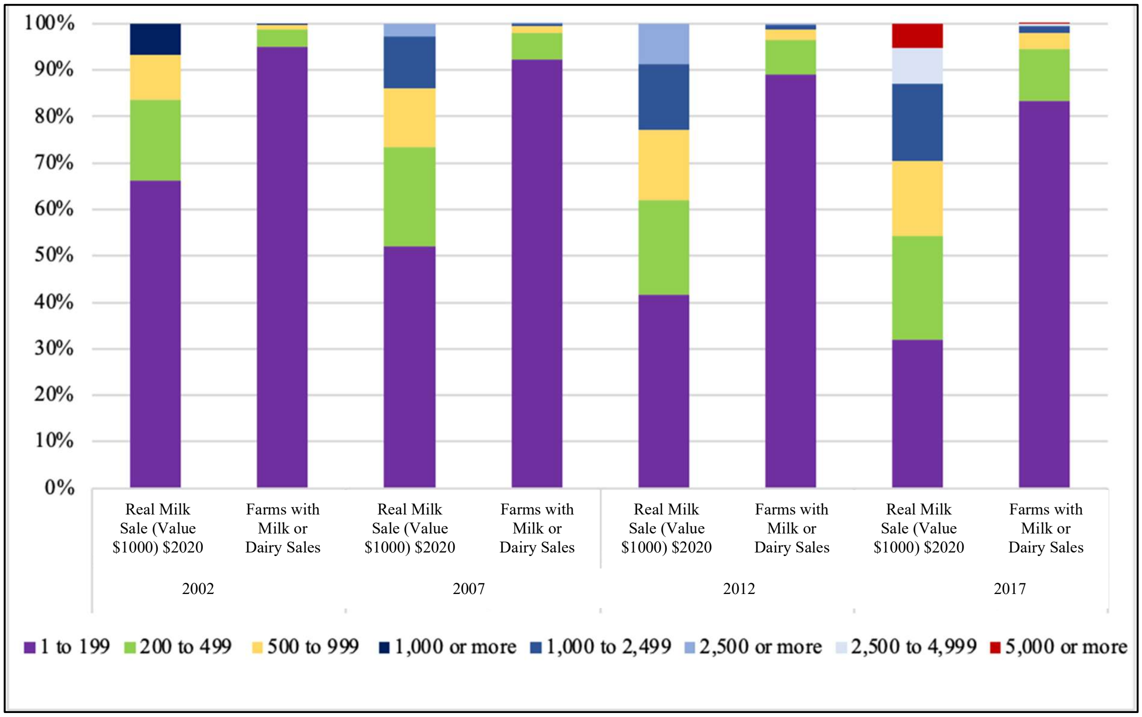
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)

Figure 3.11 Distribution of farms with milk or dairy sales by herd size, Wisconsin, 2002 – 2017



Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)
Note: Figure 3.10 uses Available Census categories which become more differentiated for larger heard sizes in later years, with the category 2,500-4,999 only available in 2017.

Figure 3.12 Wisconsin revenue distribution by herd size ($2020)



Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017,
Link: (https://quickstats.nass.usda.gov/)

Chapter 4: Dairy Farm Size Distributions: Patterns Over Time

4.1 INTRODUCTION

The size distribution of farms in the U.S. has been a topic of economic research and discussion for decades. Changes in farm size along with reductions in farm numbers have raised concerns based on it the possible impact on rural communities, particularly movement out of certain regions leading to a possible decrease of employment opportunities in that region. Moreover, accurate and descriptive analysis of farm size is often used to inform agricultural policy and discussion, particularly in the dairy industry. In both industry discussion and policy-based decision-making, surrounding farm size, the trend of consolidation is central to the discussion on the future of the dairy industry. Some suggest that the trend of farm size is characterized by consolidation with an increase in large farms, and fewer small farms remaining.

One assumption is centered around the idea of the disappearing middle, mid-sized farms, in agriculture with some arguing that the farm size distribution can be considered bimodal. This language can be vague and detailed analysis by state is needed for a clear characterization of farm size. Wolf and Sumner (2001) find that the argument of U.S. farms being bimodal is not the case for the dairy industry in 1989 and 1993. This thesis research aims to expand on this finding by discussing correlations related to farm size changes, kernel density plots of herd size and using parametric statistical density functions to characterize the herd size by state, utilizing recent Census of Agriculture (COA) data. The COA is a representative sample of all farms in the United States. This is individual farm level data across six states and four years which is a unique sample for research studies. This research looks at individual farm-level characteristics including farm size and operator characteristics and discuss the shifts across time and states.

The trend of dairy consolidation in the United States has been characterized by a decrease in the number of dairies with the number of milk cows remaining relatively stable (MacDonald et al. 2020). Using the COA data, the number of milk cows on a commercial dairy has remained relatively stable with most states seeing slight increases in the number of milk cows, except New York (Table 4.1). Whereas the number of commercial dairies has decreased significantly across all six states, except New Mexico which only decreased slightly (Table 4.2). California and Idaho both had about a 36-37% decrease in the number of commercial dairies, while in New York, Texas, and Wisconsin the number of commercial dairies decrease by about 50%.

Farm size distribution remains a prevalent agricultural policy issue, as characterization of the dairy industry's farm size is used to inform legislation and often characterizes colloquial discussion about the state of the industry. This is in part due to firm size growth's correlation with innovation and technology, as well as the firm's ability to capture economies of scale. Although dairy farm size can be characterized for the U.S. overall, there are important distinctions by state, as the dairy farm size distributions differ greatly by state.

It is important to distinguish growth patterns of dairy farms by state. Macdonald et al. (2020) detail that larger dairy farms are able to capture economies of scale, more so than smaller dairies, resulting in a lower average milk production cost. However, the article does go on to specify that the distribution of dairy farm size differs greatly by state based on the specific financial and economic environment of the dairy industry in that state.

Alternatively, some dairy farms lower the average milk production costs by capturing the economies of scope, i.e., diversification of sales. This could be characterized as raising and selling replacement dairy heifers, or other agricultural products such as grain to maintain economic viability. Finally, I consider the relationship that farm operator characteristics may have with farm size and the decision of a farm to exit. In Chapter Five, I detail a specific line of analysis related to the influence of female farm operators on farm size, but in this chapter, I will discuss the influence that the age of the farm operator may have on the farm size. Dairy farm size changes in response to these and other factors is important in considering future trends in farm size and their impact on milk production in the U.S. and the future structure of the dairy industry.

This chapter aims to characterize the herd size distributions of the U.S. dairy industry, present evidence on the characteristics of the farm size distributions, and then finally discuss the correlation between farm level characteristics and farm size. This chapter will be structured as follows: a brief overview of previous literature on firm and farm size, a discussion about farm size distribution estimation, and then the results and discussion.

4.2 PREVIOUS LITERATURE: FIRM, FARM, AND DAIRY FARM SIZE

Economic research and discussion have produced several theories on firm size and firm growth to characterize industries and the economy. This section will briefly review important studies related to firm size more generally and then will move on to research specific to the study of farm size and the economics of dairy farm size and size distributions.

The study of firm size by economists can be best discussed chronologically, as much of the research builds off one another or finds results inconsistent with previously held theories. In 1931, Gibrat postulated what has come to be known as Gibrat's Law that a firm's growth rate is independent of its size. This would mean that the growth rate of an individual firm over a particular time period should not be influenced by its original size. Ijiri et al. (1967), using the foundation built by Gibrat's Law, finds that firms that grew over 10% in the subsequent period are more likely to see above industry average growth, due to continued benefits of innovation that occurred in the subsequent periods. Viner (1932) theorizes that firm size distribution is based on the industry environment and that individual firms have a U-shaped average cost curve and will function at the minimum of this curve. He goes on to specify that firm entries and exits are determined by the quantity demanded by the market. Lucas (1978) used these previous works to build a new theory about the size distribution of firms in an industry that looks at size distribution as a solution for output maximization with a given set of production factors and managers with varied human capital levels. This model predicts the size distribution of firms based on the managerial ability of laborers and then subsequent resource allocation. Jovanovic (1982) finds that smaller firms will tend to have higher growth rates than larger firms, but that these smaller firms are more likely to exit the industry than the larger firms. Evans (1987) discusses growth relative to a firms age, finding that a firm's growth can be tied to the age of the firm itself and that older firms have a slower growth rate. This theory is hypothesized to remain true for dairy farms.

Stemming from foundation of Gibrat's law, which claims that the firm size distribution follows a lognormal distribution, there has been significant literature on the size distribution of firms that looks at fitting parametric distributions to actual firm size data. Kondo, Lewis, and Stella (2018) evaluate recent non-farm panel data from the U.S. Census Bureau and find that the current U.S. firm size data best fits with a lognormal distribution, but there are differences in goodness of fit by industry. Akhundjanov and Toda (2020) use the original data, in Gibrat's original paper, find that a Pareto distribution better characterizes the empirical size distributions. The distribution of firm size remains a fundamental part of research firm growth patterns and the literature on firm size has been directly applied to research on the growth rate of farms and farm size changes in different agricultural industries. Two common parametric distribution used in farm size distribution analysis are lognormal and exponential. Allanson (1992) evaluates farm size trends in England and Wales finding that the lognormal distribution fits farm size measures relatively well across time. Whereas

Boxely (1971) uses an exponential distribution to evaluate farm size data from the Agricultural Census and finds that from 1935-1964 farm size shifted to the right, but that at the state level farm size does tend to follow the exponential distribution with some regularity.

Before going any further in the analysis, it is important to outline the concept of farm size for this analysis. Farm size measures across the whole agricultural industry tend to leave out key details that give better and more accurate accounts of the size of the farm for the commodity/industry. For example, when looking at the size of U.S. farms overall measuring the size of the farm based on acreage will lead to inaccurate or confusing results. The acreage needed to generate the same revenue for corn versus dairy milk or strawberries is substantially different. However, looking at the dairy industry specifically, many different characteristics shape a dairy's economic footprint on the market, and therefore, defining how to characterize dairy farm size is fundamental to discussing changes in the dairy market.

One can characterize the size of a dairy by the number of milk cows, or herd size, as one measure of dairy firm size. However, other characteristics such as the quantity of milk produced, the value of production, and value-added on the farm could also be considered as farm size measures (Sumner and Wolf 2002). Different farm size measures allow us to answer different agricultural economic questions. While analyzing the dairy industry it is relevant to consider herd size, the milk and/or dairy sale revenue of the firm, and the total value of production, as we have already discussed in Chapter 2.

Previous research on dairy farm size documents strong trends toward consolidation in the U.S. with a decrease of about 50% of all registered U.S. dairies from 2002 to 2019 (MacDonald et al. 2020). These trends in consolidation have differed by location with historically dairy producing regions (Northeast and Midwest) seeing a large share of exits, these states were historically made up of smaller and mid-size dairies. MacDonald et al. (2007) detail the cost differences between larger and smaller dairies with cost advantages for larger dairies that drive the investment decision to increase herd size. This research suggested that there would continue to be a steady decline in the number of smaller and mid-size dairies and that the trend of consolidation would likely continue. This trend has raised research questions about what factors influence the distribution of farm size and the decisions of some farms to exit the industry.

A common, albeit incorrect, assumption about the size distribution of the U.S. dairy industry is that it is bimodal. This assumption comes from news reporting and political commentary that there is a "declining" middle of farms in the U.S. and that there is this dichotomy between small, sometimes organic, farms and larger farms. Again, Wolf and Sumner (2001) find no evidence of a bimodal dairy industry using Farm Cost and Return Surveys of dairy farms for the years 1989 and 1993. In MacDonald et al. (2020), they suggest that larger dairies tend to have lower costs per cow, which allows them to capture greater economies of scale.

The cost-minimizing efforts of individual dairy farms will influence the specific farm management choices that the farm makes, as only the individual farm has a true sense of where it sits on its long-run average cost curve. Some of these management decisions include the dairy's strategy to capture economies of scope, through sales diversification, or vertically integrate to minimize input and production costs. Sumner and Wolf (2002) find that vertical integration has little influence on the farm size and that the tendency for farms in the Pacific and South to have larger herd sizes remains true, even when accounting for the levels of vertical integration. The farm's choice to incorporate different management strategies reflects the incentives and constraints that the farm faces, i.e., influences of geographic location and capital. Other influences on management choices by dairies are in part due to different environmental regulations in each state that impact the average cost of production for dairy farms.

There has been a significant amount of agricultural economic research on dairy farm size with respect to their risk management and technical efficiency. Tauer (2001) finds that smaller dairies in New York do have a high average cost of production than dairies with larger herd sizes, but that these higher costs are due to inefficiencies and efficient small dairies are competitive with the larger dairies. Tauer and Mishra (2006) examine whether differences in technology or efficiency characterize the higher cost that smaller dairy farms face and find that using a frontier cost of production analysis show that inefficiencies in smaller dairies characterize the higher costs, not technological differences. There has also been significant analysis in farm structure changes of the dairy industry. Zimmermann and Heckelei (2012) utilize a Markov Chain Model on dairies in the European Union to characterize farm size change and find that regional characteristics such as off-farm opportunities and unemployment rates are significant in relation to dairy farm size change. They also find that high milk prices slow down farm size change due to high milk prices correlation to uncertainty and price volatility leading to a decrease in investment. Wolf (2012) details how dairy farms in Michigan have increased their use of risk management tools from 1999 to 2011 and find that the use of such risk management tools was positively correlated with measures of dairy farm size. This research also discusses how age related to risk management adoption with younger dairy farmers being less likely to utilize the risk management tools. Wolf (2003) outlines characteristics of dairy farm size change across time

Beyond management decisions influencing or being correlated with the farm size and farms' decision to exit, previous economic literature has hypothesized about the possible influences of operator characteristics, like human capital (Sumner and Leiby 1987), the number of female operators, the age of operators, or other farm operator characteristics on farm size. Sumner and Leiby (1987) find that human capital positively influences the size of the farm, and this is hypothesized to be due to increasing opportunity costs for dairy farmers with high levels of human capital. Dairy farmers that have the possibility of making more money elsewhere (in a different career) will do so, therefore it seems likely that dairy farms with sufficient returns, which tend to be found on larger dairy farms, will attract high human capital management.

Another aspect of the previous research related to farm size and the dairy industry is farm exits. There have been several studies of individual farm movement across farm size groups and characterization of exits. Most of this literature, however, has been limited to regions or states. Macdonald et al. (2020) finds that in 2016 about 40 percent of dairy farms with at least 2,000 milk cows did not have positive net returns and that the share of dairies that did not have positive net returns increased as herd size decreased. However, they do note that negative returns in the dairy industry are seen as temporary lows by dairy operators, so they do not serve as a direct indication of an expected exit from the industry. Other reasons for exits from agriculture, or dairy specifically, include increased suburbanization of previously agricultural land, driving land prices up, and strong local economies, opening off-farm employment opportunities for farm operators. As outlined in Sumner and Leiby (1987) and Sumner (2014), the human capital element remains prevalent through economic explanations of farm exit. Of course, age of the farm operators plays key role. Macdonald et al. (2020) discuss the role of the advanced age of many dairy farmers and the fact that many dairy farms are family-run, suggesting that there will be an increase in exits as more farmers choose to retire. Furthermore, the study relates the probability of exit to farm size, finding that not only does the age of the operator increase the likelihood of exit, but the smaller the farm size also increases the probability of exit.

4.3 DATA AND METHODS

This section discusses the sample used in this analysis and details changes in the COA questions that are relevant to this analysis. The research utilizes COA data from 2002, 2007, 2012, and 2017 for six select states: California, Idaho, New Mexico, New York, Texas, and Wisconsin. The results presented have gone through a disclosure review process and no data on individual/farm-specific is specific to individual farms and instead characterizes them more generally. Although the COA is federally mandated, it does not collect data on every U.S. farm and as such weights responses to create the most accurate sample that reflects the true U.S. farm sample.

As discussed in Chapter 2, I use a specific definition of a commercial dairy in order to capture dairies with significant engagement with the dairy industry. A commercial dairy for the purposes of this analysis is defined as a farm with (1) at least 20 milk cows on the farm as of December 31 of the Census year and (2) the farm must have dairy or milk sales revenue above the dollars of milk sale revenue that would have been generated by 30 milk cows.

4.3.1 COA Data and Survey Questions

The survey questions asked of farmers and ranchers by the COA change slightly every Census round, although most remain the same across time. Below are descriptions of question changes for relevant variables to the analysis. First, in 2002 and 2007, farms were asked for the total amount of dairy sales in that year, but in 2012 and 2017, this question was dropped and replaced with the total amount of milk sales. Furthermore, whether the dairy farm had any level of organic production was only asked in 2007, 2012, and 2017.

Second, operator characteristic questions have become more detailed over the years and allowed more information about operators to be collected. In 2002, 2007, and 2012, the COA asked detailed operator characteristic questions about up to three operators, but only one operator was identified as the principal operator. In 2017, the COA expanded its detailed operator questions to include up to four operators and allowed for up to four operators to be identified as principal operators. In this Chapter, the operators for which the number per farm is limited and detailed information is provided will be referred to as the "core operators."

There is other no limit to the number other operators listed per farm and only the gender of each such operator and the total number per farm are provided in the Census.

The COA has three potentially relevant farm size variables for dairy farms, the number of milk cows, the value of farm production, and the value of milk or dairy sales. I utilize all three in this chapter. However, I focus particular attention on the number of milk cows for the kernel density graphs. I characterize the distributions of number of milk cows per commercial dairy farm using two approaches. One approach is to fit a nonparametric distribution by year, and by state for each year to the data on milk cow herd size per farm. The other approach is to fit two commonly used parametric distributions to characterize dairy farm size distributions for the national and individual states over census years.

4.3.2 Nonparametric Farm Size Distribution

Following the methods of Wolf and Sumner (2001), I begin by creating kernel density estimates for the farm size variable, number of milk cows, by state and by year. I take a standard approach to kernel density estimation by using a kernel density estimator with a set kernel and determining smoothing for a clear representation of the density of the number of milk cows. Equation 1 describes the kernel density estimator, where K is the kernel, h is the smoothing parameter and n is the number of observations:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left[\frac{x - X_i}{h}\right]. \quad (1)$$

Although there are several specific kernels used in empirical research I utilize the normal kernel, as seen in equation 2 where z = $\frac{x-X_i}{h}$. This is generally accepted as an efficient estimator for kernel density plots

$$K(z) = \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-1}{2}\right)(\,z\,). \quad (2)$$

The window-width or smoothing based on the Silverman (1981) method which sets the optimal smoothing parameter to be: $\mathrm{h} = 0.9\mathrm{An}^{\left(-\frac{1}{5}\right)}$ with $\mathrm{A} = \min\left(\mathrm{SD}, \mathrm{interquartile}\,\frac{\mathrm{range}}{1.34}\right)$. The Silverman (1981) method evaluates the smoothing parameter to see at what level the smoothing parameter reduces or adds modes to the distribution. With large smoothing parameters it is more likely the distribution will have only one mode than in smaller parameters where it is more likely to have additional modes. This allows me to create kernel density plots of the farm size variable; number of milk cows, and then compare each state and year to one another and then compare these graphs to the nonparametric distribution estimations of interest.

4.3.3 Parametric Farm Size Distribution

One aim of my thesis is to characterize the farm size distribution of dairy farms and fitting parametric density functions serves as a starting point for characterizing and analyzing dairy size distribution. As explained above, there is previous literature that utilizes parametric distributions to characterize farm size and this research provides evidence that commonly used distributions do not fit well with the U.S. commercial dairy industry. It is common in farm size analysis to fit parametric density functions to characterize farm size distribution (i.e., exponential, lognormal, etc.). I create kernel density plots for the herd size distribution by state across the years and then find and fit two common parametric density functions to the distribution. This section will be structures as follows: a brief overview of the mathematics used in fitting parametric density functions.

There are three steps to fitting the parametric density function to the farm size variables. First, I hypothesize based on the kernel density plots what distributions seem reasonable. For this analysis I use the lognormal and the exponential function, as those are two common distributions used in farm size literature and are likely shapes for most farm size distributions. Lognormal is the typical selection, as it is referenced in Gibrat's Law. The exponential distribution was selected because it can account for the same skewed shape but has more flexibility. Second, I estimate the parameters of interest needed to form that distribution in order to create an estimated distribution of random numbers that follow the specific distribution. For this analysis, the measures of farm size, the number of milk cows for each farm, are random variables $x_1, x_2, x_3, \ldots, x_n$, where n is the sample size of farms, for which the joint distribution depends on distribution parameters. For example, using the lognormal the parameters are the mean and variance, and there are two related parameters for the exponential distribution. The estimates of the parameters are functions of the milk cow herd size variable in question. From there, we can calculate the estimates of these parameters to create a different distribution with those same parameters and compare them to the actual distribution of the number of milk cows. Some estimated parametric distributions appear to have slight irregularities, this is due to the number of observations and the impose parameters.

4.4 PATTERNS OF COMMERCIAL DAIRY FARM SIZE

This section will summarize the resulting farm size graphs and detail the trends across time and states. Overall, when looking at the six select states together commercial dairy farm distributions have shifted towards larger dairies. In 2002, there was a clear peak in the number of farms with less than 200 milk cows, but the peak falls significantly from 2002 to 2017 (Figure 4.1). Whereas farm size distribution shows a clear increase in the farms with larger herd sizes in 2017. Although this graph gives interesting detail about the trends in herd size for the U.S. overall it is mostly characterized by Wisconsin and New York which have a significantly larger share of the number of commercial dairies and tend to have smaller herd sizes relative to other states. This graph clearly shows that there remains a large share of dairies that have a herd size of less than 200 milk cows, despite the relative shift in herd size.

Moving to state-specific trends, overall California dairies have had larger herd sizes than other states, such as New York or Wisconsin across all years (Figure 4.2). California had a peak in the share of dairies with less than 1,000 milk cows from 2002 to 2017, but the peak fell significantly between 2007 and 2012. There was a clear shift in 2012 with an increase in the 1,000 to 2,000 milk cow herd size in 2012 and then another shift in 2017 in the 2,000 to 3,000 milk cow herd size. This documents a clear movement of California dairies towards larger herd sizes and a decrease in smaller herd sizes.

Idaho had a large peak in commercial dairies with less than 500 milk cows in 2002 and then a significant drop in that peak in 2007 with smaller subsequent decreases in 2012 and 2017 (Figure 4.3). Interestingly, in 2007 there was an increase in the number of dairies with a milk cow herd size between 500 to 1,000, but then a subsequent decrease the following year. In 2017 there was a clear increase in the number of commercial dairies with a milk cow herd size between 1,500 and 2,000.

New Mexico had one of the more unique herd size distributions with no clear peak in the smaller herd size ranges (Figure 4.4). From 2002 to 2007, there was a clear drop in the density of commercial dairies with less than 1,000 milk cows and a relative increase in the density of commercial dairies with 1,000 milk cows. Then in 2012, there was a shift towards commercial dairies with more than 2,000 milk cows and a downward shift in commercial dairies in the 500 to 1,000 milk cow herd size range. This trend continued in 2017 with even further shifts in each direction.

From 2002 to 2017, New York has seen a slight decrease in the smaller herd sizes and a little increase in the larger herd sizes (greater than 200 milk cows. However, the trend is not as distinct as in other states and there remains a relatively large share of commercial dairies with smaller herd sizes (Figure 4.5).

In Texas, the most distinct trend was a significant drop in the density of commercial dairies with herd sizes of less than 500 milk cows between 2012 and 2017 (Figure 4.6). There has previously been a trend of decreases in this herd size range, but these follow a similar pattern as compared to most other states. However, in other states, there was not such a significant drop. In 2017, there was an increase in commercial dairies with more than 1,000 milk cows.

There was a significant decrease the commercial dairies in Wisconsin with less than 100 milk cows from 2007 to 2012 and then again from 2012 to 2017 (Figure 4.7). In 2017, there was an increase in commercial dairies with a herd size of between 150 and 200 milk cows. Wisconsin's dairy industry is characterized by a significant number of smaller dairies and few dairies with large milk cow herd sizes. Across the states, there is a trend of consolidation with few commercial dairies and an increase in the number of dairies with larger herd sizes.

Despite the decrease in the number of farms in each state, the number of milk cows increased in some states and broadly remained relatively stable (Table 4.1). California had a 6.7% increase in the number of milk cows from 2002 to 2017, but Idaho had a 55% increase. The number of milk cows in New Mexico and Wisconsin both remained roughly the same. There was a 6% decrease in the number of milk cows in New York and number of Texas grew by more than 70%.

Neither of the two parametric distributions fit the national data well. In particular, both the lognormal and exponential distributions failed to capture the very high mode at the low herd size in 2002. The herd sizes in California did not fit any distribution well in 2002 or 2017 (Figure 4.8 and Figure 4.9). Idaho has a large peak in the smaller ranges that is well above either the lognormal or the exponential distribution in 2002 (Figure 4.10). The herd size does fall significantly when looking at the Idaho herd size distribution in 2017, this does somewhat follow a lognormal pattern, but not very well (Figure 4.11). New York follows a similar pattern with the smaller herd size peak being significantly higher than either the lognormal or the exponential peaks in 2002 or 2017 (Figure 4.12 and Figure 4.13). As we saw across years in Texas, the herd size shifted dramatically. In 2002, the herd size distribution slightly resembled a lognormal trend but had definite deviations and in 2017 did not follow any distribution well (Figure 4.14 and Figure 4.15). Wisconsin follows a similar pattern to New York with no clear distribution trend in 2002 or 2017, but with significantly high peaks in the lower herd size range that deviate from the distributions.

4.5 RELATIONSHIP BETWEEN INDIVIDUAL FARM CHARACTERISTICS AND DAIRY FARM SIZE

This section discusses the method and regression results. First, I will provide a summary of the variables used in this analysis. This thesis seeks to characterize farm size change in the dairy industry and identify operation and operator characteristics that have a relationship with dairy farm size.

4.5.1 Description of method and variables

As explained above there are several possible influences, but given the Census data, I have chosen the following variables: characteristics of the operators (maximum and mean operator age), farm sales diversification across commodities, and share of farm operators who have off-farm employment. I also account for state fixed effects and Census year fixed effects. Clearly sales diversification and off farm work are jointly determined with dairy farm size, so I do not claim to be measuring a causal impact in the regressions presented discussed in this section. The aim here is to discuss statistical relationships between these characteristics and the farm size measures because although they cannot be thought of as directly influencing farm size the relationship between such measures is of interest and allows for discussion about the characteristics of the U.S commercial dairy.

The age of the operator is likely to influence the size of the dairy operation because it is likely that as an operator gets older and remains in the dairy industry as a dairy operator, they expand their business. Since most dairy farm operators enter the industry when they are young, age is likely to be highly correlated dairy farm experience and often with specific experience at a specific farm in a particular location. Therefore, it is reasonable to suggest that age is heavily correlated with on-farm experiences which is a form of human capital. High level of human capital at the farm level could be hypothesized to be attributed to a farm's success and growth. The trend of increasing farm size as the age of the operator increases is likely to occur until they reach the age of retirement, maybe decreasing slightly as they get closer to retirement age.

Table 4.3 shows the share of dairy operators by age range, state, and year. We can see that the average age of dairy farm operators is increasing for both female and male operators. Based on the information available, I include the following variables in my analysis: the average age of operators ($MeanAge_{it}$) and maximum age of any one operator ($MaxAge_{it}$). There are no COA questions directly asking about the farm's level of sales diversification ($SaleDiv_{it}$). However, I created a variable intended to capture sales diversification by taking the share of milk or dairy sales divided by total sales revenue. This gives an idea of the level of sale diversification on the dairy farm with dairies with little to no sale diversification being near one and those with significant sales diversification with lower values. I also included the share of operators that have off farm employment ($\text{Off-Farm Income}_{it}$). These are not clear independent variables, as there appears to simultaneity bias between sales diversification and other variables. For the farm size variables, of the individual farm (i) at time (t), are the dependent variables including $Cows_{it}$ number of milk cows (herd size), TMD_{it} total sales revenue from dairy or milk, and TVP_{it} total value of production.

4.5.2 Regressions, Results and Discussion

Equation 5 is the regression used to show the correlation between farm level characteristics and farm size where (Age_{it}) represents either the maximum age or the mean age of the operators of the individual farm. In addition, α_i and λ_t represent the state fixed effect and the time fixed effect, respectively, and u_{it} is an error term. The farm size variables are logged to account for the skewness of the data.

$$logFarmSize_{it} = \beta_0 + \beta_1 Age_{it} + \beta_2 SharePart_{it} + \beta_2 SaleDiv_{it} + \alpha_i + \lambda_t + u_{it} \quad (5)$$

Table 4.4 shows the regression results for Equation 1 with the maximum age selected as the age variable. First starting with the farm size variable, number of milk cows, the sales diversification is significant and with a 1% increase in share of sale diversification relates to about 124% increase in the number of milk cows. Whereas a 1% increase in the share of operators with off farm employment would suggest a decrease by 31.1% of the number of milk cows. Finally, age has relatively little relationship with the number of milk cows on the farm but does show that a year increase in the max age does correspond with an increase by about 0.7%. Next, using the milk sales or dairy sales as the farm size variable, there are very similar results to those for the number of milk cows. The relationship of the maximum age of the operator remains the same. I find that a 1% increase in the share of operators with off farm employment relates to a decrease in the total milk or dairy sales of about 32.4%. Interestingly, a 1% increase in sales diversification suggests an increase of 215% in total milk or dairy sales. Finally, when we consider the farm size variable total value of production, the relationship of the maximum age of the operator remains similar to the results of the other farm size variables with a year increase in the maximum age there is a decrease of 0.6% in the total value of production. I also find that a 1% increase in the share of operators with off farm income corresponds to a decrease by 32.2% of the total value of production. In contrast with the other two farm size variable specifications, a 1% increase in sales diversification relates to a decrease in the total value of production by 34.1%.

Table 4.5 shows the regression results for Equation 1 with the mean age selected as the age variable. First starting with the farm size number of milk cows, I find that the coefficient on the mean age variable is not significant. A 1% increase in the share of operators with off farm employment suggests a decrease in the number of milk cows by 30.8%. Whereas a 1% increase in sales diversification corresponds with an increase of 107% in the number of milk cows. Now looking at the farm size variable total milk or dairy sales, the mean age variable is now significant. A year increase in the mean age of dairy operators relates to a decrease of 0.1% in the total milk or dairy sales. Sales diversification level has a relatively strong relationship with a 189% increase in the total milk or dairy sales given a 1% increase in the level of sales diversification. Finally, when we consider the total value of production as the farm size variable, a year increase in the mean age of dairy operators corresponds to a decrease in the total value of production by 0.1%. Also, a 1% increase in the share of operators with off farm employment relates to a decrease in the total value of production by 32% and a 1% increase in sales diversification suggests a decrease the total value of production by 39.3%.

4.6 CONCLUSION

Between 2002 and 2017, there has been a significant change in the dairy industry with distinct shifts in herd size towards larger farms and a decrease in the share of dairies with smaller herd sizes. This result differs greatly by state. California and New Mexico increased the number of commercial dairies with more than 1,000 milk cows. New York and Wisconsin started with much smaller herds in 2002 and the increases in herd size but tended to see large decreases in the number of commercial dairies with smaller herd sizes. The lognormal or exponential distributions fit neither the national distribution nor any of the states herd size distribution well.

Neither maximum operator age nor average operator age had a very strong relationship with farm size. Both the degree of farm diversification across non-dairy commodities and the share of operators with off farm employment were highly correlated with the farm size measures. Future research on this topic could explore the relationship of individual farm size over time across Census years to examine individual farm growth. Moreover, there is much more to explore when looking at the farm characteristics on farm size, including exploring relationships between vertical integration and other measures of human capital with farm size.

Table 4.1 Total number of milk cows from commercial dairy by state and year

State	2002	2007	2012	2017
California	1,638,670	1,837,698	1,806,991	1,748,149
Idaho	386,742	532,317	575,255	601,228
New Mexico	314,369	325,962	317,824	337,322
New York	622,234	581,789	556,261	584,452
Texas	302,403	400,717	430,406	530,254
Wisconsin	1,103,059	1,118,929	1,157,688	1,207,583

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 4.2 Number of Commercial Dairies by State and Year

State	2002	2007	2012	2017
California	1,920	1,671	1,428	1,225
Idaho	625	521	496	393
New Mexico	161	146	119	119
New York	5,039	3,710	3,095	2,558
Texas	842	547	491	370
Wisconsin	11,641	9,564	7,586	6,165

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 4.3 Share of commercial dairy operators by age group, year, and state

California	2002	2007	2012	2017
<50	52.9	49.0	41.7	33.5
51-60	22.1	26.4	30.3	31.3
61-65	8.8	7.9	10.4	13.4
66-75	11.3	11.4	11.2	13.2
75+	5.0	5.3	6.4	8.6
Idaho	2002	2007	2012	2017
<50	61.3	53.1	44.1	39.3
51-60	23.5	30.0	30.7	30.4
61-65	6.1	7.3	11.0	13.1
66-75	5.6	5.8	10.6	13.3
75+	3.5	3.8	3.6	3.9
New Mexico	2002	2007	2012	2017
<50	63.1	54.3	43.0	35.8
51-60	22.7	30.5	33.8	24.6
61-65	5.8	4.5	13.5	18.8
66-75	4.6	3.7	6.3	16.3
75+	3.8	7.1	3.4	4.6
New York	2002	2007	2012	2017
<50	61.3	53.3	48.9	43.9
51-60	21.6	26.8	29.2	27.4
61-65	6.4	7.7	8.8	11.4
66-75	8.0	8.8	9.1	12.6
75+	2.8	3.4	4.0	4.8
Texas	2002	2007	2012	2017
<50	55.4	59.1	43.2	37.1
51-60	23.2	23.4	32.3	35.3
61-65	7.5	6.9	12.6	10.2
66-75	10.1	7.6	8.6	12.1
75+	3.8	3.0	3.2	5.2
Wisconsin	2002	2007	2012	2017
<50	68.4	58.5	49.1	44.2
51-60	19.7	27.8	33.2	32.4
61-65	5.3	6.4	9.0	11.6
66-75	5.1	5.2	6.4	8.9
75+	1.5	2.1	2.3	2.8

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 4.4 Maximum farm operator age and farm characteristics and on herd size and revenue [a]

Independent Variables	Dependent Variables		
	$lnCows_{it}$	*$lnTMD_{it}$*	*$lnTVP_{it}$*
Coefficients, with standard errors in parenthesis.			
$MaxAge_{it}$	0.0069*	0.0066*	0.0064*
	(0.0003)	(0.0003)	(0.0003)
Off-Farm $Income_{it}$	-0.372*	-0.392*	-0.389*
	(0.016)	(0.017)	(0.017)
$Diversification_{it}$	0.0054058310*	0.0065181647*	0.004505917*
	(0.025)	(0.027)	(0.027)
Idaho	-0.619*	-0.669*	-0.679*
	(0.021)	(0.023)	(0.023)
New Mexico	0.959*	0.940*	0.944*
	(0.037)	(0.040)	(0.040)
New York	-1.903*	-1.890*	-1.902*
	(0.013)	(0.014)	(0.014)
Texas	-0.771*	-0.874*	-0.877*
	(0.020)	(0.022)	(0.022)
Wisconsin	-1.949*	-1.956*	-1.979*
	(0.012)	(0.013)	(0.013)
2007	0.149*	0.614*	0.616*
	(0.009)	(0.009)	(0.009)
2012	0.286*	0.859*	0.848*
	(0.009)	(0.010)	(0.010)
2017	0.449*	1.042*	1.029*
	(0.010)	(0.0101)	(0.011)

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

a. These regressions are for the sample n = 60,123 (Cowsit) and 60,432 (TVPit and TMDit)

* p < .01

Table 4.5 Farm operator age and farm characteristics and on herd size and revenue [a]

Independent Variables	Dependent Variables		
	lnCows$_{it}$	*lnTMD*$_{it}$	*lnTVP*$_{it}$
Coefficients, with standard error in parenthesis.			
MeanAge$_{it}$	-0.0004	-0.0011*	-0.0012*
	(0.0003)	(0.0003)	(0.0004)
Off-Farm Income$_{it}$	-0.368*	-0.387*	-0.385*
	(0.016)	(0.017)	(0.017)
Diversification$_{it}$	0.00540.530*	0.00651.064*	0.00450.590*
	(0.025)	(0.027)	(0.027)
Idaho	-0.641*	-0.692*	-0.702*
	(0.021)	(0.023)	(0.023)
New Mexico	0.947*	0.927*	0.931*
	(0.037)	(0.040)	(0.040)
New York	-1.931*	-1.919*	-1.931*
	(0.013)	(0.014)	(0.014)
Texas	-0.795*	-0.898*	-0.901*
	(0.020)	(0.022)	(0.022)
Wisconsin	-1.997*	-2.006*	-2.029*
	(0.012)	(0.013)	(0.013)
2007	0.162*	0.628*	0.630*
	(0.009)	(0.009)	(0.010)
2012	0.304*	0.878*	0.867*
	(0.009)	(0.010)	(0.010)
2017	0.487*	1.080*	1.068*
	(0.010)	(0.011)	(0.011)

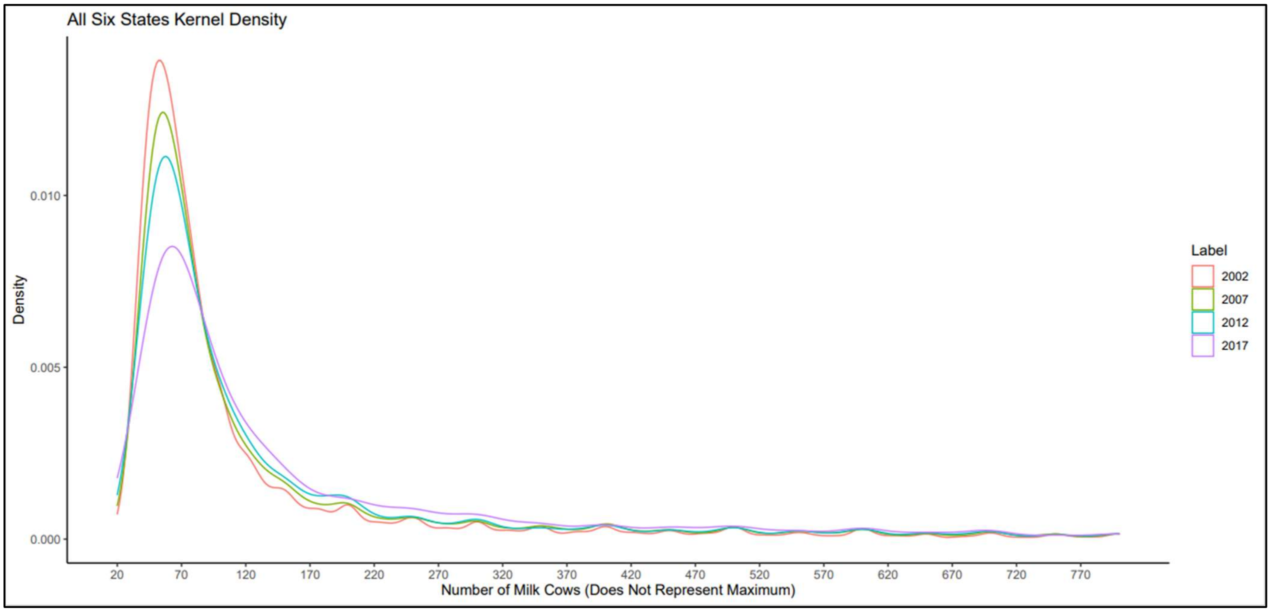
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

a. These regressions are for the sample n = 60,123 (Cowsit) and 60,432 (TVPit and TMDit)

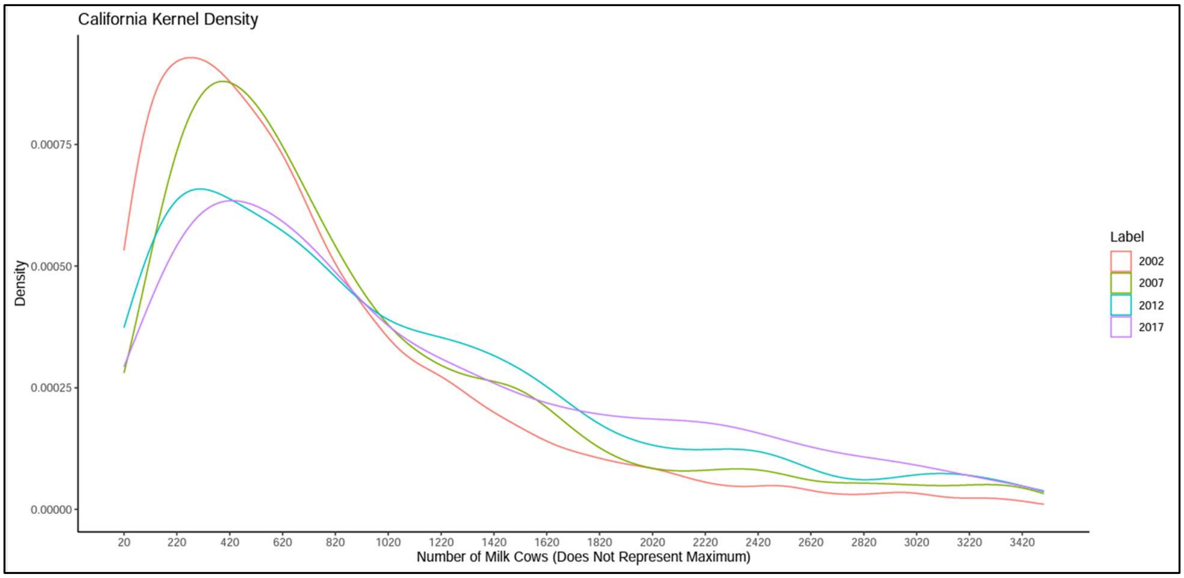
* p < .01

Figure 4.1 All states kernel density



Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.2 California kernel density

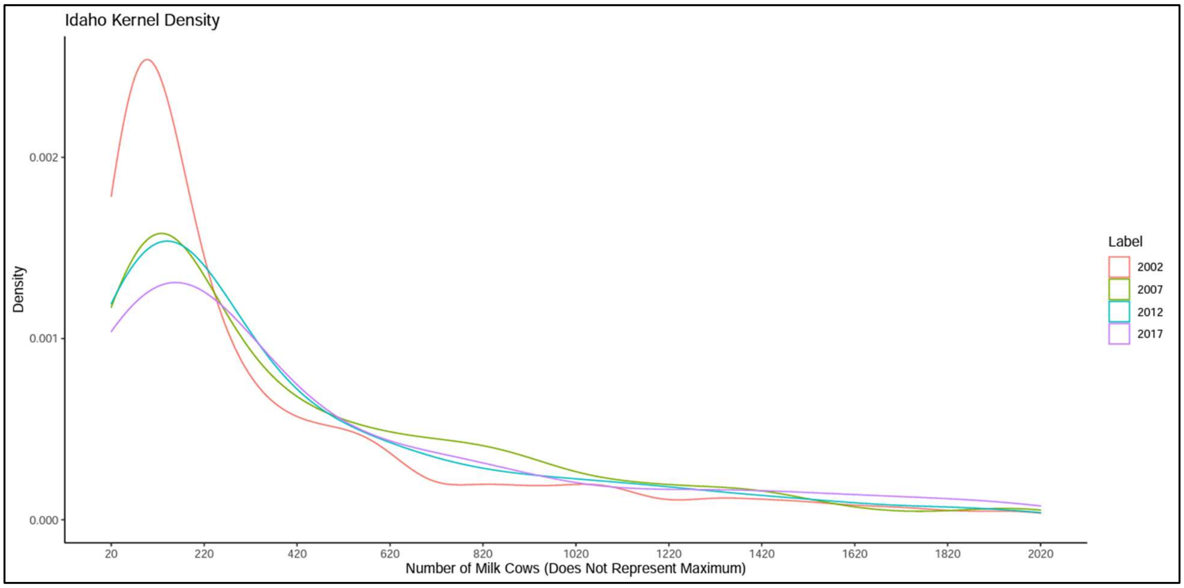


Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

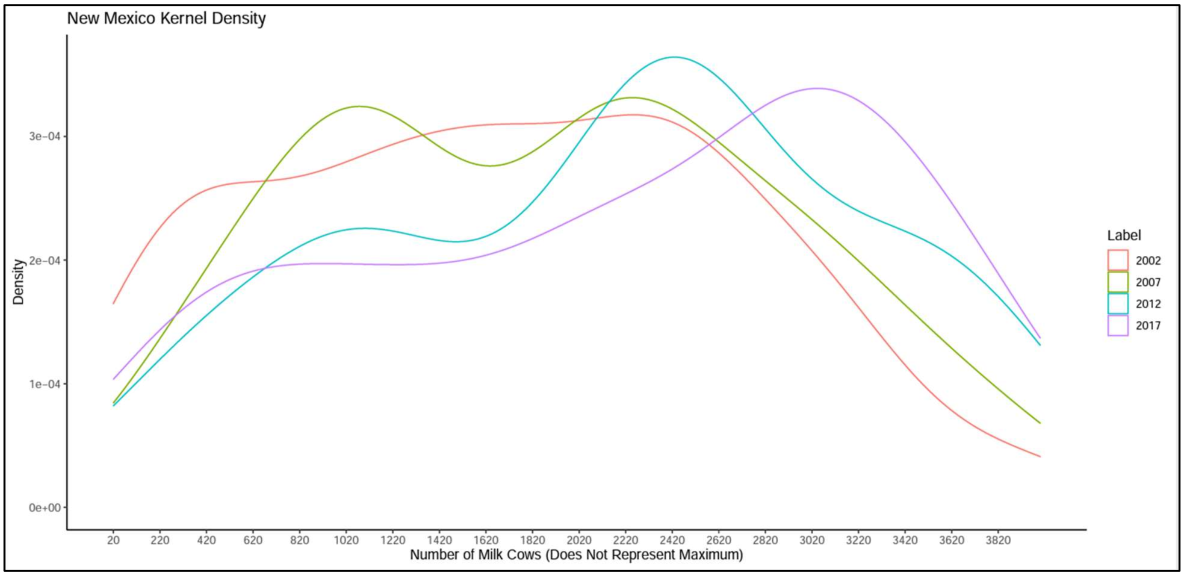
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.3 Idaho kernel density



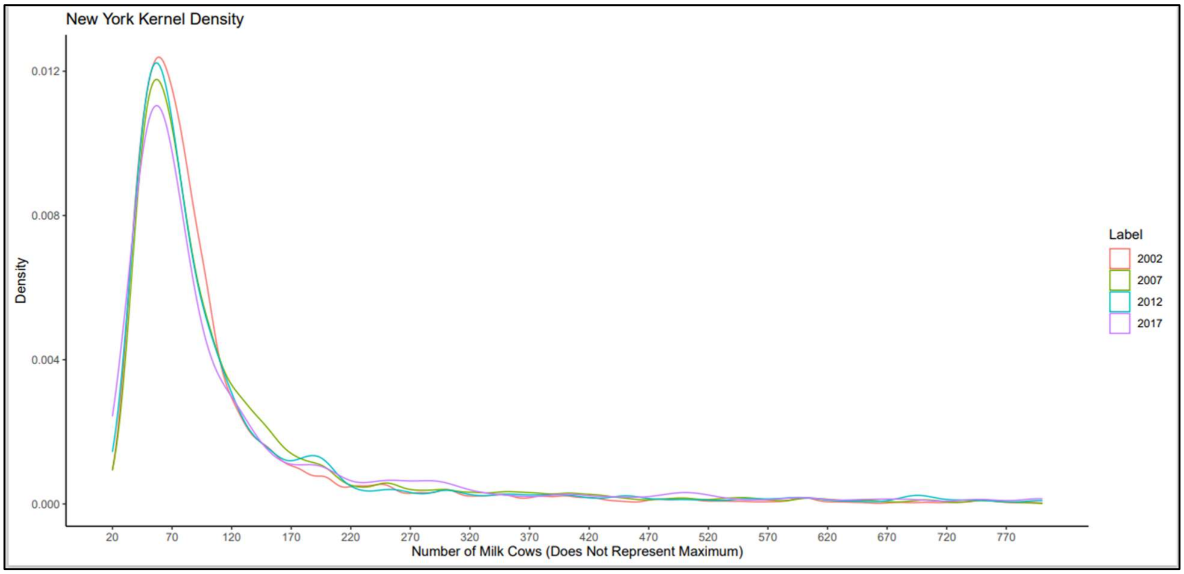
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.4 New Mexico kernel density



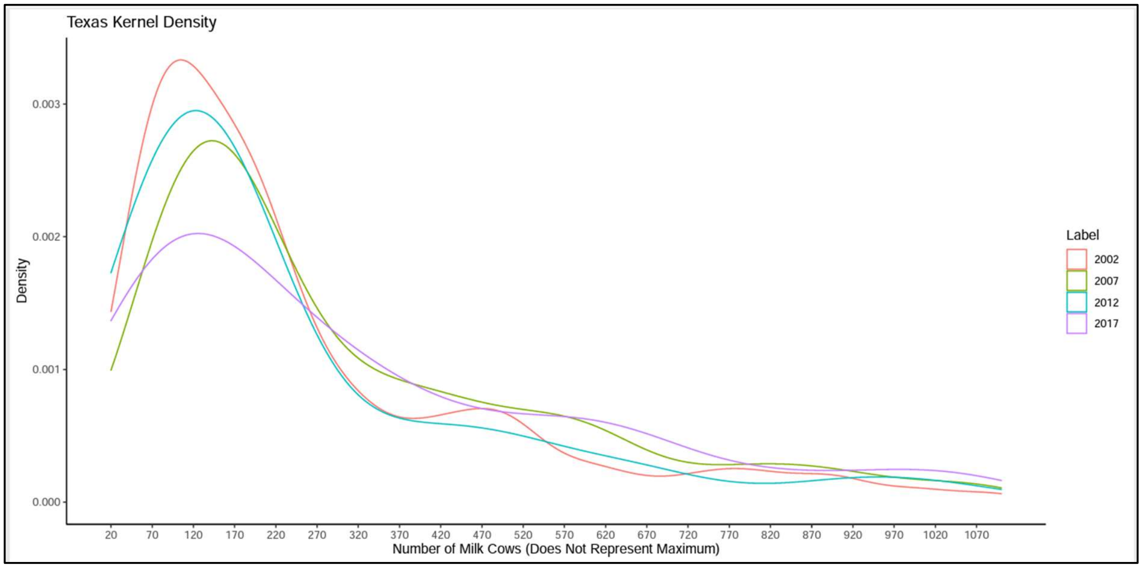
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.5 New York kernel density



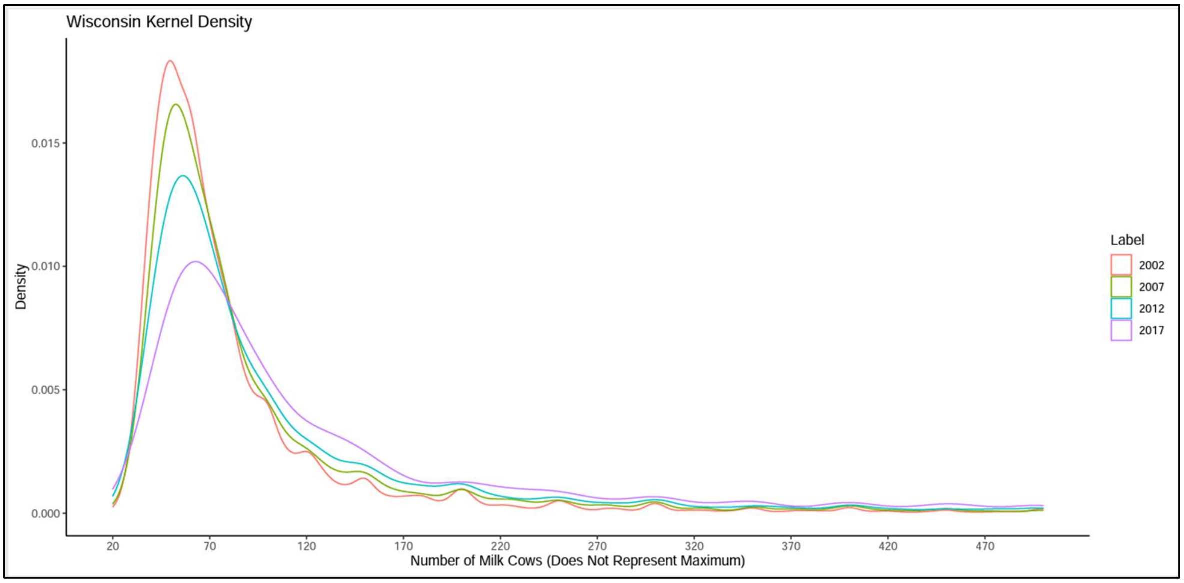
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.6 Texas kernel density



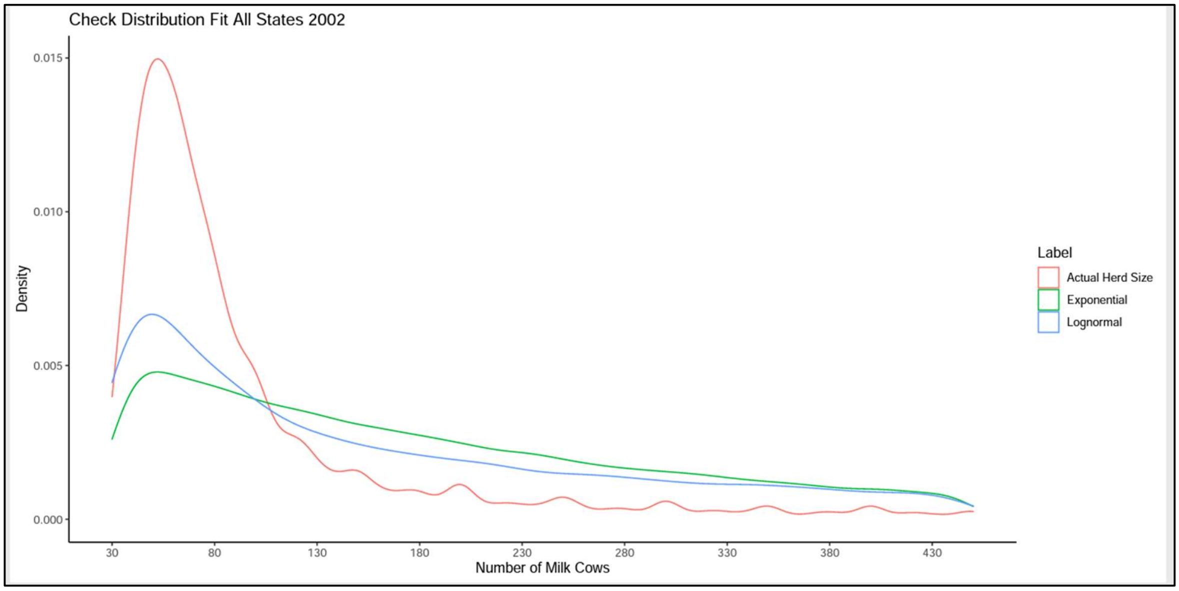
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.7 Wisconsin kernel density



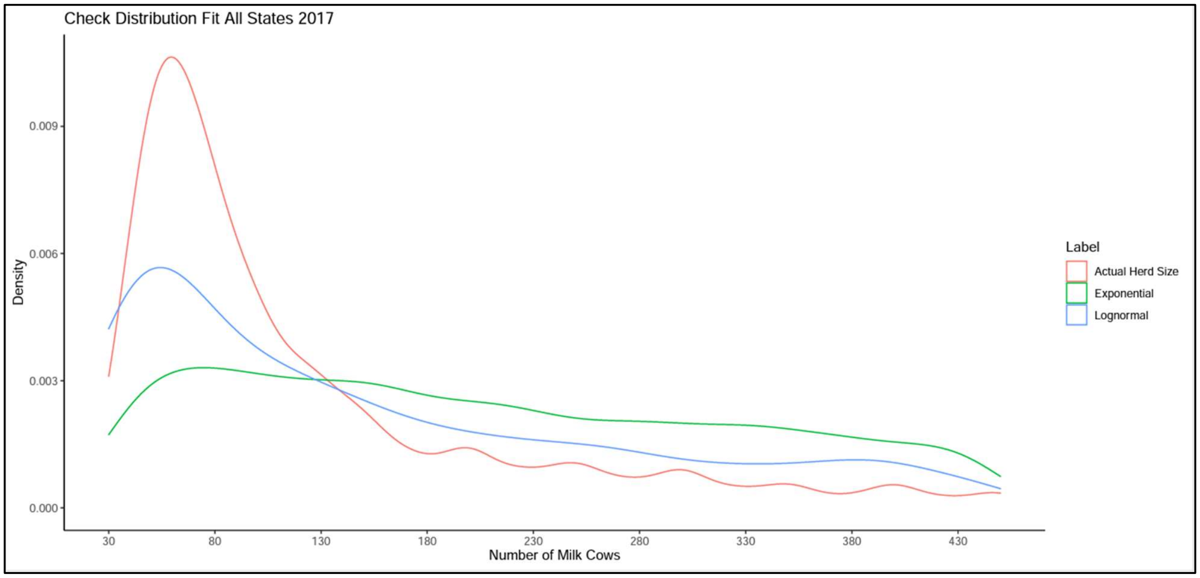
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.8 All six states fitted parametric density functions (2002)



Note: (1) The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 1.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.9 All six states fitted parametric density functions (2017)

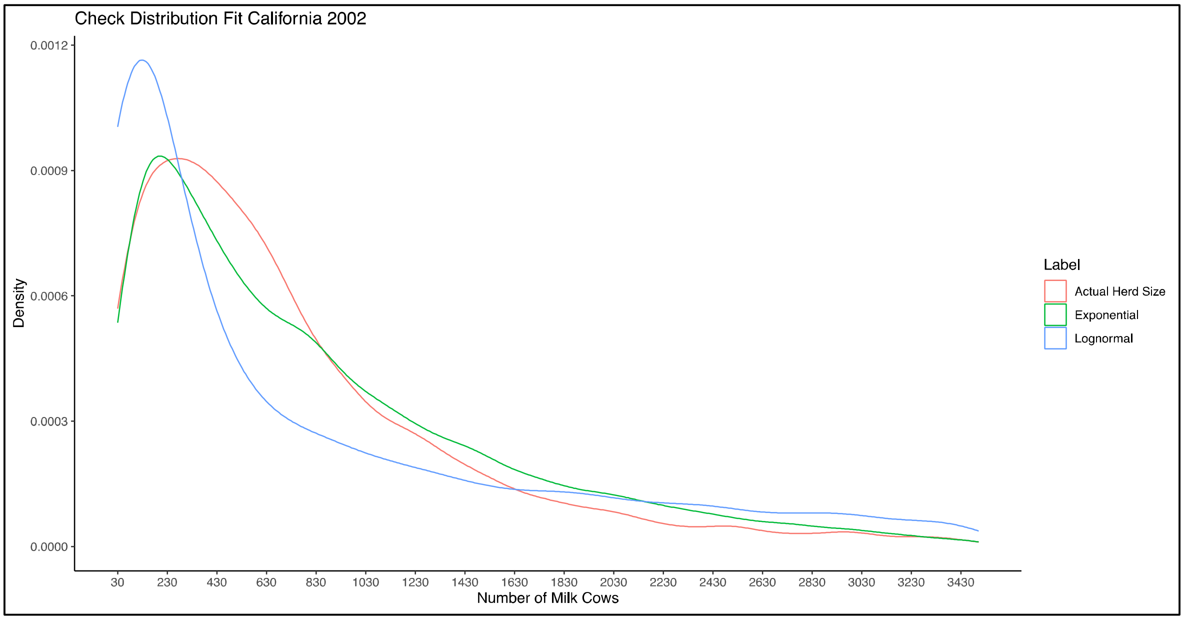


Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 1.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

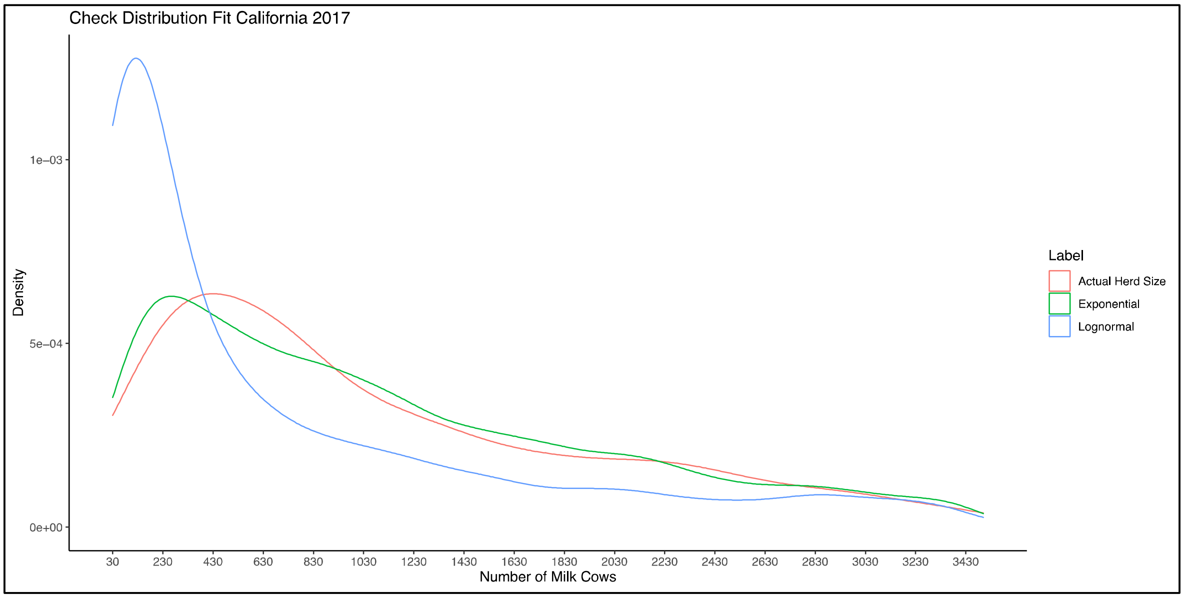
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.10 California fitted parametric density functions (2002)



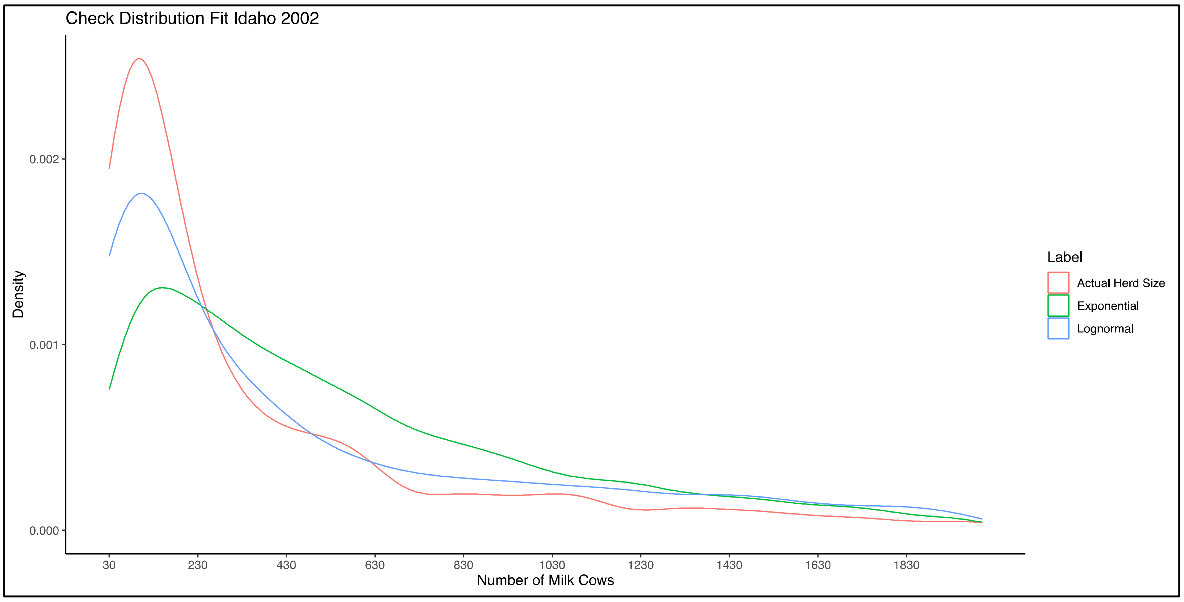
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 2.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.11 California fitted parametric density functions (2017)



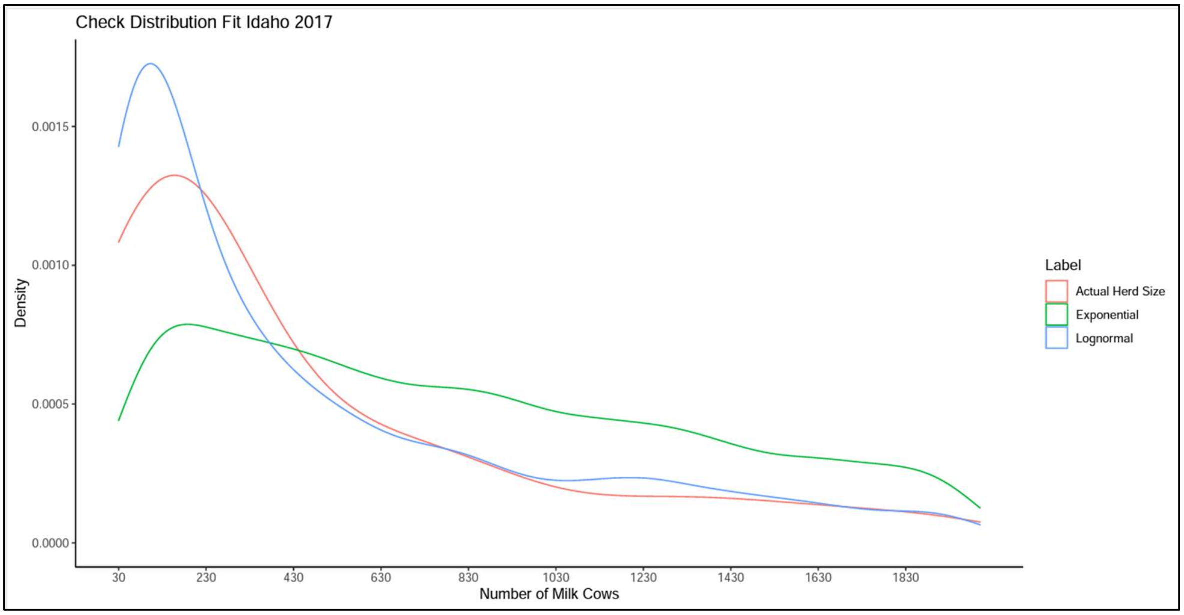
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 2.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.12 Idaho fitted parametric density functions (2002)



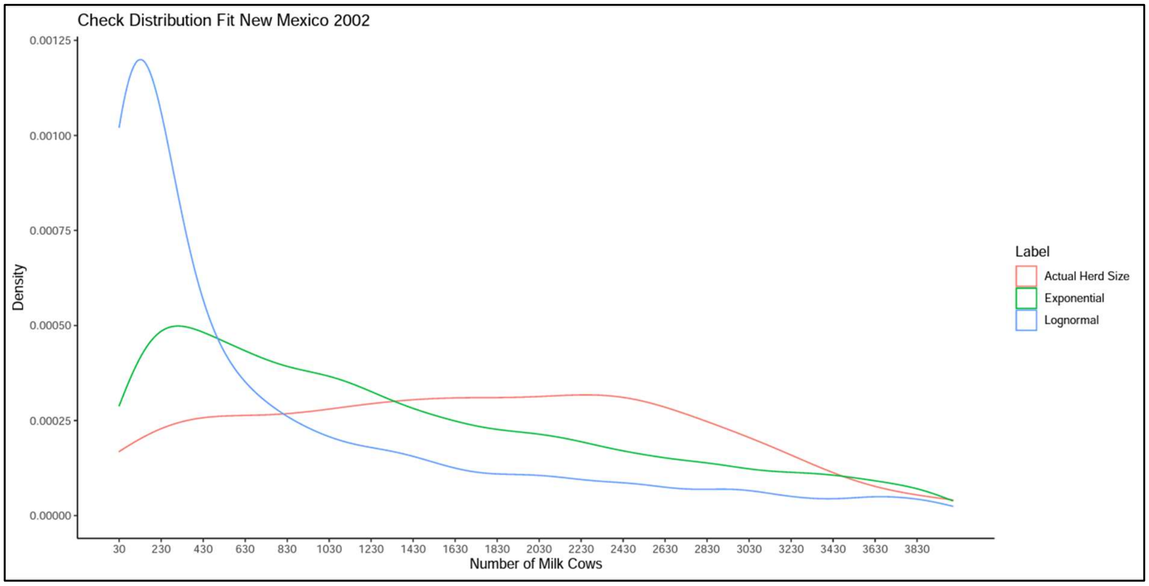
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 3.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.13 Idaho fitted parametric density functions (2017)



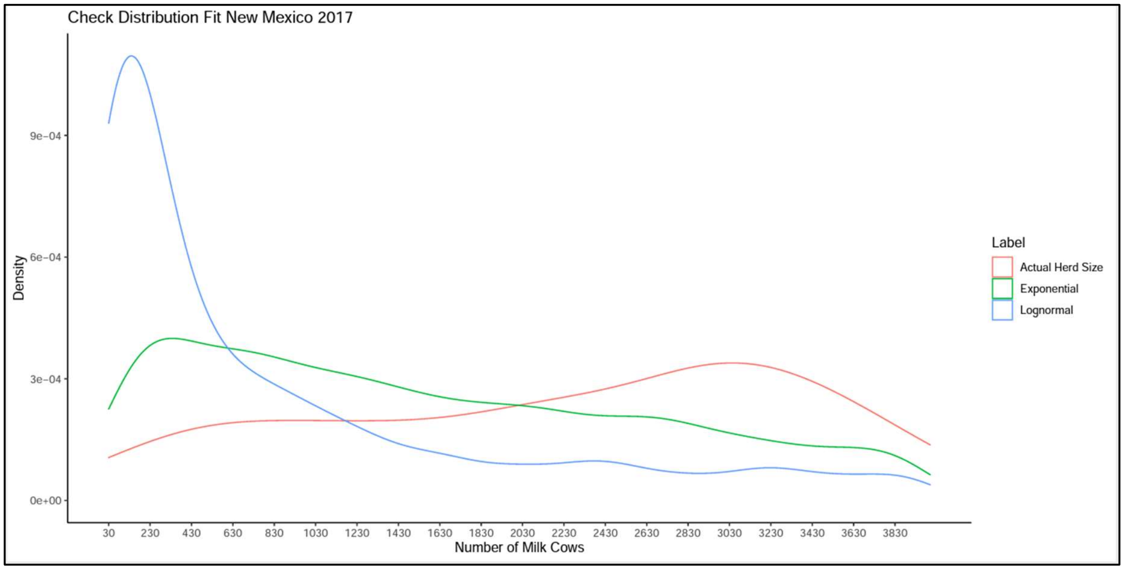
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 3.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.14 New Mexico fitted parametric density functions (2002)



Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 4.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.15 New Mexico fitted parametric density functions (2017)

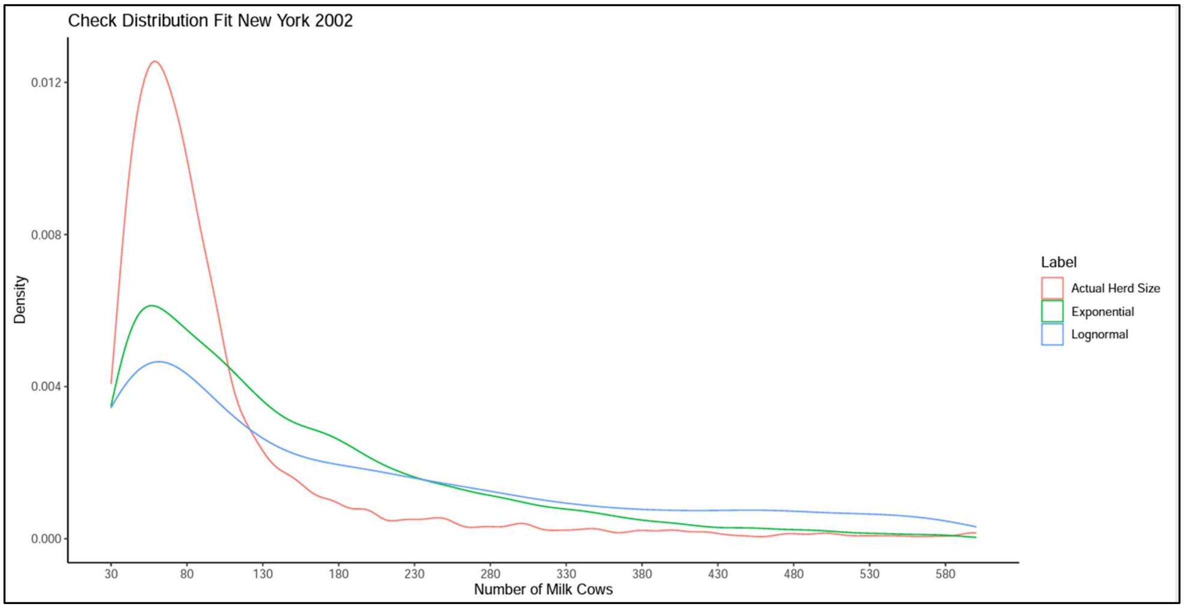


Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 4.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.16 New York fitted parametric density functions (2002)

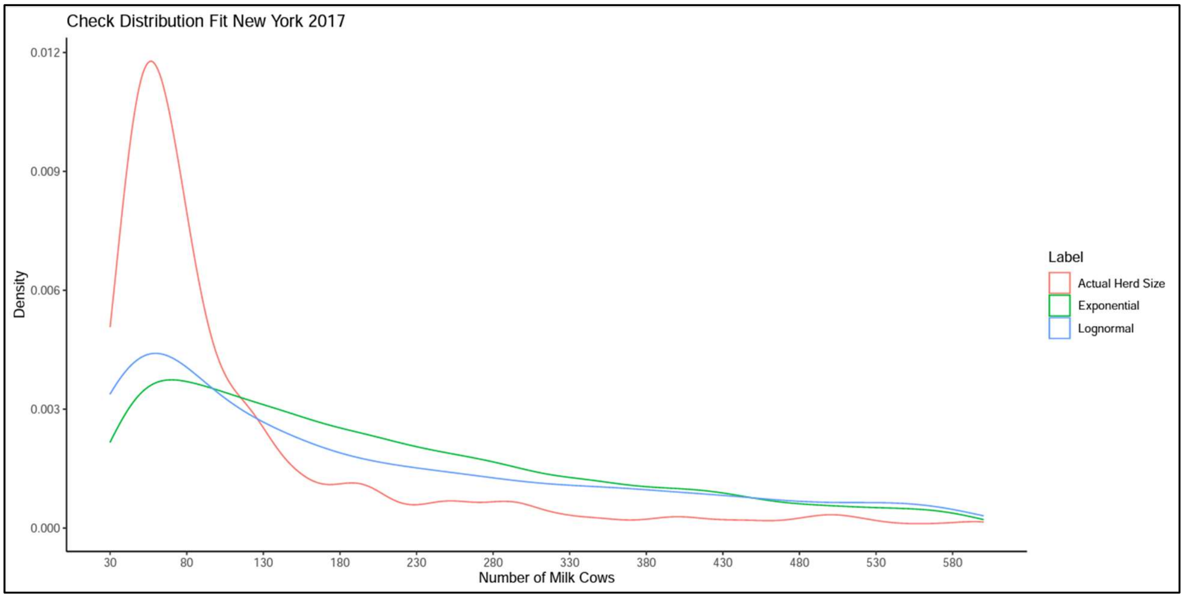


Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 5.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.17 New York fitted parametric density functions (2017)

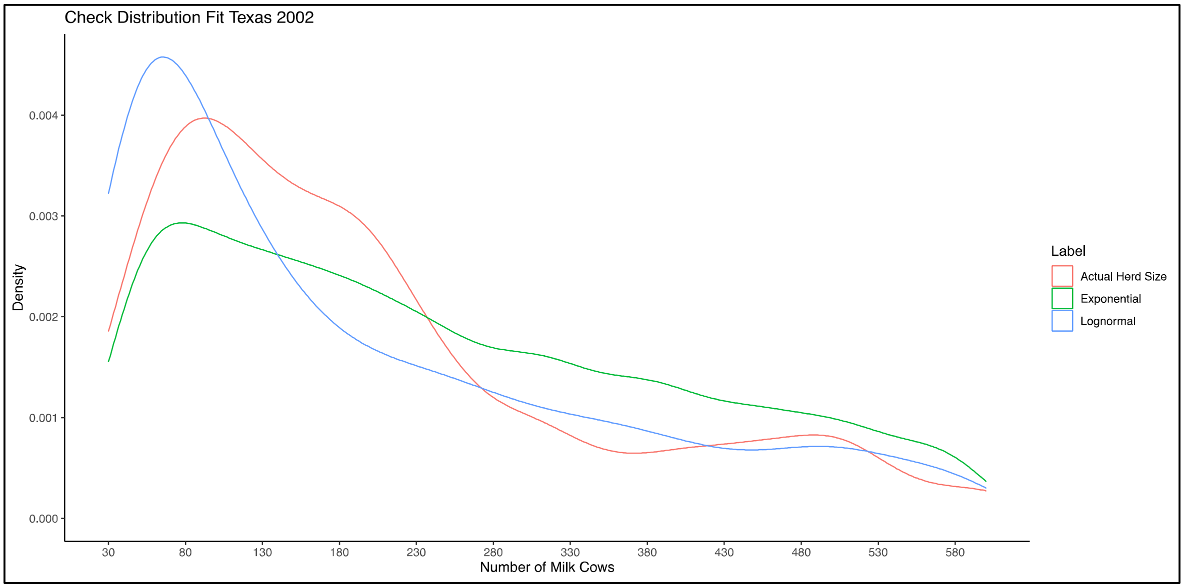


Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 5.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017

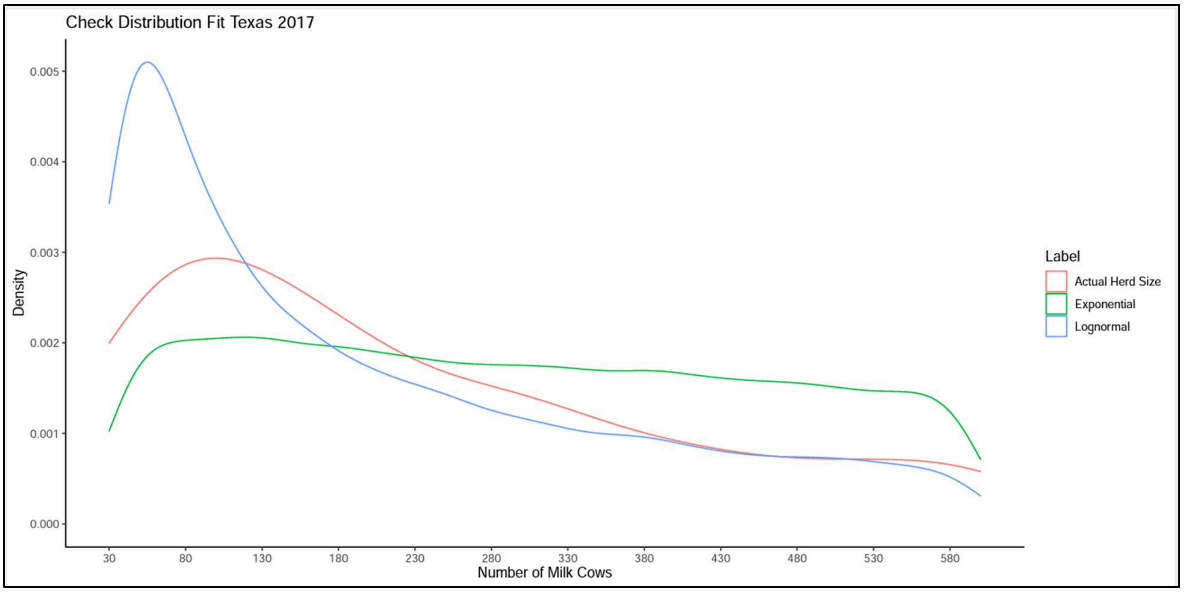
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.18 Texas fitted parametric density functions (2002)



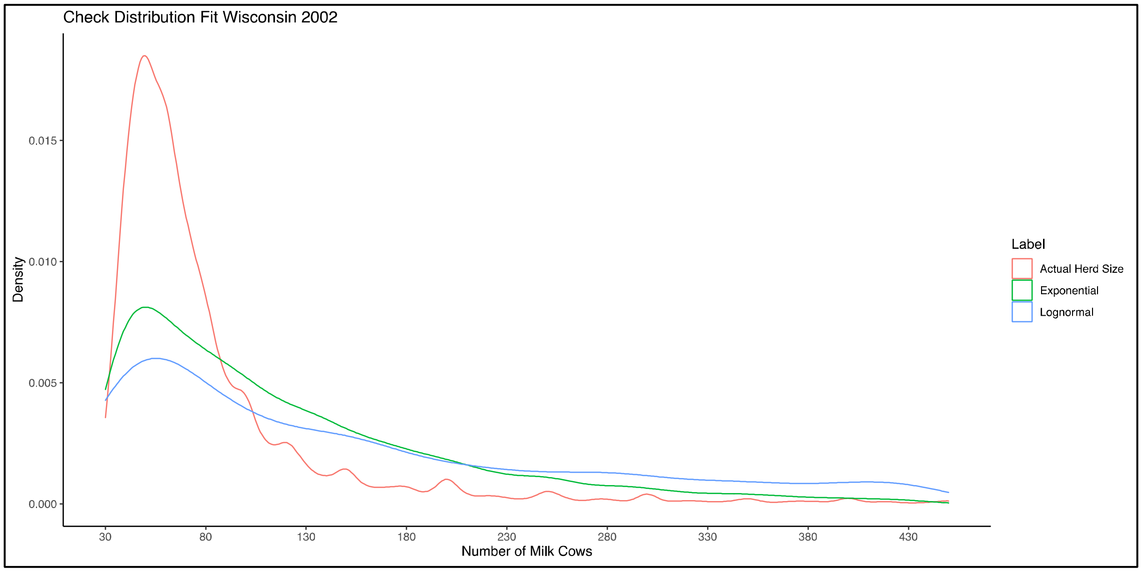
Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the red line (2002) in Figure 6.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.19 Texas fitted parametric density functions (2017)



Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements. (2) Actual herd size line is the same as the purple line (2017) in Figure 6.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

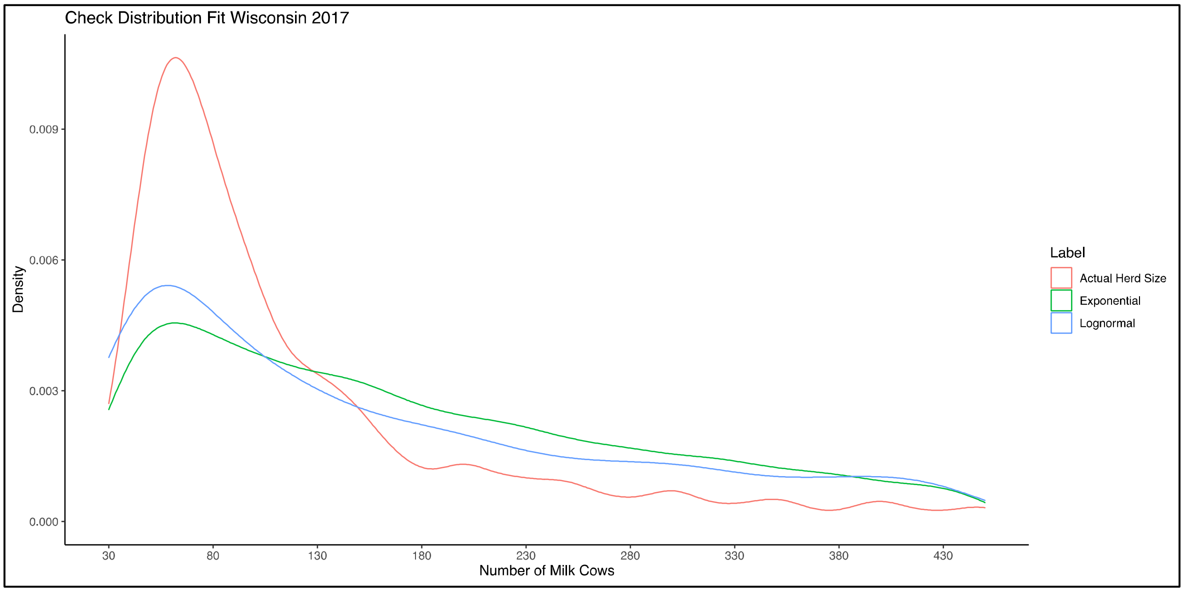
Figure 4.20 Wisconsin fitted parametric density functions (2002)



Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Figure 4.21 Wisconsin fitted parametric density functions (2017)



Note: The right tail of the kernel density plot does not represent the maximum number of milk cows possible in a herd size for this state. This was done in order to remain compliant with USDA NASS disclosure requirements.
Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agriculture (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Chapter 5: Women Dairy Farm Operators: Trends and Patterns

5.1 INTRODUCTION

Dairy farms have long been run by men, with relatively few women acknowledged as farm operators. Women have played a substantial role on farms, even when their contribution was often not classified as contributing to the farm operation or management. The role of women on farms has likely changed along with changes in agriculture itself.

With the rapidly changing dairy industry, it is important to document the validity of assumptions we have about the demographics of farm operators. Successful farms have high-quality management, and women have become a crucial part of the supply of farm management expertise. Based on recent U.S. Department of Agriculture (USDA) Census of Agriculture (COA) data, there appears to be both an increase in the share of female dairy farmer operators and an increase in the share of dairies with at least one female operator. There are two confounding factors that influence these statistics, but fundamentally it implies that farms that have been successful (remaining in the industry) have tended to include female operators. Furthermore, the current data support the previously held assumption that there are a significant number of dairies that are run by spouses with a large share of female farm operators married to a principal operator. Understanding the correlation between the presence and the share of female operators, as well as operations run by spouses on farm size provides insight to a previously limited section of agricultural economics literature. Furthermore, by providing evidence and understanding of dairy farm management demographics this research is able to add to discussions about the future of the dairy industry and a better understanding past patterns.

Very little agricultural economics literature has addressed the intersection of gender and agricultural industry in developed countries, but there has been some work on this topic for developing countries (Schmidt et al. 2021). It was not until 1978 that the COA even asked about the gender of the farm operators. Historically, being a farm operator has been thought of as a male profession with the work done by women on farms tending not to be labeled as farm management. Interest in the role of women on farms is prevalent across several disciplines with some sociology and anthropology research on women in agriculture claiming that women farmers tend to run smaller farms and adopt more sustainable practices than their male counterparts (Trauger 2004, Brasier 2014, and Sander 1986).

There has been no agricultural economics research on the role and impact of female operators in agriculture for the dairy industry, specifically. An increase in the share of commercial dairy farms with a female operator suggests that farms that have not exited, during a trend of consolidation, are likely to have a female operator as compared those with only male operators. However, the increase in shares of women may also reflect a change in the practice of reporting to data collectors in addition to a change in actual farm practices.

This chapter explores the hypotheses that the presence of a female operator on the dairy farm may indicate that the dairy farm is more adaptable or more open to change in management practices. Listing a female farm operator among all the farm operators may be at least correlated with a willingness to adopt new technology, diversify sales, or increase vertical integration on the dairy farm. This is a feasible hypothesis because the presence of a female operator may indicate that the farm is more open to change than many peers in the industry.

Part-time farming is common in crop and beef cow-calf operations, whereas commercial dairy farm operators tend to be full-time operators. Also, in the dairy industry, a female operator of dairy farms is likely to be married to a principal operator. Having both spouses as farm operators likely implies less off-farm income and, therefore, higher financial reliance on the dairy farm's success than for families with more diversified income sources. Moreover, dairy farms tend to have more concentrated farm incomes with crop and dairy enterprises vertically integrated rather than the diversification common among crop farms. (Wolf and Sumner 2002) This changes the incentives of the spousal operators to remain economically viable because it likely increases risk aversion leading to diversification of sales and mitigation of feed price volatility risk by increasing economies of scope.

The COA finding of an increase in the share of women dairy operators and farms with women operators reflects three things: an actual increase in women operators playing a more prominent role, their male associates being more likely to recognize and report female operators, and changes in COA questions that better collect previously unmeasured management activity by women. It is important but difficult to disentangle how these factors affect the data. The increase in the share of female dairy farms must be considered against the broader pattern of dairy farm consolidation, changes in dairy farm size distribution, farm characteristics, and geographic shifts (Sumner and Wolf 2002, Sumner 2020, and MacDonald 2020). This research seeks to provide statistical evidence of differences in farm size of dairies operated by dairies with at least one female operator relative to all male operators, the share of female operators, and those operated by spouses. By considering farms with at least one female operator and/or married operators as a “treatment” group, I compare the herd size, milk or dairy sales, and total value of production, between the two treatment groups, while holding location and year constant. This chapter is structured as follows: a brief overview of previous literature on the intersection of women and agriculture, a description of COA data related to women and farm operators, a discussion of statistics, empirical method, and results, and then a brief conclusion.

5.2 OVERVIEW OF PREVIOUS LITERATURE

Research on the intersection of women and agriculture has tended to be limited in scope and by academic discipline. Previous research on the topic from an agricultural economic perspective has focused on the intersection of women and agriculture in developing countries or limited its analysis to some demographic statistics on female farm operators without much commodity distinction within the agricultural industry. Industry distinction is important because of generally held assumptions about particular commodity farms, including that dairy farms are run by spouses. Moreover, although there have been many anthropology and sociology research studies that have been done on the intersection of women and agriculture in both developing and developed countries, these have tended to be on a case study basis that are limited in geographic scope. I found little empirical agricultural economics research on the patterns over time and across states of female farmers, and I found no prior research on the economics of patterns of female operators in the dairy industry, specifically.

A recent article by Schmidt et al. (2021) summarizes the current literature on the intersection of women and agriculture, specifying that most economic literature on this subject focuses on developing nations. The article calls for further research on this topic to further characterize the change in gender demographics and collect information on influences in the economy that may have impacted or continue to impact the number of female farm operators in agriculture. Schmidt et al. outline three possible influences on the share of female farmers, including push-pull factors, characteristics of local agriculture, and the type of farming practiced. Push-pull factors refer to the influence of off-farm employment wages that may influence an individual's decision to be an entrepreneur or push them to seek off-farm employment. For this analysis, this influence could be considered on an individual basis or at a spousal level. The change incentives when both spouses' incomes come from farming could change and push or pull one or both spouses into off-farm employment or to stay on the farm. Characteristics of local agriculture describe the general state of the region's agricultural economy. This is accounted for by holding constant location and presenting statistics by state. Finally, Schmidt et al. suggest the influence that the type of farming might have, or farming characteristics may influence, as their results find that farms run by women tended to be smaller. There is some association of dairy farms being family-run, or spousal run, this claim is one that we provide evidence on for the dairy industry, specifically. The characterization of such influences provides insight into the possible impacts of female representation on farms across different industries.

Again, the agricultural economic literature on the intersection of gender and agriculture has tended to be limited to developing countries. However, in a recent article by USDA Economic Research Service (ERS), ERS released statistics about the characteristics of U.S. female-run farms and female operators based on the 1978 to 2007 COA (Hoppe 2013). Their results focus mostly on statistics of characteristics of overall U.S. female-run farms and female farm operators. They find that 58% of all female operators have no reported off-farm labor, and that female operators of dairy farms tend to be younger than the U.S. female operators' average age. Griffin et al. (2018) utilize the COA data over five Census rounds and discuss the impact of farm operators' demographics on farm exit rates. They find that larger farms are less likely to exit, and those female operators are more likely to exit than male operators. However, their study includes all farms with no industry limitations. Furthermore, research on female operators' impact and representation within the dairy industry is a point of interest because, historically, it was not uncommon for dairy farms to be run by spouses and because off-farm employment is less likely on a dairy farm than it is on other farms. Sander (1986) finds that women working on dairy farms tend to have less off-farm employment than other farm types. He outlines the role of income variability on farms run by spouses' decision to be both spouses' main income with off-farm work as a possible risk mitigation strategy for farms run by spouses when farm revenue is highly variable.

Schultz (2001) detailed some economic theories related to women focusing mainly on developing nations. Specifically, the role of family dynamics in economic choices on farms and female influence on such outcomes. Rather than taking a theoretical approach, Zeuli and King (2001) provide detailed statistics of the characteristics of farmers and their commercial farms in 13 states. They find that in 1991 the average age of females relative to males is insignificant, but that the women in their sample tended to have a higher level of schooling. Interestingly, they found contradicting results, at least based on acreage, to other studies stating that women tend to manage smaller farms, with women operating more acreage on average, but this could be heavily influenced by what they grow and location.

Sociology and anthropology research on female farm labor and agriculture tends to report findings based on case studies of specific regions and industries (Brasier 2014 and Trauger 2010). These papers tend to discuss social incentives, norms, or barriers that influence the gender demographics of the industries of interest and, therefore, influence female representation and the impact of management decisions on the farm. Brasier et al. discuss the history of how women identify their labor on farms. Historically, female participation in farming communities was accessed through family or marriage. Typically, women involved in agriculture were either born into a family that farmed or married a farmer. In the past women often viewed their role on the farm as farm homemakers or farm helpers, following gender norms of the times, and often because they had off-farm income or only participated in farm labor seasonally (Brasier 2014). This way of thinking about farm labor could have influenced the representation of female operators of farms. Other sociology research has documented trends in farm management through case studies on regions. Trauger (2004) finds that women are more likely to adopt sustainable agriculture. Trauger (2010) limits its scope to a few farms in Pennsylvania, finding that there may be a trend of female-operated farms to adopt socially minded practices, i.e., community education. This research helps build evidence that supports our claim that the presence of female operators can be considered a proxy variable for being adaptable to change.

It seems like a basic assumption, but there was, and remains, a large share of women that participate in farm labor that were/are married to principal operators; this trend continues today. Therefore, the research on the relationship between gender and agriculture would not be complete without mentioning research done on agricultural spouses. A large share of female operators are the spouses of a farm operators. Barlett (1993) details the typical marriage models of agricultural spousal relationships, characterizing how farm labor related to agricultural spousal relationships is defined from a social perspective and may have influenced how women viewed their labor on the farm and subsequently the data representing farm labor, historically. The role of identity for female farmers and the professional connections can be a pivotal part of female farmer participation.

This research provides evidence of the change in gender demographics based on farm size for the dairy industry. It adds to the literature detailed agricultural economic analysis on the intersection of women and agriculture for the dairy industry and discusses the change in data collection and availability by one of the most prevalent data sources for agricultural data, the COA.

5.3 DATA AND METHODS

This section will discuss how the COA questions differed from year to year and what farms are included in the sample. The detailed level operator characteristics collected by the COA allow us to see how representation of gender varies by the age of operators, state, time, and farm and herd size for dairy operators. For this analysis, I utilize USDA COA data, as was described in previous Chapters.

The survey questions asked of farmers and ranchers by the COA change slightly every Census round, although most remain the same across time. Below are descriptions of questions changes for relevant variables to the analysis. First, in 2002 and 2007, farms were asked for the total amount of dairy sales in that year, but in 2012 and 2017, this question was dropped and replaced with the total amount of milk sales. Furthermore, whether the dairy farm had any level of organic production was only asked 2007, 2012, and 2017.

Second, operator characteristic questions have become more detailed over the years and allowed more operators' data to be collected. In 2002, 2007, and 2012, the COA asked detailed operator characteristic questions about up to three operators, and only one operator was able to be identified as the principal operator. However, in 2017, the COA expanded its detailed operator questions to include up to four operators and now allows for up to four operators to be identified as a principal operator. Furthermore, in 2012, the COA started asking farmers and ranchers if the secondary operators (those not labeled as the principal operator) were married to the principal operator. This question was then adapted in 2017 to reflect the increase in possible principal operators identified and asked if the operator (principal or secondary) was married to a principal operator. The Census collects two categories of operators. The first category is for which detailed operator characteristics and for which at most three operators are listed per farm in 2002-2012 and at most four operators per farm are listed in 2017. Going forward, the operators for which the number per farm is limited and detailed information is provided will be referred to the "core operators". The second category has no limit to the number listed per farm and only gender of each operator and the number per farm is provided in the data.

5.4 PATTERNS AND RELATIONSHIPS IN THE DATA ON FEMALE OPERATORS

5.4.1 Statistics about Female Commercial Dairy Farm Operators and Their Farms

This section detail statistics and characteristics of female commercial dairy farm operators and their commercial dairies. The number of commercial dairies with at least one female core operator increased in every state, except New Mexico, which experienced no change from 2002 to 2017 (Table 5.1). In 2017, every state, but New Mexico, has more than 40% of the commercial dairies reporting at least one female core operator. Although these states demonstrate significant increases in the representation of female core operators, the addition of a fourth core operator for the 2017 Census could distort these results. Table 5.2 shows the share of commercial dairies with at least one female operator by state and year. This has very interesting results with all commercial dairies reporting at least one female operator in 2017. All six states saw significant increases in the share of commercial dairies with at least one female operator.

The actual share of female operators compared to the share of operators gives us a better representation of demographic changes. The share of female core operators increased from 2002 to 2017 in every state but New Mexico, for which the share of female core operators decreased in 2007 and 2012 but was the same in 2002 as in 2017 (Table 5.3). California and New York both increased the number of across each Census year. California had a 27% increase in female core operators from 2002 to 2017 and the share of female core operators in New York increased by 33%. Idaho, Texas, and Wisconsin all had a slight decrease in female core operators in 2007 and 2012, but an increase in 2017 relative to all previous years. Interestingly, when we look at the share of female operators it follows a similar pattern. California and New York both increases in the share of female operators across each Census. Wisconsin, Idaho, and Texas all had slight decreases in 2007 and 2012 relative to the 2002 share, but the share of female operators in 2017 was larger than in 2002

(Table 5.4). However, the share of female operators in New Mexico had a small decrease from 2002 to 2017. This suggests that despite the addition of a fourth core operator in the 2017 COA the pattern is not substantially different from the trend in operators and that the trend was not only facilitated by capturing previously unmeasured management activities by women. From here characterizing the trend could be thought of in two ways: 1) this describes an actual increase in women operators playing a more prominent role and/or 2) an increase in their male associates being more likely to recognize and report female operators. Disentangling exactly what characterizes these trends is impossible, but it seems likely that the addition of a fourth core operator and the ability for more than one principal operator may have signaled a conversation about representation on the COA for many commercial dairies.

Next, it is important to characterize the management characteristics of commercial dairy operators. These results are only characteristic of core operators as this data was not collected for all operators. The COA asked core operators whether their principal occupation was off farm. Overall, a larger share of female core operators had a principal off-farm occupation than male core operators (Table 5.5). In California, less than 10% of the male core operators had an off-farm principal occupation, but about 30% of female core operators had an off-farm principal occupation with little variation over time. In other states, like Idaho and Texas, the share of core operators with off-farm principal occupation followed a similar pattern to California by gender. However, there was an 86.6% increase in male core operators with an off-farm principal occupation and an 18% decrease in female core operators in New Mexico. Along a similar thread, a very small portion of female core operators was labeled as principal operators. Now, the definition of a principal operator did change for the 2017 COA, but even with the 2017 addition of more than one core operator being labeled as a principal operator the share of female core operators that are labeled as a principal operator is relatively small. In California, 5% of female core operators are principal operators from 2002 to 2012 with a jump in 2017 to 17% with the addition of the fourth core operator (Table 5.6). Idaho, New York, and Wisconsin follow a similar pattern as California with little to no change from 2002 to 2012 and a large jump in 2017. New Mexico and Texas, however, had a decrease from 2002 to 2012 and then a large jump in 2017. In 2017, most states had about 16-20% of female core operators listed as a principal operator, but New Mexico only had 11%.

This research would be incomplete without a description of the presence of spousal-run dairy farms in the U.S. A spousal-run dairy refers to a dairy that is managed by two operators that are married to one another. There is a historic assumption that many dairy farms are run by spouses, however, this research finds that trends in spousal commercial dairy operations does differ greatly by state (Table 5.7). For some states, like Wisconsin, New York, and Idaho, a significantly large share of commercial dairy farms was being run by spouses, with over 40% of commercial dairy farms in each state being spousal run. In California, 31% of commercial dairy farms are run by spouses, but New Mexico had relatively few commercial dairies run by spouses and a decrease from 15% to 13% from 2012 to 2017. A large share of female core operators of commercial dairies was married to a principal operator in 2012 and 2017 (Table 5.8). In 2017 Texas had the largest share with 80% of female core operators married to a principal operator and then Idaho and Wisconsin both had more than 75%. New Mexico had the smallest share of female core operators married to a principal operator with 48%, but that remains a significant share.

Next, age of commercial dairy operators has been a point of discussion for because of the increasing age of dairy farm operators. Table 5.9 presents the share of operators by gender and age group for the Census year and state. Across all state the largest share of female operators was in the less than 50 years old age group with all states following a similar trend of a decreasing share of younger operators and increase in the share of older operators. For male operators the largest share was the less than 50 age group also had the largest share. There was a significant share of male operators in the larger age group categories across all states with every state, but Wisconsin, have at least 10% of operators being male and over the age of 66.

Finally, previous literature suggested that women may be more likely to adopt sustainable-minded practices. Regarding organic production, this seems to be true. In 2017, most organic commercial dairies have at least one female core operator, except in New Mexico for which only 17% of organic commercial dairies have at least one female core operator (Table 5.10). The share of organic commercial dairies with at least one female operator is larger than the overall share of commercial dairies with at least one female operator. There was an increase in the share of female core operators that operated an organic commercial from 2007 to 2017 (across all states), but this was also with the addition of the fourth operator. There has been a slight increase in the share of organic commercial dairies across all states, but in 2017 all states had less than 15% of commercial dairies with organic production (Table 5.11). Organic dairies do tend to have smaller herd sizes, in general and more milk sales revenue per cow. Organic commercial dairies have a larger share of female core operators than commercial dairies overall for all states, except New Mexico. In 2017, organic commercial dairies report at least a 30% or more share of female core operators, except New Mexico which only had an 8% share of female core operators (Table 5.12). In every state, except New York, there was an increase in the share of female core operators that manage organic commercial dairy. The share of female core operators that manage an organic dairy decreased by 28% in New York but increased by 66% in Idaho.

5.4.2 Female Operators and Spousal Run Farms on Farm Size

Next, I turn to explore the relationship between the farm size and gender demographics of farm operators and spousal-run operation. COA is panel data, meaning that it is both times series and cross sectional in nature. For my analysis, I utilize a log-linear model with fixed effects in order account for cross-state and cross-time differences. The farm size variables, of the individual farm (i) at time (t), are the logged dependent variables including $Cows_{it}$ number of milk cows (herd size), TMD_{it} total sales revenue from dairy or milk, and TVP_{it} total value of production. I utilize farm-level operator characteristics variables including a binary variable ($FemOper_{it}$) for the presence of a female core operator (1 for at least one female operator, 0 for no female operators), the share female operator on the individual farm ($ShareFem_{it}$), and a binary variable ($Spouse_{it}$) that indicates a spousal run farm variable (1 for at least one operator married to a principal operator, 0 for no operator married to a principal operator). Furthermore, I included a variable to control for a relationship between the age demographics of operators on farm size. $MaxAge_{it}$ describes the maximum age listed by any given core operator on an individual commercial dairy. Table 5.13 shows the list of variables use in regressions and their corresponding definition. In addition, α_i and λ_t represent the state fixed effect and the time fixed effect, respectively, and u_{it} is an error term. X_{it} represents a vector of farm operator characteristics and farm management characteristics. $logFarmSize_{it}$ represents a vector of the logged farm size variables listed above.

5.4.3 Relationship Between Presence of a Female Core Operator and Farm Size

Equations 1 is the regression equation used to show the relationship between the presence of a female operator and farm size, accounting for age, state, and year influences on farm size. Table 5.14 shows the relative coefficients and standard errors of each regression. Concerning the number of milk cows, the presence of at least one female core operator relates to a decrease in the herd size by about 12.9%, when holding constant for age, state, and year influences on farm size. With herd size, when accounting for the presence of a female operator, the max age corresponds to an increase in the herd size by 0.5%. The presence of at least one female core operator suggests a decrease of the total value of production by 31% and all milk or dairy sales by about 13.4% as well. So, across all farm size measures, there are relatively similar results.

A one-year increase of the maximum age of any core operator relates to an increase in the total value of production by about 0.7%.

$$(1) logFarmSize_{it} = \beta_0 + \beta_1 FemOper_{it} + \beta_2 MaxAge_{it} + \alpha_i + \lambda_t + u_{it}$$

5.4.4 Relationship Between Share of Female Operator and Farm Size

Equations 2 is the regression equation used to show the relationship between the share of female operators and farm size, accounting for age, state, and year influence on farm size. Table 5.15 shows the relative coefficients and standard errors of each regression. Across all farm size variables, a 1% increase in the share of female operators has a very similar results of about a 34% decrease of farm size variables. When looking specifically at herd size relationships, a 1% increase in the share of female operators relates to a decrease in the relative herd size by about 32%. Whereas there is a larger coefficient for the relationship between the total value of production with the share of female operators. Farm sizes' relationship with maximum age, when controlling for the share of female operators, follows a relatively similar trend. A one-year increase of the maximum age of core operators suggests an increase in farm size by 0.5%.

$$(2) FarmSize_{it} = \beta_0 + \beta_1 ShareFem_{it} + \beta_2 MaxAge_{it} + \alpha_i + \lambda_t + u_{it}$$

5.4.5 Relationship Between the Presence of Spousal Operator and Farm Size

Equations 3 is the regression equations used to show the relationship between the presence of spousal core operators on the farm and farm size, accounting for age, state, and year influences on farm size. Table 5.16 shows the relative coefficients and standard errors of each regression. Regarding herd size, being managed by spouses corresponds with a reduction in the herd size by about 19.2%. When we consider the influence on the total value of production or total milk or dairy sales the presence of spousal core operators had a slightly stronger relationship with farm size with about a 20.9% decrease in the total value of production or total milk or dairy sales. A one-year increase in the maximum age of core operators on an individual farm relates to an increase in farm size by about 1%.

$$(3) FarmSize_{it} = \beta_0 + \beta_1 Spouse_{it} + \beta_2 MaxAge_{it} + \alpha_i + \lambda_t + u_{it}$$

5.5 CONCLUSION

Since 2002, there has been an increase in the share of female core operators and commercial dairies with at least one female operator. The trends in the share of the core operator and the share of operators suggest that these increases are not due to the increase in the number of core operators' data collected by the COA, but, in fact, an actual increase in female commercial dairy farm management.

Furthermore, both the presence of female operators and the share of female operators had significant negative relationship with farm size of commercial dairies across states and time. Furthermore, the presence of spouses running the commercial dairy also shows a significant decrease on the farm size. Due to the significant share of female core operators that are married to principal operators, it seems likely that this trend could be due to change in management and risk incentives of the operators resulting from both spouses' income being likely determined by the success of the dairy.

Table 5.1 Share of commercial dairies with at least one female core operator by state and year

State	2002	2007	2012	2017
California	30%	34%	34%	42%
Idaho	35%	35%	36%	47%
New Mexico	29%	23%	20%	29%
New York	36%	39%	40%	55%
Texas	33%	36%	33%	42%
Wisconsin	44%	46%	45%	55%

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.2 Share of commercial dairies with at least one female operator by state and year

State	2002	2007	2012	2017
California	31%	50%	50%	100%
Idaho	37%	54%	52%	100%
New Mexico	30%	36%	29%	100%
New York	37%	52%	60%	100%
Texas	34%	54%	53%	100%
Wisconsin	46%	63%	64%	100%

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.3 Share of commercial dairy core operators that identify as female by state and year

State	2002	2007	2012	2017
California	18%	19%	20%	23%
Idaho	20%	20%	19%	24%
New Mexico	18%	13%	13%	18%
New York	21%	22%	22%	28%
Texas	23%	21%	21%	25%
Wisconsin	26%	26%	25%	29%

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.4 Share of commercial dairy operators that identify as female by state and year

State	2002	2007	2012	2017
California	19%	20%	21%	24%
Idaho	21%	20%	20%	25%
New Mexico	19%	14%	15%	18%
New York	22%	23%	23%	29%
Texas	23%	22%	22%	26%
Wisconsin	27%	26%	26%	29%

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.5 Share of male and female operators of commercial dairies whose principal occupation is off the farm, by state and year

	2002	2007	2012	2017
California				
Male	9%	8%	8%	7%
Female	32%	36%	39%	31%
Idaho				
Male	7%	7%	5%	6%
Female	33%	33%	35%	35%
New Mexico				
	15%	19%	20%	28%
Female	44%	43%	25%	36%
New York				
Male	5%	4%	4%	4%
Female	19%	21%	25%	25%
Texas				
Male	13%	7%	9%	8%
Female	29%	21%	27%	26%
Wisconsin				
Male	5%	4%	5%	4%
Female	20%	23%	24%	25%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.6 Share of female commercial dairy principal core operators by state and year

State	2002	2007	2012	2017
California	5%	5%	5%	17%
Idaho	3%	2%	2%	16%
New Mexico	4%	4%	1%	11%
New York	4%	5%	4%	20%
Texas	6%	4%	3%	18%
Wisconsin	3%	3%	3%	19%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.7 Share commercial dairies run by spousal operators

States	2012	2017
California	24%	31%
Idaho	32%	41%
New Mexico	15%	13%
New York	33%	42%
Texas	28%	38%
Wisconsin	40%	46%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.8 Share of female commercial dairy core operators that are married to a principal operator

States	2012	2017
California	62%	64%
Idaho	79%	78%
New Mexico	64%	48%
New York	75%	69%
Texas	79%	80%
Wisconsin	83%	75%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.9 Share of operators of commercial dairy by gender, age group, state, and year

California	Female				Male			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	9%	9%	8%	7%	44%	40%	34%	27%
51-60	4%	6%	6%	8%	18%	21%	24%	24%
61-65	2%	2%	2%	3%	7%	6%	9%	10%
66-75	2%	2%	2%	3%	9%	9%	9%	10%
75+	1%	1%	1%	2%	4%	4%	5%	7%
Idaho	Female				Male			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	13%	10%	8%	8%	49%	43%	36%	31%
51-60	5%	6%	5%	9%	18%	24%	25%	22%
61-65	1%	1%	3%	3%	5%	6%	8%	10%
66-75	1%	1%	2%	3%	4%	5%	9%	10%
75+	0%	1%	1%	1%	3%	3%	2%	3%
New Mexico	Female				Male			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	12%	7%	6%	8%	51%	48%	37%	28%
51-60	3%	5%	3%	5%	19%	26%	31%	20%
61-65	1%	0%	3%	4%	5%	4%	11%	15%
66-75	1%	1%	0%	2%	4%	3%	6%	14%
75+	0%	0%	0%	0%	3%	7%	3%	5%
New York	Female				Male			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	13%	12%	11%	12%	48%	41%	37%	32%
51-60	5%	6%	7%	8%	17%	21%	22%	19%
61-65	1%	1%	2%	3%	5%	6%	7%	9%
66-75	1%	2%	2%	4%	7%	7%	7%	9%
75+	0%	1%	1%	1%	2%	3%	3%	3%
Texas	Female				Male			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	12%	12%	8%	10%	43%	47%	35%	27%
51-60	5%	5%	8%	9%	18%	18%	24%	26%
61-65	1%	1%	4%	2%	6%	6%	9%	8%
66-75	2%	2%	2%	3%	8%	6%	6%	9%
75+	1%	0%	0%	2%	3%	3%	3%	4%
Wisconsin	Female				Female			
	2002	2007	2012	2017	2002	2007	2012	2017
Less than 50	18%	15%	12%	12%	50%	43%	37%	32%
51-60	5%	7%	9%	10%	15%	21%	25%	22%
61-65	1%	2%	2%	3%	4%	5%	7%	8%
66-75	1%	1%	1%	2%	4%	4%	5%	7%
75+	0%	0%	0%	1%	1%	2%	2%	2%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.10 Share of organic commercial dairies with at least one female operator by state and year

State	2007	2012	2017
California	51%	45%	62%
Idaho	41%	38%	67%
New Mexico	0%	0%	17%
New York	57%	43%	71%
Texas	80%	50%	100%
Wisconsin	44%	50%	72%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.11 Share of commercial dairies with any organic production by state and year

State	2007	2012	2017
California	4%	10%	13%
Idaho	3%	5%	8%
New Mexico	2%	2%	5%
New York	4%	6%	11%
Texas	1%	2%	2%
Wisconsin	2%	4%	6%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.12 Share of female organic commercial dairies core operators by state and year

State	2007	2012	2017
California	27%	26%	30%
Idaho	18%	22%	30%
New Mexico	0%	0%	8%
New York	32%	26%	35%
Texas	57%	25%	41%
Wisconsin	26%	28%	33%

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2007, 2012, and 2017
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

Table 5.13 List of variables used in regressions

Variable	Description
TVP_{it}	Total value of production sold
$Cows_{it}$	Total inventory of milk cows (lactating or dry) on the farm
TMD_{it}	2002 and 2007: fix as above value of milk and other dairy sales 2012 and 2017: value of milk sales
$Organic_{it}$	Dummy variable equal to one if the dairy farm is organic; zero otherwise This variable is only available for 2007, 2012, and 2017 Census years. No question was applicable in 2002 and therefore was left blank.
$State_{it}$	Categorical variable in which there are coefficients for Idaho, New Mexico, New York, Texas, and Wisconsin that are relative to a base variable of California.
$Year_{it}$	Categorical variable in which there are coefficients for 2007, 2012, and 2017 that are relative to a base variable of 2002.
$FemOper_{it}$	Dummy variable equal to one if a least one female operator; zero otherwise
$ShareFem_{it}$	Share of total female operators of all operators
$Spouse_{it}$	Dummy variable equal to one if at least one core operator is married to a principle operator: zero otherwise
$MaxAge_{it}$	Maximum age of a core operator
$MeanAge_{it}$	mean age of core operators

This variable is only available for 2007, 2012, and 2017 Census years. No question was applicable in 2002 and therefore was left blank.
You need to include the details of the data definitions in an appendix to the chapter but clear short definitions here.

Table 5.14 Presence of a female commercial dairy core operator on herd size, and maximum age [a]

Independent Variables	Dependent Variables		
	$lnCows_{it}$	*$lnTVP_{it}$*	*$lnTMD_{it}$*
$FemOper_{it}$	-0.13846*[b]	-0.16527*	-0.1438*
	(0.00693)	(0.007449)	(0.007522)
$MaxAge_{it}$	0.005792*	0.006975*	0.004907*
	(0.000276)	(0.000297)	(0.0003)
Idaho	-0.66119*	-0.64349*	-0.73194*
	(0.021329)	(0.022957)	(0.023184)
New Mexico	0.938413*	0.888104*	0.924798*
	(0.037334)	(0.040159)	(0.040556)
New York	-1.90422*	-1.85961*	-1.9022*
	(0.012718)	(0.013677)	(0.013812)
Texas	-0.79841*	-0.8661*	-0.91264*
	(0.020573)	(0.022127)	(0.022346)
Wisconsin	-1.99396*	-1.90636*	-2.03147*
	(0.01163)	(0.012507)	(0.01263)
2007	0.1601*	0.617897*	0.628052*
	(0.008826)	(0.009502)	(0.009596)
2012	0.238353*	0.872407*	0.791398*
	(0.009381)	(0.010101)	(0.010201)
2017	0.426622*	1.066938*	1.000407*
	(0.010171)	(0.010888)	(0.010996)

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

a. These regressions are for the continuous sample n = 60,123 (Cowit) and 60,432 (TVPit, and TMDit)

b. Coefficients, with standard error in parenthesis.

* $p < .01$

Table 5.15 The share of female commercial dairy operators on herd size and revenue [a]

Independent Variables	Dependent Variables		
	$lnCows_{it}$	*$lnTVP_{it}$*	*$lnTMD_{it}$*
$ShareFem_{it}$	-0.37633*[b]	-0.43407*	-0.38969*
	(0.013814)	(0.014846)	(0.014999)
$MaxAge_{it}$	0.005453*	0.006586*	0.004559*
	(0.000275)	(0.000296)	(0.000299)
Idaho	-0.66196*	-0.64464*	-0.73281*
	(0.021268)	(0.022888)	(0.023124)
New Mexico	0.930606*	0.879457*	0.916625*
	(0.037231)	(0.040042)	(0.040455)
New York	-1.90305*	-1.85873*	-1.90109*
	(0.012679)	(0.013633)	(0.013773)
Texas	-0.7956*	-0.86311*	-0.90988*
	(0.020516)	(0.022062)	(0.02229)
Wisconsin	-1.99198*	-1.90484*	-2.02952*
	(0.011586)	(0.012457)	(0.012586)
2007	0.160456*	0.618178*	0.628392*
	(0.008801)	(0.009474)	(0.009572)
2012	0.238626*	0.872607*	0.791643*
	(0.009355)	(0.010071)	(0.010175)
2017	0.42991*	1.070101*	1.003824*
	(0.010133)	(0.010847)	(0.010959)

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017
Link: (https://quickstats.nass.usda.gov/)
Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.
a. These regressions are for the continuous sample n = 60,123 (Cowsit) and 60,432 (TVPit and TMDit)
b. Coefficients, with standard error in parenthesis.
* p < .01

Table 5.16 Presence of spousal-run commercial dairy size[a]

Independent Variables	Dependent Variables		
	$lnCows_{it}$	*$lnTVP_{it}$*	*$lnTMD_{it}$*
$Spouse_{it}$	-0.20281*[b]	-0.23509*	-0.21349*
	(0.012571)	(0.013115)	(0.013379)
$MaxAge_{it}$	0.008061*	0.009641*	0.007089*
	(0.000485)	(0.000507)	(0.000517)
Idaho	-0.65447*	-0.58586*	-0.69458*
	(0.036245)	(0.037978)	(0.038744)
New Mexico	0.908128*	0.859441*	0.928509*
	(0.063474)	(0.066298)	(0.067635)
New York	-1.99236*	-1.90618*	-1.99344*
	(0.022152)	(0.023168)	(0.023635)
Texas	-0.74341*	-0.76169*	-0.80429*
	(0.036696)	(0.03845)	(0.039225)
Wisconsin	-1.97596*	-1.84251*	-2.0046*
	(0.020096)	(0.021021)	(0.021444)
2017	0.181472*	0.186203*	0.202712*
	(0.012285)	(0.012812)	(0.01307)

Source: National Agricultural Statistics Service, United States Department of Agriculture; Census of Agricultura (COA): 2002, 2007, 2012, and 2017 Link: (https://quickstats.nass.usda.gov/)

Definition: A commercial dairy in a year is defined here as one that has (a) at least 20 milk cows and (b) dairy (2002-2007) revenue or milk (2012-2017) revenue greater than or equal to at least the milk revenue equivalent to what would have been generated by 30 milk cows producing the average milk per cow sold for the average farm price of milk in the state and year. More discussion of this criterion is in the text.

a. These regressions are for the continuous sample n = 23,805 (Cowsit) and 24,045 (TVPit and TMDit)

b. Coefficients, with standard error in parenthesis.

* $p < .01$

Chapter 6: Conclusion

The aim of this thesis is to provide insight and evidence of two important trends within the U.S. dairy industry: 1) farm consolidation and increase in farm size, and 2) shift in gender demographics toward more women dairy farm operators.

The trend of consolidation within the dairy industry is clear and distinct across all states between the years 2002 to 2017. The herd size has increased as the number of commercial dairies tended to fall significantly, although there is variation across states. Furthermore, this research supports the findings of previous research (Wolf and Sumner 2001) that there appears to be little or no evidence of the U.S. dairy size distribution becoming bimodal.

Dairy farming was long a male dominated occupation, but evidence suggests that this is changing. Across the four Census years studies here, there was an increase in the share of commercial dairy farm operators who are female and an increase in the share of commercial dairies with at least one female operator. The largest majority share of female dairy operators is married to a principal operator. Furthermore, with state and year fixed effects, I find that gender representation on the dairy farm has a strong relationship with dairy farm size with the presence of female operators on a dairy farm, and a spousal run dairy, are negatively related to the commercial dairy farm size. This suggests that there may be differences in management decisions of dairies with female operators or spousal run dairies.

Chapter 7: References

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