Computerized Technology Adoption Among Farms in the U.S. Dairy Industry

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Abstract

This article examines the rate of adoption of four computerized technologies in U.S. dairy production: an on-farm computer to manage dairy records, accessing the internet for dairy information, computerized milking systems and computerized feed delivery systems. Data from the USDA-Agricultural Resource Management Survey were used for the analysis. Computers for managing records were used by most farmers, but adoption rates for the remaining technologies were much lower. Adoption rates differed by demographics, financial status, farm size and adoption of other technologies. Farm profitability differed by adoption status.

Introduction

Agricultural scientists have long recognized the accruing benefits to farmers from adopting technology. Early adopters have been the primary beneficiaries of investment in technology, capturing rents associated with adopting before output prices adjust downward in reaction to lower production costs. Today's U.S. dairy industry is characterized by the presence of a number of technologies that have been adopted by only a portion of farmers, leading researchers, extension personnel, industry stakeholders and government to have interest in the types of producers most likely to adopt. This paper examines the adoption rates and types of dairy farms adopting four computer-based technologies used in U.S. dairy production during 2005. The four computer-based technologies include: (1) an on-farm computer to manage dairy records; (2) accessing the internet for dairy information; (3) computerized milking systems; and (4) computerized feed delivery systems. The profitability and use of complementary technologies associated with farms using these technologies are also determined.

Since 1990, the number of milk cows in the U.S. has decreased on average one percent per year, while milk output per cow has increased on average two percent per year (Figure 1). An important driver in this increased cow productivity is the adoption of various technologies including but not limited to those that are computer-based. According to Shook, considerable gains of 3,500 kg of milk, 130 kg of fat and 100 kg of protein per cow per lactation result from genetic improvements, nutrition and management during the past 20 years, although the gains are not uniform across breeds. According to Christensen and Fehr, computer technology for farm use began to be developed in the 1970s and 80s. This technology has continued to become more highly sophisticated. The following discussion deals specifically with the four computer-based technologies that are the focus of this study.

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Use of Computers for Record-keeping and the Internet for Information

A number of studies have examined computer adoption by U.S. farmers (Putler and Zilberman; Jarvis; Iddings and Apps; Amponsah; Hoag, Ascough and Frasier; Gloy and Akridge). Most have found farm size and demographics to influence computer adoption. Though we have identified no previous studies explicitly linking computer or internet use with higher profit, Mishra, El-Osta and Johnson showed that formal record-keeping systems were associated with higher farm profits. This is as expected since computer adoption requires a relatively small fixed initial investment and the benefits of better record-keeping are likely to be significant (Grisham). Computerized record-keeping systems improve the timeliness and accuracy of decision-making (Jofre-Giraudo, Streeter and Lazarus).

There has been limited analysis of the nature and extent of internet use among farmers. Hall et al. found that approximately 40 percent of leading Southeastern beef and peanut farmers searched the Internet for information concerning the farm business. Mishra and Park examined Internet use for nine different farm activities. They found that farm diversification, size and location, farmer educational level and use of marketing contracts were correlated with Internet use. Grisham and Gillespie found Internet experience among Louisiana dairy farmers to be positively influenced by farm size, a family successor expected to take over the operation upon the farmer's retirement, off-farm income and previous technology adoption. Approximately 52 percent of the farmers in Grisham's study had Internet experience. Briggeman and Whitacre found that farmers who used the Internet to purchase inputs had more education and were younger. The more educated non-adopters had concerns primarily about internet security.

Computerized Milking Systems

The introduction of computerized milking systems has sparked much debate as to the advantages and disadvantages of implementing automated systems. This technology offers a wide range of options for complex systems, e.g., fully automated robotic systems to simpler systems, such as computerized data acquisition from the milker. The Automatic Milking System (AMS), or robotic system, offers a more flexible method for milking cows compared to the labor-intensive schedule required by conventional milking (Reinemann and Smith).

Robotic AMS was originally developed in the 1980s for small family farms where a constant supply of labor had been problematic, as other industries with higher wages bid away labor from the dairy industry. The first system was installed on a commercial farm in the early 1990s. According to Rotz, Coiner and Soder, a robotic AMS is competitive with traditional milking when the farm is milking 50 to 120 cows and the herd size is appropriately matched to the capacity of the milking system. Once above this 120 cow threshold, a traditional milking system (non-AMS) is more labor efficient.

Larger U.S. dairy farms, however, have implemented robotic technologies. With the use of AMS, dairy farmers have another way to handle decreasing milk quality in late lactation. Robotic AMS allows cows to be milked voluntarily, which allows for the possibility that a cow in this phase could be milked three or more times a day, possibly improving milk quality to the point where it can be used in cheese making. Another benefit of a robotic AMS is that milk production increases as compared to traditional milking (Wagner-Storch and Palmer). AMS systems have the flexibility to be implemented not only into confined systems, but also to pasture based dairy systems. In pasture based systems, however, the daily routine of the cow cannot be controlled as well, so that must be factored into the management of AMS (Devir et al.).

To implement an AMS, several additional decisions must be made by the operator. First, according to Rotz, Coiner and Soder, the initial investment for a robotic AMS can be as much as two to three times that of a traditional parlor system. This is why many dairymen decide to implement a less complicated system that includes only a computerized system that tracks milk production. Second, milk quality can be altered because there is an inverse relationship between number of milkings per day and the milk fat concentration (Klungel, Slaghuis and Hogevenn). Third, there are increased maintenance requirements compared to a traditional system, requiring a skilled operator to handle daily maintenance (Svennersten-Sjaunja and Petterson). Fourth, there is an increased potential for mastitis pathogens to be transferred throughout the herd since one AMS may be responsible for milking 50-60 cows (Klungel, Slaghuis and Hogevenn). Additionally, the operator must decide on the most efficient way to entice cows to enter the voluntary milking system. With robotic AMS, unlike conventional dairies, self-feeders are an essential technology (Devir et al.; Devir, Maltz and Metz; Spahr and Maltz; Ketelaar-De Lauwere et al.; Halachmi, 2000, 2004).

Computerized Feed Delivery Systems

A computerized feed delivery system (CFDS) allows each dairy cow or group of cows to receive a specific ration depending upon lactation phase. The CFDS can be implemented in several configurations and in conjunction with or without an AMS. For example, self-feeders can be located in the robotic milking stall or can be accessed only after the cow has been milked (Halachmi, 2004). Self-feeders are typically used to supplement the ration with additional grain or, in the case of robotic AMS, to entice dairy cows to enter the milking stall.

The CFDS can also be implemented on dairy farms that feed a Total Mixed Ration (TMR). The primary feeding method used by U.S. dairy farmers includes a TMR that meets the dairy cow's complete nutritional needs (Schroeder and Park). Many TMRs are developed using computerized scales that mix the grain, forages and other supplements in the proper ratios depending on the cow's lactation phase.

Data and Methods

The dairy-specific version of the 2005 Agricultural Resource Management Survey (ARMS), conducted by USDA's National Agricultural Statistics Service and Economic Research Service, obtained from 1,816 dairy farmers not only the costs, returns and general farm data collected of all farms in the Phase III portion of the survey, but also data that pertained specifically to the dairy enterprise. As part of the survey, the following questions were asked about 2005 production: "Did this operation use an onfarm computer to manage dairy records?" "Did this operation access the internet for dairy information?" "Was the milking system(s) computerized in order to automatically gather data about each milking?" Finally, "Did this operation use a computerized feed delivery system?" Answers to each of the questions were either "Yes" or "No." These results enable estimates of the proportion of adopters in the U.S. dairy farm population to be made because the ARMS contains a weight for each farm observation that allows for the expansion of the results to the U.S. farm population.

In addition to being interested in the proportion of farmers adopting each computerized technology, we are interested in selected characteristics of the adopting farmers. Characteristics of interest include demographics such as the farmer's age and whether the farmer holds a college degree; financial characteristics of the farm business, such as the debt-asset ratio and the percent of the farm's income derived from milk; dairy enterprise profitability such as enterprise net returns over total costs per hundredweight of milk produced; enterprise net returns over operating costs per hundredweight of milk produced; and whole-farm profitability measured as net farm income per hundredweight of milk produced. Milk produced per cow is another productivity measure of interest. Finally, we are interested in whether there is complementarity associated with adoption among the four technologies of interest; i.e., are adopters of one computerized technology also the likely adopters of other computerized technologies?

Significant differences between adopters and non-adopters are determined based upon pairwise two-tailed delete-a-group Jackknife t-statistics at the 90 percent level or higher, with 15 replicates and 28 degrees of freedom. Use of the delete-a-group Jackknife estimation procedure is preferred to conventional methods due to the design-based nature of the ARMS survey (Dubman).

Results

Table 1 presents information on adopters and non-adopters of computerized technology in dairy production. Results suggest that approximately 25.9 percent of dairy farmers used a computer for record-keeping, but this represented 61.5 percent of the cows and 66.1 percent of the milk produced. Approximately 38 percent of dairy farmers accessed the internet for dairy information, but this represented 60.7 percent of the cows and 63.6 percent of the milk produced. Approximately 5.3 percent of dairy farmers used a computerized milking system, but this represented 20.3 percent of the cows and 22.8 percent of the milk produced. Finally, approximately 7.1 percent of dairy farmers used a computerized feeding system, but this represented 25.1 percent of the cows and 28.2 percent of the milk produced. Clearly, the larger-scale farms were those utilizing each of the computerized technologies, as further shown by the number of cows per farm and the number of acres on the farms. Adopters of computers for record-keeping, the Internet for accessing information, computerized milking systems and computerized feeding systems milked 4.57, 2.50, 4.57 and 4.38 times more cows on average, respectively, than non-adopters. Total farm acreage was also greater for the adopters.

Farmer demographics differed between adopters and non-adopters. While farmer age was not found to differ, adopters were more likely than non-adopters to hold a college degree for all technologies except for the computerized milking system. Adopters were more likely to work fewer hours off the farm for all technologies except for the use of a computer for record-keeping. Percent of farm income derived from milk did not differ by adoption status for any of the technologies.

Financial situation and profitability differed by adoption status. Adopters of all four technologies were found to hold greater debt relative to assets, and were thus more highly leveraged, a result that would be expected especially for more costly systems such as a computerized feeding system or computerized milking system, but also since the adopters were of larger-scale. Adopters were more profitable than non-adopters for at least one profitability measure for all four technologies. For all four technologies, the enterprise net return over total costs per hundredweight of milk produced was higher for adopters than non-adopters. This profitability measure includes opportunity costs for land and operator labor. In the case of the computerized milking system, adopters held greater enterprise net returns over operating costs per hundredweight of milk produced, though differences were not found using this measure for the other three technologies. When whole-farm net farm income was compared for adopters versus non-adopters, adopters of a computer for record-keeping and a computerized feeding system were found to have higher profit. Another measure of productivity is milk produced per cow. For all four technologies, adopters had greater milk produced per cow than did non-adopters.

In examining adoption rates for each of the four computerized technologies, it was of interest to determine whether there was complementarity in adoption of the other three computerized technologies. In all four cases, complementarity was found. For instance, of the non-adopters of a computer for record-keeping, three percent had adopted a computerized feeding system, while of the adopters of a computer for record-keeping, nineteen percent had adopted a computerized feeding system. Similarly significant differences were found in all combinations of computerized technology, providing evidence that the technologies are complementary, or at least that adopters of one innovation are more likely to also adopt another innovation.

Conclusions

In cases where new technological innovations have been developed and made available to farmers and adoption has begun to occur, it is of interest to farm managers to understand the extent of adoption, the relative profitabilities of adopters and non-adopters and the types of farmers that have decided they would benefit from adopting the technologies. Results of this study provide insight into each of these issues regarding computerized technology adoption in U.S. milk production.

On an individual technology basis, the majority of U.S. dairy farmers had not adopted one or more of the four identified computerized technological innovations. However, the percentage of milk being produced under these innovations is relatively higher since the larger farms are the adopters of each. Furthermore, adopters were more likely to hold college degrees, to be more highly leveraged and to work fewer hours in off-farm jobs, suggesting they faced relatively higher risk, not considering any risk-altering effects that might be associated with the innovations. Adopters of all four computerized technologies realized greater profit using at least one of the three profitability measures considered. Finally, it was found that adopters of one computerized innovation were also more likely to be among adopters of other computerized innovations, a result which was expected.

While our results show adopters of computerized technologies in milk production to have realized greater profit than non-adopters, cause-and-effect cannot be established, as it is possible that there is self-selection bias. In the case of self-selection bias, this suggests that the adopters are the better managers and would have been more profitable even if they had not adopted these technologies. This calls for further research that would examine adoption in a multivariate framework and treat for self-selection bias. What the results do suggest, however, is that the more profitable farms are the adopters of these innovations.

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Table 1. Comparisons of adopters versus non-adopters of computerized technology in United States milk production

Variable of Interest	Unit	Non-adopters	Adopters
----------Use of Computer for Record-keeping----------			
Age	Years	51.57	50.21
College Degree*	0 – 1	0.11	0.30
Acres*	No.	340.49	600.20
Debt-asset Ratio*	Ratio	0.13	0.21
Operator's Off-farm Work	Hr/Yr	131.40	117.51
Percent of Farm Income from Milk	%	86.47	89.25
Enterprise Net Return / Total Costs per cwt Milk*	$/cwt	-11.59	-4.08
Enterprise Net Return / Oper Costs per cwt Milk	$/cwt	4.92	5.06
Net Farm Income per cwt Milk*	$/cwt	5.19	3.61
Milk Produced per Cow*	cwt	158.97	197.44
Number of Cows*	No.	79.96	365.48
Percent of Cows	%	38.50	61.50
Percent of Milk Produced	%	33.90	66.10
Number of Farms	No.	38,698	13,539
Portion Adopting Computerized Feeding System*	Portion	0.03	0.19
Portion Adopting Computerized Milking System*	Portion	0.02	0.15
Portion Using the Internet for Dairy Information*	Portion	0.24	0.80
----------Internet Use----------			
Age	Years	51.92	50.08
College Degree*	0 – 1	0.09	0.28
Acres*	No.	345.90	507.96
Debt-asset Ratio*	Ratio	0.12	0.19
Operator's Off-farm Work*	Hr/Yr	132.73	119.82
Percent of Farm Income from Milk	%	87.37	86.91
Enterprise Net Return / Total Costs per cwt Milk*	$/cwt	-11.35	-6.88
Enterprise Net Return / Oper Costs per cwt Milk	$/cwt	4.71	5.36
Net Farm Income per cwt Milk	$/cwt	4.86	4.64
Milk Produced per Cow*	cwt	162.39	179.54
Number of Cows*	No.	97.87	244.71
Percent of Cows	%	39.3	60.7
Percent of Milk Produced	%	36.4	63.6
Number of Farms	No.	32,283	19,953
Portion Adopting Computerized Feeding System*	Portion	0.05	0.11
Portion Adopting Computerized Milking System*	Portion	0.03	0.08
Portion Adopting a Computer for Record-Keeping*	Portion	0.08	0.54

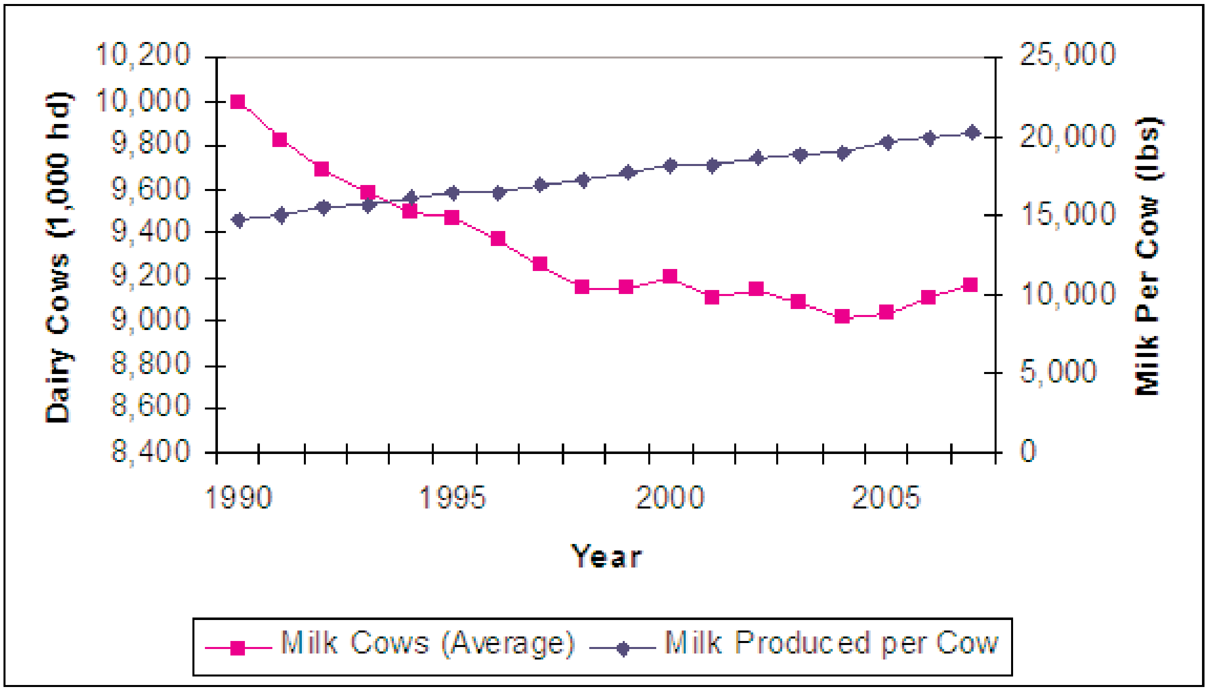
* indicates significant differences based on pairwise-two-tailed delete-a-group Jackknife t-statistics at the 10% level.

Table 1 (continued). Comparisons of adopters versus non-adopters of computerized technology in United States milk production

Variable of Interest	Unit	Non-adopters	Adopters
-----Computerized Milking System-----			
Age	Years	51.15	52.36
College Degree	0 – 1	0.16	0.19
Acres*	No.	385.78	803.23
Debt-asset Ratio*	Ratio	0.14	0.22
Operator's Off-farm Work*	Hr/Yr	132.90	36.12
Percent of Farm Income from Milk	%	87.20	87.09
Enterprise Net Return / Total Costs per cwt Milk*	$/cwt	-10.08	-1.75
Enterprise Net Return / Oper Costs per cwt Milk*	$/cwt	4.87	6.59
Net Farm Income per cwt Milk	$/cwt	4.79	4.48
Milk Produced per Cow*	cwt	167.08	202.37
Number of Cows*	No.	129.55	592.35
Percent of Cows	%	79.7	20.3
Percent of Milk Produced	%	77.2	22.8
Number of Farms*	No.	49,482	2,755
Portion Adopting Computerized Feeding System*	Portion	0.06	0.28
Portion Adopting a Computer for Record-Keeping*	Portion	0.23	0.76
Portion Using the Internet for Dairy Information*	Portion	0.37	0.61
-----Computerized Feeding System-----			
Age	Years	51.30	50.13
College Degree*	0 – 1	0.15	0.25
Acres*	No.	386.76	682.51
Debt-asset Ratio*	Ratio	0.14	0.18
Operator's Off-farm Work*	Hr/Yr	133.93	47.71
Percent of Farm Income from Milk	%	86.60	94.91
Enterprise Net Return / Total Costs per cwt Milk*	$/cwt	-10.14	-3.20
Enterprise Net Return / Oper Costs per cwt Milk	$/cwt	4.91	5.57
Net Farm Income per cwt Milk*	$/cwt	4.86	3.70
Milk Produced per Cow*	cwt	165.93	208.28
Number of Cows*	No.	124.09	543.89
Percent of Cows	%	74.9	25.1
Percent of Milk Produced	%	71.8	28.2
Number of Farms*	No.	48,521	3,716
Portion Adopting Computerized Milking System*	Portion	0.04	0.21
Portion Adopting a Computer for Record-Keeping*	Portion	0.23	0.69
Portion Using the Internet for Dairy Information*	Portion	0.37	0.61

* indicates significant differences based on pairwise-two-tailed delete-a-group Jackknife t-statistics at the 10% level.

Figure 1. Total U.S. dairy cows and milk per dairy cow, 1990-2007



Source: USDA, NASS