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Automatic Milking Systems: An Exploratory Study of Wisconsin Dairy Farms



By Luis Peña-Lévano, Shaheer Burney, and Jalyssa Beaudry

Luis Peña-Lévano is an Assistant Professor in the Department of Agricultural Economics at the University of Wisconsin–River Falls and a Dairy Innovation Hub Faculty Affiliate in the Department of Agricultural and Applied Economics at the University of Wisconsin–Madison. Shaheer Burney is an Assistant Professor in the Department of Agricultural Economics and Director of the Survey Research Center at the University of Wisconsin–River Falls. Jalyssa Beaudry is an Undergraduate Research Assistant in the Department of Agricultural Economics at the University of Wisconsin–River Falls.

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Abstract

Automatic milking systems (AMS) are seen as an alternative to manual milking using agricultural labor and have been shown to decrease labor dependence while improving milk yield. This study is based on a survey mailed to 500 randomly selected Wisconsin licensed herds in January 2022. The study shows that although AMS are still in nascent stages, they are already the second most common type of primary milking facility

used by respondents. Our survey also shows important implications for adopting AMS on dairy farms. During the COVID-19 pandemic, AMS dairies opted for reducing herd size to reduce milk production, whereas non-AMS dairies used a combination of smaller herd sizes and less animal feed. AMS farmers also claim price risk is the most significant barrier to grow their business, but non-AMS farmers consider labor recruitment and management as the most crucial adversity. AMS adopters also seem to have a more positive attitude toward the future outlook of the dairy industry relative to non-AMS farms.

INTRODUCTION

Wisconsin is the second largest milk producer in the United States, producing 14% of the U.S. milk output. Although dairy production in Wisconsin has steadily grown in the past decade (Figure 1), total cow head count has remained relatively stable at 1.2 million dairy cows statewide, indicating substantial increases in milk yield per cow. In 2021, Wisconsin's average milk yield was 24,884 pounds per cow and annual production of fluid milk was 31.7 billion pounds (Figure 1), generating an annual revenue of \$45.6 billion (Dairy Farmers of Wisconsin, 2022).

Dairy farms rely heavily on family and hired agricultural labor, which constitutes about 20% to 30% of the daily operational cost (Tranel, 2017). Labor activities include feeding animals, cleaning and maintaining barns, milking cows, and managing manure. On average, a farm with at least fifty cows employs 5.1 full-time equivalent (FTE) workers, a number that has remained relatively constant since 2006 (Charlton and Kostandini, 2021).

Although dairy owners were expected to report positive profits in 2022, driven primarily by inflation-induced increases in milk prices (Liebrand, 2022), the dairy industry is facing supply chain bottlenecks (Luckstead, Nayga, and Snell, 2021) and labor shortages that have been intensified by the COVID-19 pandemic (Peña-Lévano, Burney, and Adams, 2020). Rising inflation has also led to higher feed cost, freight, fertilizer, and fuel, further exacerbating production costs (Liebrand, 2022) and shrinking margins. In addition, dairy enterprises face a high labor turnover ratio, an 11.9% rate during 2008 according to Rosson (2012), further decreasing efficiency in production and feeding. The uptrend in input costs (including a recent rise in domestic wages) may offset the spike in dairy product prices (Kiel, 2021), reducing farmers' profit margin in the upcoming years.

These challenges have adversely affected dairy farms in Wisconsin, a state that is home to 23% of all U.S. dairy farms—95% of which are family owned. Small farms and those unable to cope with this turmoil have either consolidated into larger enterprises or exited the industry. On average, 43 Wisconsin licensed herds have shut down every month in the period 2012–2022 (Figure 1), a 46% decline in the past 10 years, leaving only 6,275 dairy farms still in business as of September 2022 (USDA NASS, 2023).

In an effort to overcome the limited availability of domestic and foreign farm workers, dairies are opting to adopt labor-saving technologies such as automatic milking systems (AMS), also known as milking robots, which are able to milk 60–70 cows per day (Salfer and Minegishi, 2018). AMS offer a potential solution to the need for manual labor in the milking process and enhance operations by permitting farmers to devote more time to farm management (Tranel, 2017). Although the literature on AMS is sparse since it is a relatively new technology, some studies have quantified the economic benefits of AMS. For example, Tse et al. (2018) conducted a survey that showed that small-scale farmers experienced a 20% reduction in the number of workers after adopting AMS, in addition to higher milk yields and improved animal health. Not surprisingly, the most important reason farmers adopt AMS is the potential labor savings (Lage et al., 2021). Salfer et al. (2017) simulated the profitability differences between AMS and traditional parlor-style milking methods and showed that 120- and 240-cow dairies are more profitable with AMS. Duplessis et al. (2021) provide evidence from Canadian producers that AMS may lead to better milk yields. In their study, about 34% of producers reported having higher milk yields after transitioning to AMS and only 18% experienced a decline. Finally, Malacco (2022) discusses how AMS

can generate a wealth of valuable data on cow health, welfare, animal behavior, and nutrition that can assist farmers in management.

However, AMS also require large up-front investments, estimated to be \$150,000 to \$275,000 per robot, not accounting for maintenance cost and infrastructure needed to adapt the barn to this technology (Salfer et al., 2019). This up-front cost is a significant barrier to adoption for small- and medium-sized dairies. Thus, it is not immediately clear whether adopting AMS may lead to positive returns (Charlton and Kostandini, 2021; Salfer et al., 2019).

In light of this need, this study is the first to explore whether implementing AMS may improve farmers' perception of the dairy industry's future outlook and alleviate some of the challenges of managing a dairy operation. Specifically, this case study focuses on the differences in perceptions between AMS vs. non-AMS dairies in the state of Wisconsin. Our findings are based on an exploratory survey conducted in spring 2022. Results shed light on differences in farmers' background and dairy operations, barriers to expansion, risk aversion, perception on future challenges for the industry, and changes in management practices and production due to the pandemic.

SURVEY IMPLEMENTATION

The exploratory survey was mailed to 500 randomly selected Wisconsin dairy farmers in January 2022. The contact information for survey recipients was obtained from the Wisconsin Department of Agriculture, Trade, and Consumer Protection's (DATCP) repository of licensed milk producer profiles. Data collection was conducted by the Survey Research Center (SRC) at the University of Wisconsin–River Falls over an eight-week period, with two reminders sent to non-respondents. Specifically, using Dillman's (1978) Total Design Method, the SRC sent one postcard reminder three weeks after the initial survey mailing and a second copy of the survey three weeks after the postcard reminder. Based on historical experience of the SRC and literature on survey methodology (e.g., Hoddinott and Bass, 1986), this method has been proven to boost response rates in a cost-effective way. A total of 183 responses were received, a robust response rate of 37%, which shows some evidence of the interest of dairy farmers in learning about robotic adoption. After data cleaning and dropping incomplete responses, a sample size of 172 licensed herds was used for this study.

AMS ADOPTION

Overall, three-quarters of survey respondents indicate their dairy operations were established more than 30 years ago. Over half of the dairy facilities are primarily stall barns with pipelines (54%), followed by parabone/swing (11%) and herringbone (10%) pit parlors (Figure 2). Stanchion/stall barns have continued to be the most common barn type in the past decade, when compared to the results of the USDA (2010) survey report.

The use of robotic milking units is still in its infancy stages (Charlton and Kostandini, 2021), but adoption is increasing at a steady pace. AMS dairies comprised about one-fifth of the overall sample (i.e., 34 responses). DeLaval and Lely are the two leading brands, encompassing 67% of robotic milking systems in the state (Figure 2). DeLaval's major technology is the Voluntary Milking System, including the VMS V300 and V310 series (DeLaval, 2022), a robotic arm that includes four milk-meters that attach to each teat and collect data on milk flow and yield. Lely's most recent robot is the Astronaut (A5) series (Lely, 2022), which is a hybrid arm with a 3D camera that detects the cow's position within the box and a three-laser system used to correctly attach the arm to each teat. New technologies created by GEA and BouMatic are also emerging. Particularly, GEA specializes in automatic rotary parlors, called the DairyRotor T800 series (GEA, 2022), whereas BouMatic focuses on simultaneous milking systems, such as the Gemini series (BouMatic, 2022), which allows two cows to be milked concurrently.

DIFFERENCES IN DAIRY FARM OPERATIONS

Survey results show that herd size correlates with land ownership, when contrasting AMS vs. non-AMS adopters. Greater than 90% of AMS dairies possess more than 100 acres of land compared to 74% of non-AMS farms. This may allow AMS farms to obtain large sources of financing by offering a significant amount of land as collateral. Similarly, two-thirds of AMS operations expressed the need for renting an additional 100–1,000 acres (Figure 3), as most AMS adopters are midsized farms (100–250 cows, 38%) and large farms (more than 250 cows, 24%).

Notably, most dairies milk cows an average of two times a day, regardless of the milking process, contrary to the previous research stating that cows are milked more frequently by robots. This will be explored further in a subsequent survey with smaller intervals (by 0.1

times a day), to investigate if rounding up or down may be influencing the results. Nevertheless, milk yield per cow was higher under AMS, with over half of these operations (56%) producing more than 76 pounds per day, whereas only 43% of non-AMS farms yielded over 76 pounds per cow per day. This fact, along with the result that AMS dairies do not milk cows more frequently than non-AMS dairies, suggests that the use of robots in the milking process may improve efficiency as the accessibility to the robot is tailored to the cow's specific needs.

FARMERS' CHARACTERISTICS AND PERCEPTIONS

Survey results show that young farmers (age 18–34) and experienced farmers (over age 65) are more inclined to adopt AMS relative to middle-aged farmers. This may be because young farmers may be more amenable to technology adoption and older farmers generally own and manage larger farms with more capital access to invest in robotics, relative to middle-aged farmers. Interestingly, higher education does not necessarily translate to higher likelihood of AMS adoption. Relative to non-AMS farmers, a greater percentage of AMS farmers (38%) have an associate or technical degree but a smaller portion (9%) have a bachelor's or graduate degree.

Survey responses also suggest that AMS may reduce time spent on farm management (Figure 4), as a greater proportion of AMS dairies (26%) have off-farm employment when compared to non-AMS farmers (18%). Notwithstanding, about 41% of AMS owners/operators expressed having more difficulty training farm workers (Figure 4). This is likely because additional instructions are needed to operate robotic milking. Once workers have learned how to use this technology, time devoted for supervision is about the same as that for traditional facilities.

PANDEMIC CONDITIONS

The COVID-19 pandemic induced many operations to change their management practices, particularly during stay-at-home regulations. Most Wisconsin dairy operations (more than 90%) did not have to dump their milk output due to low sales (which was not the case for other states). However, about 23% of non-AMS and 18% of AMS farmers reported a decrease in milk production at the onset of the pandemic. Although non-AMS farms reduced both herd size (39%) and animal feed (35%), AMS dairies focused mostly (66%) on lowering the herd size (Figure 5). However, as noted earlier, despite the decline in production by

many dairies and the closure of 343 licensed herds in one year (January to December 2020), Wisconsin production remained relatively stable in 2020 at about 30.7 billion pounds compared to the previous two years (Figure 1).

Figure 6 shows that non-AMS farmers were more inclined to raise hourly wages of agricultural workers over the previous year. About 15% of both groups increased wages by \$3 to \$4 per hour. However, about 5% of non-AMS operations raised hourly rates by \$5 to \$6 per hour, whereas only one AMS adopter raised wages by \$5 or more. This fact may be correlated to a higher need for farm labor of non-AMS dairies.

PERCEPTION OF THE DAIRY INDUSTRY'S FUTURE OUTLOOK

About one-quarter of AMS operators reported investing a value equivalent to over 25% of their herd size, and most (65%) of them felt that they made the right decision. This expansion may be linked to additional infrastructure needed to accommodate the milking robot systems in their barns. Thus, only 18% of surveyed AMS operations said they would be likely to make equivalent growth in the next five years. In contrast, around one-fifth of non-AMS dairies made an investment of over 25% of their enterprise value. Nevertheless, non-AMS farmers did express concerns about their decision, as 24% said they would not have made this investment under similar circumstances and 87% stated they are unlikely to expand operations in the medium-term.

Dairy farmers were also asked their opinion regarding the most significant barriers limiting the expansion of operations. From eight possible challenges, four were the most prominent for all farmers (shown in Figure 7): environmental regulations, price risk, recruitment and management of labor, and lack of access to capital (e.g., loans). AMS dairies emphasized price risk (37%) as the most important barrier to grow the business, with significant difference when compared to non-AMS adopters who consider labor recruitment (22%) as a more significant barrier. In addition, environmental regulations are an impending concern for 17% of AMS dairies but only for 7% of their counterparts.

Finally, respondents were asked to evaluate their perception of risk of 15 factors that may have an impact on dairy farms in the next five years. Figure 8 lists nine of these factors, which were selected because most respondents had a strong opinion on the risk level for that factor (i.e., high or low risk). Although both AMS and non-AMS adopters show similar general

attitudes toward each factor, about half of non-AMS farmers reveal a higher risk aversion to environmental and policy regulations, cost of raw materials, labor availability (consistent with their perception of barriers to expansion), milk production and yield, and shipping cost (i.e., national and international freight rates). In contrast, 50% to 60% of AMS operators have expressed lower concerns for water availability, impact of extreme weather events, and consolidation of farms into larger units. Thus, Figure 8 shows that AMS dairies may have a more positive perception regarding the outlook of dairy farms in the next five years.

CONCLUSIONS AND FINAL REMARKS

In recent years, dairy farmers have experienced labor shortages and an increase in animal feed and freight cost, contributing to a decline in the number of milking operations in Wisconsin. In the past decade, 46% of Wisconsin licensed herds have shut down, leaving only 6,275 farms (Figure 1). Driven by tight agricultural labor market conditions, dairy operations are increasingly adopting AMS, which are also perceived to improve yield per cow. In light of these facts, this study is a first attempt to explore whether AMS can improve farmers' attitudes toward the future outlook of the Wisconsin dairy sector, understand changes of management practices during the COVID-19 pandemic, and learn the differences in farm and operator characteristics between AMS and non-AMS dairies.

Dairy farmers have expressed interest in learning about robotic adoption, evidenced by high response rate (37%) of our exploratory survey, which was mailed to 500 randomly selected Wisconsin licensed herds in January 2022. This study shows that although AMS are still in nascent stages, they are the second most common type of milking facility used by respondents (Figure 2), characterized by four major AMS manufacturers. Not surprisingly, larger farms are more likely to implement AMS (Figure 3), due to better access to capital. Moreover, although AMS managers devote more time in training workers relative to non-AMS managers (Figure 4), AMS may reduce the time owners or family members spend on farm operations. During the COVID-19 pandemic, both types of dairy farms (AMS and non-AMS) decreased their milk production. Although AMS dairies opted for reducing herd size, non-AMS dairies used a combination of smaller herd sizes and less animal feed (Figure 5). In terms of investment barriers, AMS respondents claimed price risk to be the most significant barrier to growth, whereas non-AMS farmers considered labor recruitment and management as the most significant

barrier (Figure 7). Interestingly, when asked for their perception of risk factors that may cause future challenges to the dairy sector, AMS adopters reported more positive responses (i.e., stating lower risk levels) than non-AMS operators (Figure 8).

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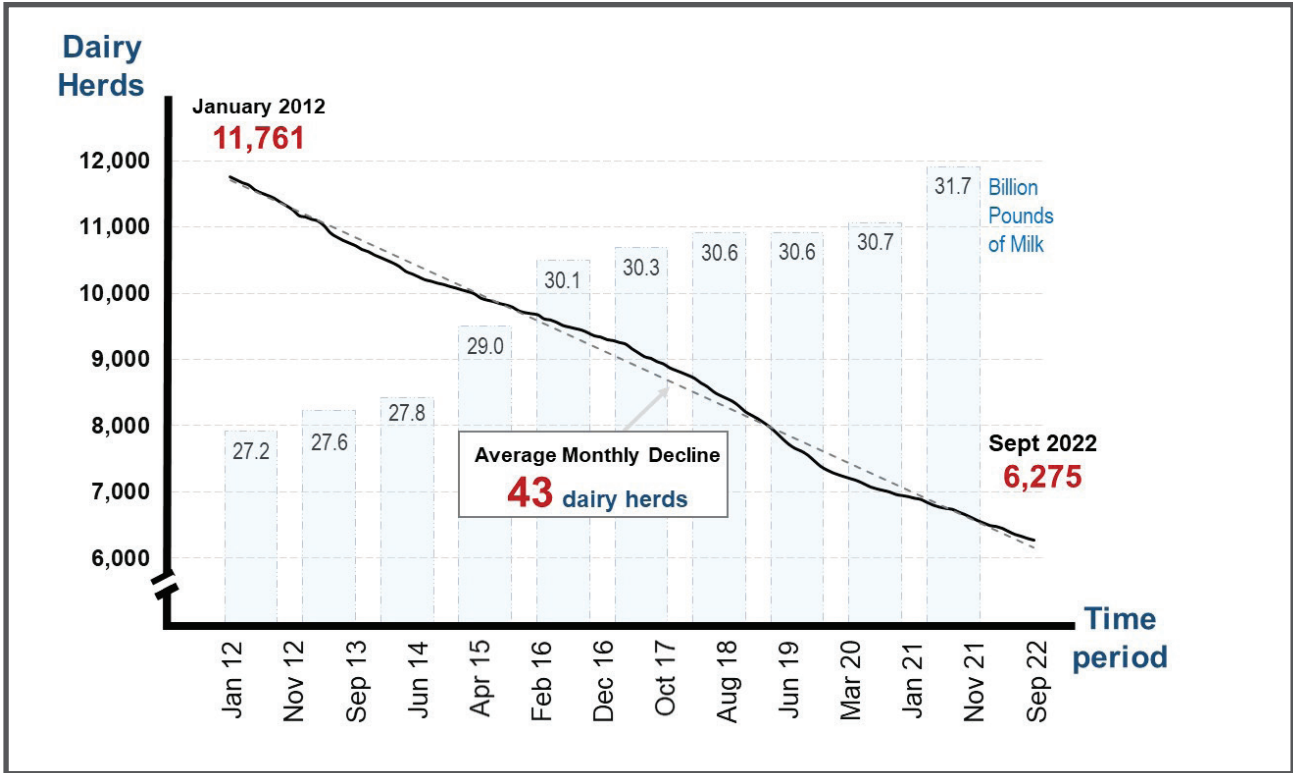


Figure 1. Number of dairy herds, Wisconsin, 2012–2022. (Source: Original calculations using data from USDA NASS, 2022.)

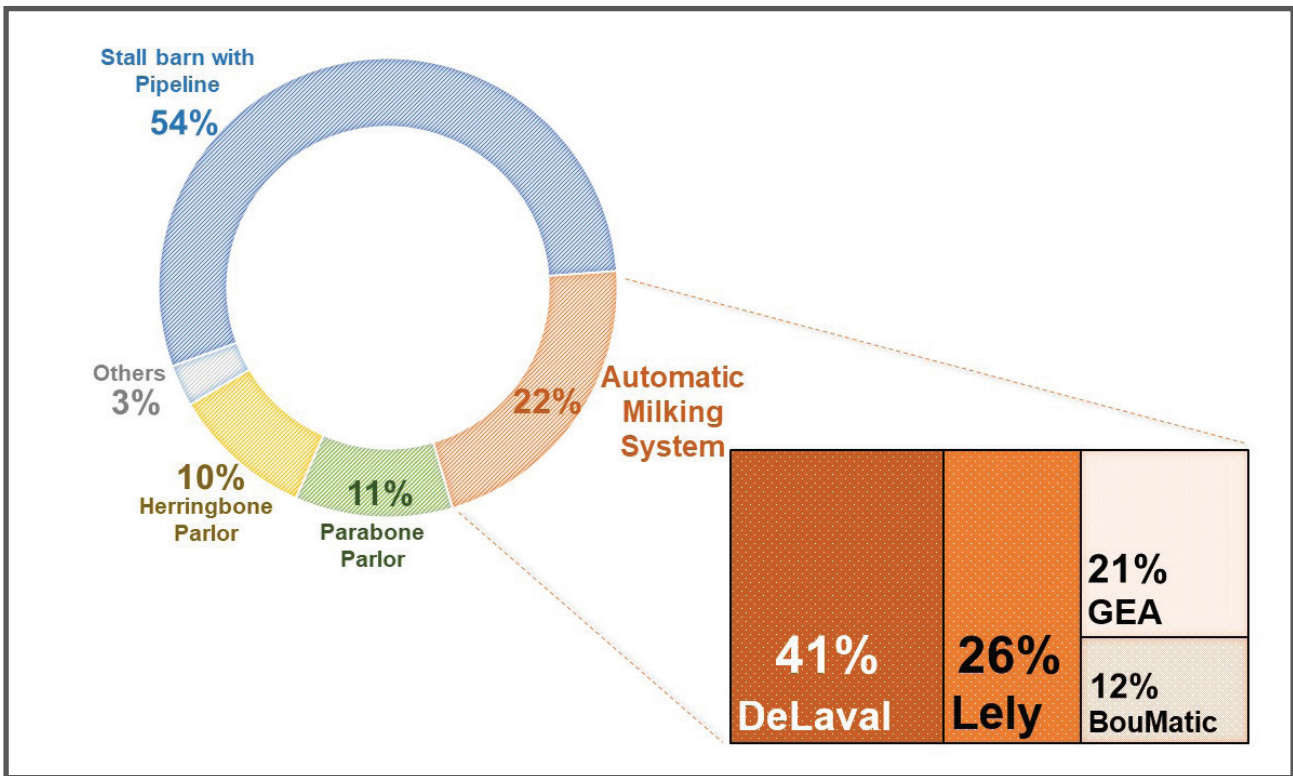


Figure 2. Type of milking systems used in Wisconsin dairy farms, 2022. (Source: Original calculations.)

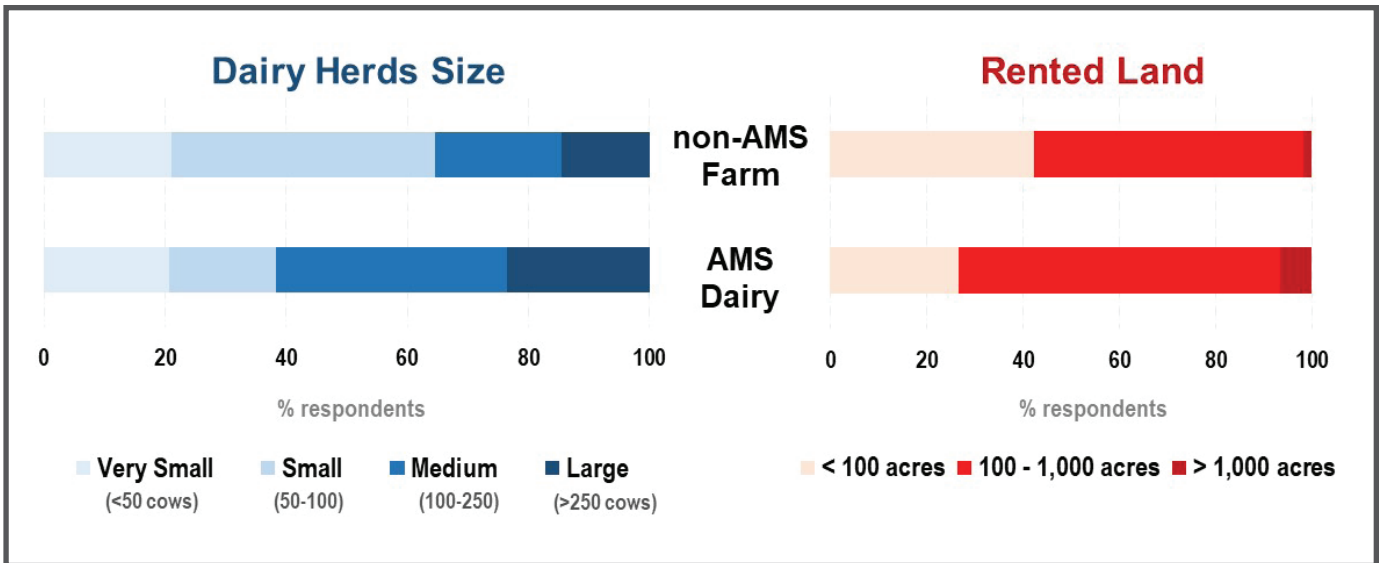


Figure 3. Dairy herd size and amount of land rented by technology type in Wisconsin dairy farms, 2022. (Source: Original calculations.)

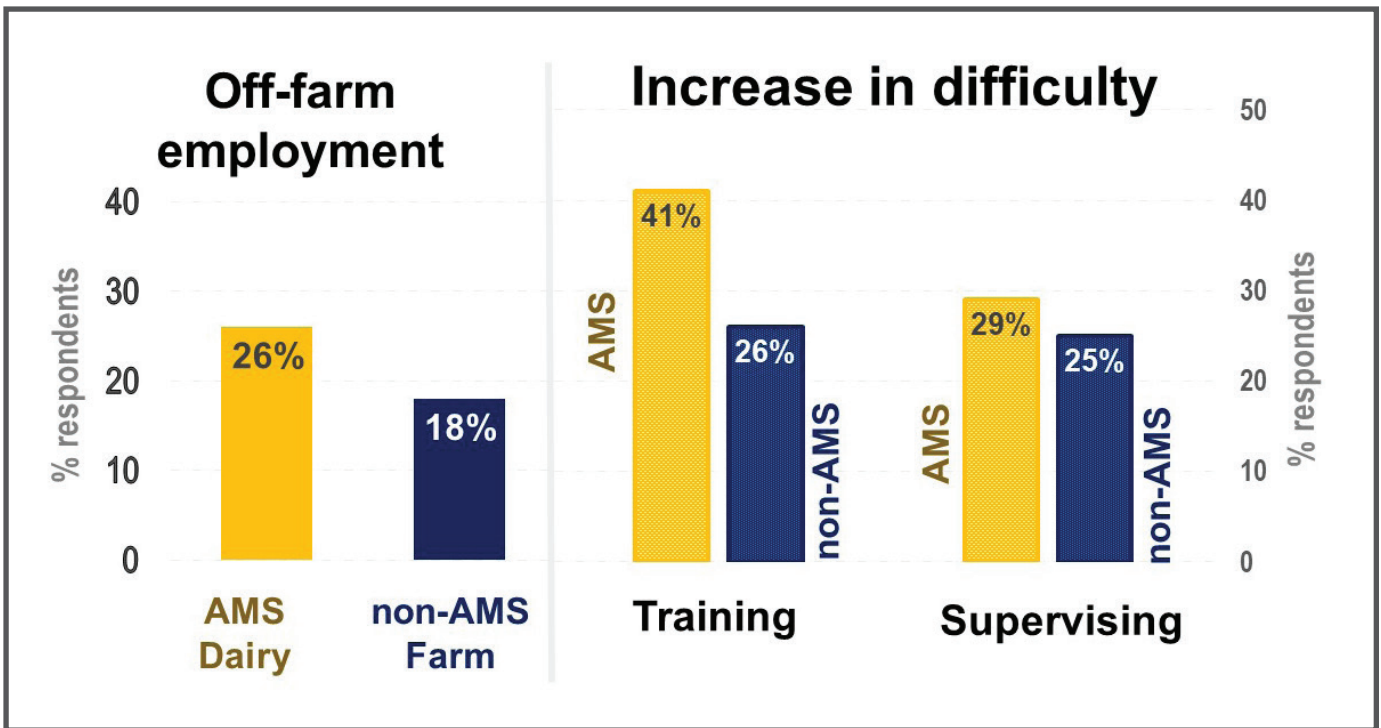


Figure 4. Off-farm employment and increase in training and supervising difficulty. (Source: Original calculations.)

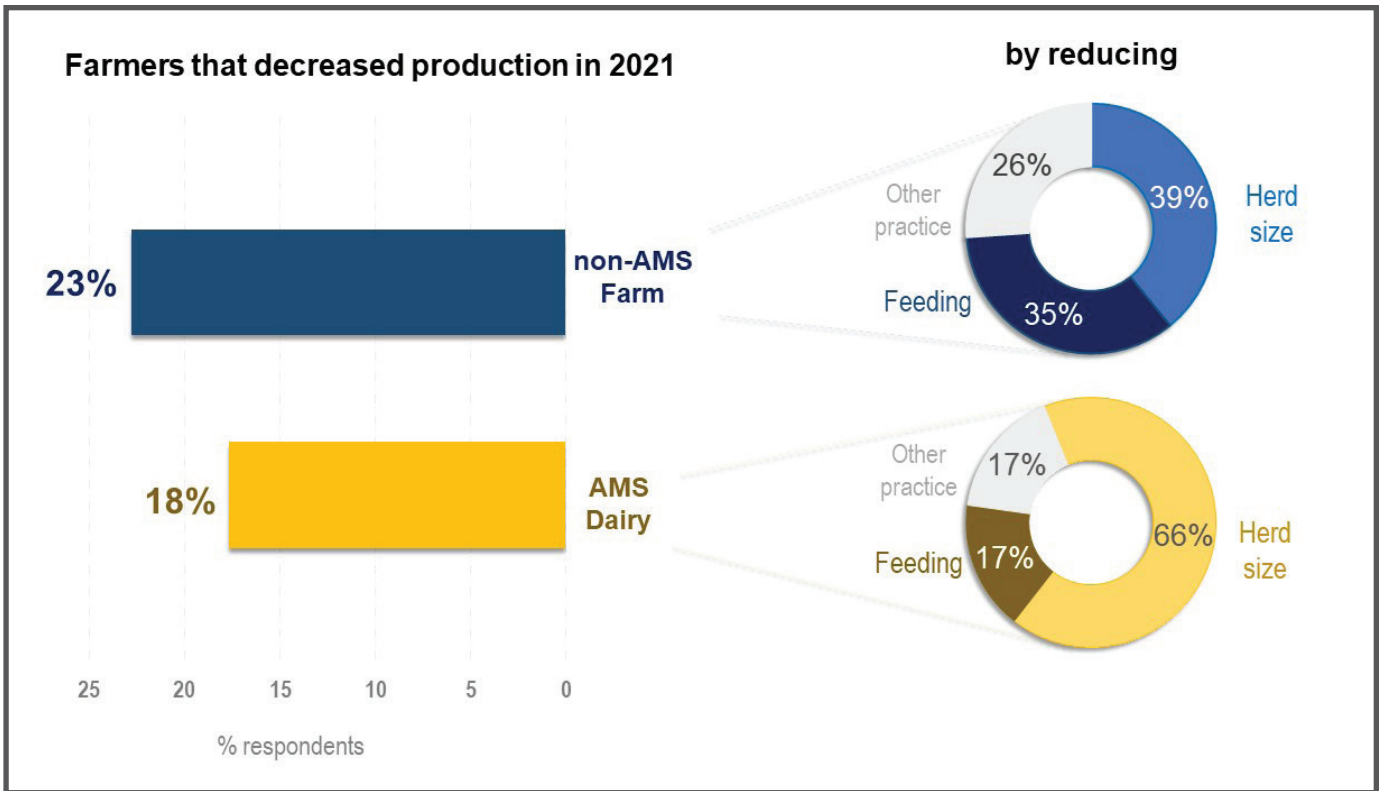


Figure 5. Fraction of farmers that reduced production in 2021 (left) and the methods used to achieve this reduction (right). (Source: Original calculations.)

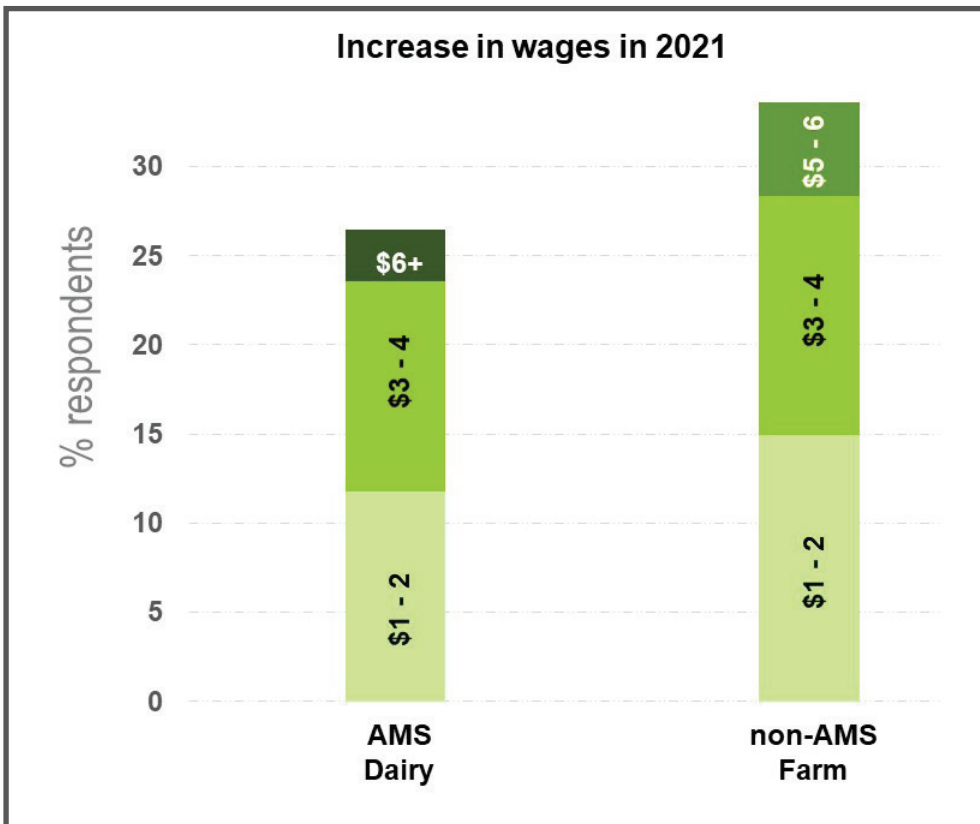


Figure 6. Increase in nominal wages in 2021 (in USD). (Source: Original calculations.)

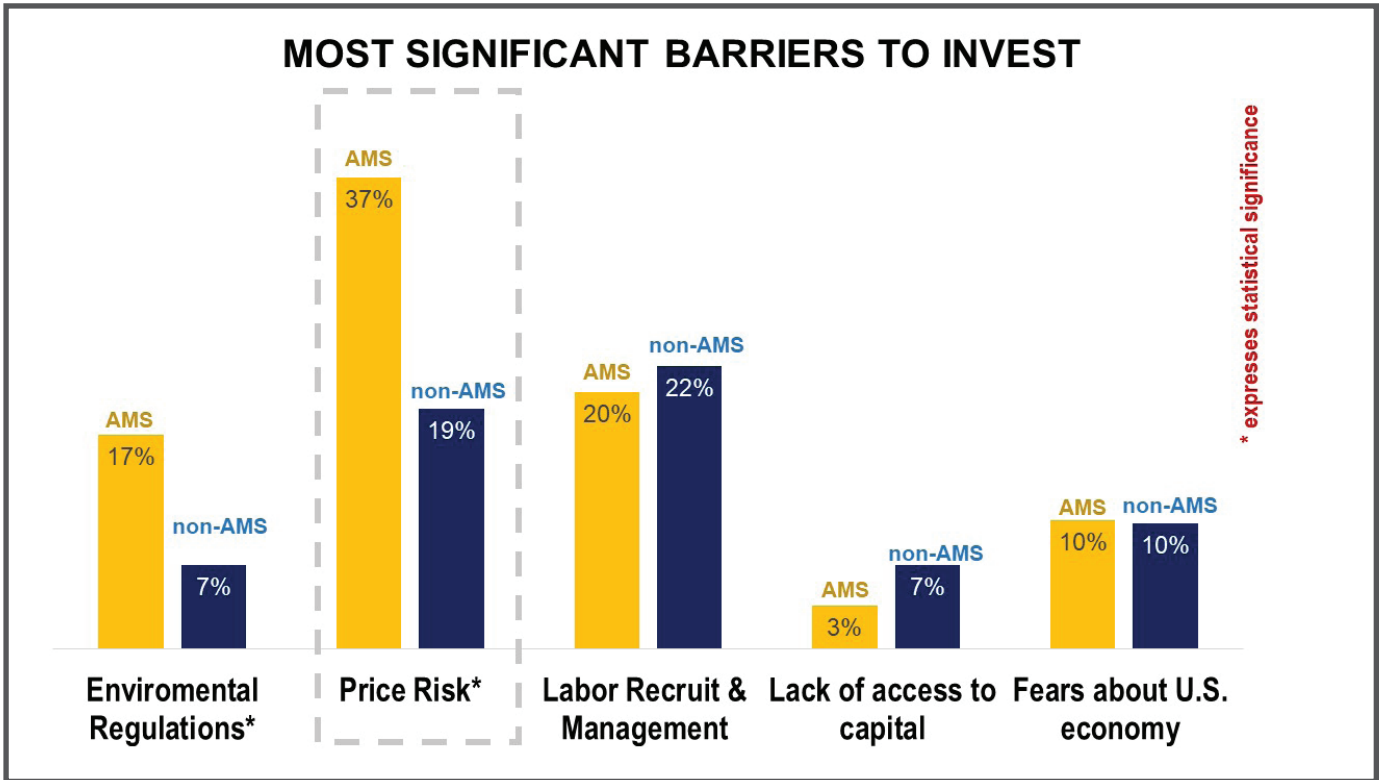


Figure 7. Most significant barriers to invest as reported by farmers (in % of respondents). (Source: Original calculations.)

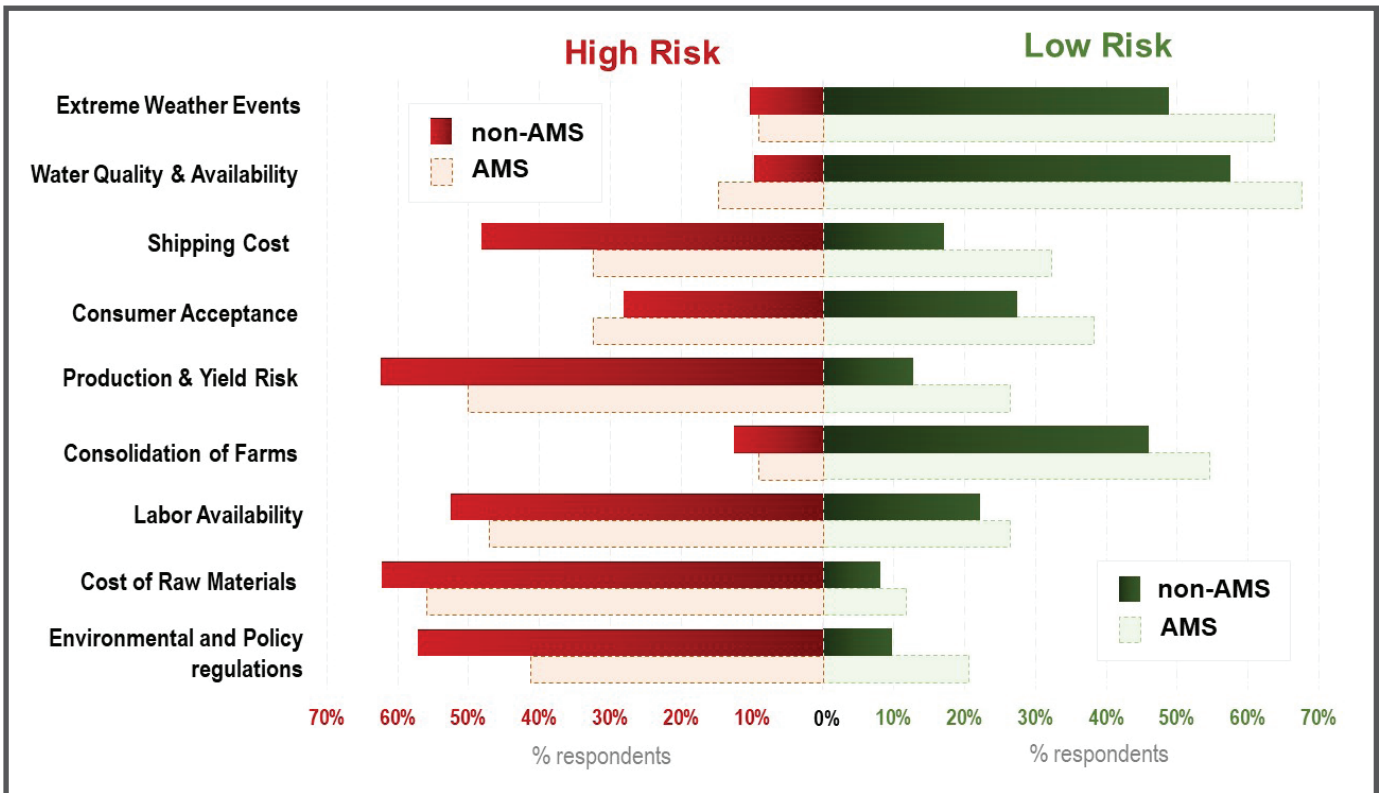


Figure 8. Risk perception of each factor on dairy's future outlook. (Source: Original calculations.)