ADOPTION OF TECHNOLOGY, MANAGEMENT PRACTICES, AND PRODUCTION SYSTEMS IN U.S. MILK PRODUCTION

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We examine U.S. dairy farmer adopter characteristics and adoption rates of eleven technologies. Excepting grazing, technologies were generally adopted complementarily. Four were used on higher percentages of farms in 2005 than 2000. The interaction of farm size with adoption suggests greater percentages of milk being produced under each, excepting grazing.

Key Words. technically complementary, technology, management practices, production system.

INTRODUCTION

The United States dairy industry has undergone rapid structural change in recent years, with adjustments occurring at all levels. The U.S. Department of Agriculture shows an almost tripling of dairy farm numbers in the "very large" ≥2,000 cow size category during the decade, 1999 to 2008, from 255 to 730 farms, with percent of production increasing from 9.2% to 30.5% (USDA-National Agricultural Statistics Service, 2000, 2009). Examining over a longer period, average U.S. herd size was 19 cows in 1970, rising to 120 in 2006 (MacDonald et al., 2007). Over that period, average milk produced per cow doubled and production per farm increased twelvefold (MacDonald et al., 2007). Figure 1 illustrates the reduction in U.S. dairy cow numbers and increase in cow productivity from 1990 to 2007. Much of this increased productivity can be attributed to improved management practices, animal selection, and technology adoption.

United States milk production has had its greatest recent growth in the West, a "nontraditional" dairy region given the historic concentration in the Northeast and Upper Midwest. The tendency for larger, more technologically advanced operations to arise outside of traditional regions is consistent with the evolution of other agricultural industries (Reimund et al., 1977). Short (2004) stresses the role of technology in dairy industry evolution, stating it has

"changed the way milk is produced," with firm growth and specialization being made possible by technology. Furthermore, it has changed the assembly, processing, and distribution of milk (Manchester and Blayney, 1997). Given the role of technology in dairy industry structural change, there is interest in patterns of technology adoption, its drivers, and its adopters. This paper examines 2000 and 2005 adoption rates of technological innovations, management practices, and production systems in the dairy industry, showing types of farms adopting, complementarity among innovations and practices, and diffusion rates between the 2 years. The following dairy farm technologies, management practices, and systems are examined: holding pen with udder washer, milking units with ATOs, genetic selection technologies, rBST, a computerized feed delivery system, a computerized milking system, use of a nutritionist to design feed rations, membership in the Dairy Herd Improvement Association (DHIA), milking cows three times daily, grazing, and a dairy parlor, each defined as follows.

Technological Innovations

Holding pen with udder washer: Udder washers are used to wash the udder in the holding pen prior to entering the milking parlor. A variety of udder washer types are available, with systems generally including a water heater with automatic teat spraying systems, spray guns and/or teat dipping operations.

Milking unit with automatic take-offs: Automatic take-offs (ATOs) are sensors used on milking units that indicate the end of milk flow to prevent under- or over-milking. At the end of milk flow, the ATO shuts off the vacuum, releasing the milking unit from the udder. The milking unit is removed from underneath the cow automatically.

Genetic Selection. Shook (2006) suggests improved genetics has accounted for 55% of the gain in milk yield and one-third of the reduction in time required to conception. In the

context of this study, improved genetic selection can be accomplished through artificial insemination (AI), embryo transfer (ET), and/or sexed semen.

Recombinant Bovine Somatotropin. Recombinant bovine somatotropin (rBST) is a genetically engineered bovine growth hormone released commercially in 1994. It is used in dairy cows to induce increased milk production. Currently marketed by Elanco Animal Health Services, it has been considered to be scale-neutral. The Elanco Animal Health Services website (accessed July 13, 2009) lists the price of one dose, given every 14 days, at $6.60.

Computerized Feed Delivery System. Feed cost accounts for the largest share of milk production costs, so improved feed utilization can significantly impact profit. To reduce labor costs, dairy feeding systems are becoming more mechanized and automated. One approach uses an integrated computerized cow identification system that feeds according to energy needs, depending upon lactation phase (Kelly, 2001). Kelly (2001) describes automated systems as either (1) variable time-feeding, which allots feed proportional to time, or (2) fixed time routines, which use fixed feeding intervals for all cows in the herd.

Computerized Milking System. Computerized milking systems can be applied in a number of different ways. Automated robotic milking systems (AMS) range from systems that merely automate attachment of cups to teats to fully automatic systems. The AMS is usually linked to automated concentrate feeding systems (Kelly, 2001). Gillespie et al. (2009) contains more information regarding computerized milking systems.

Management Practices

Using a Nutritionist to Design Mixes or Purchase Feed. Application of better nutrition furnishes immediate means of improving cow health and milk yield. Improved feed management can reduce the excretion of specific nutrients in manure (Harrison et al. 2007). The USDA-

Natural Resources Conservation Service has defined Feed Management (592) as managing "the quality of available nutrients fed to livestock and poultry for their intended purpose." A 5-step implementation process for Feed Management has been developed (White et al. 2007), with each including a nutrient management planner and/or nutritionist as a key participant.

Dairy Herd Improvement Association Membership. The DHIA is a voluntary fee-based record keeping service that allows dairy farmers to track production. In the U.S., DHIA participation has been associated with increased production efficiency and profitability (Spain and Witherspoon, 1994). McCaffree et al. (1974) found that economic returns increased with consecutive years of participation, so short participation periods may cause participants to not fully realize DHIA's economic value.

Housing and Milk Production Systems

Grazing. Grazing for provision of forage in a dairy operation can range from slight to extensive, where pasture furnishes the majority of forage needs during the grazing season. We provide a limited picture of grazing activity, not distinguishing between slight and extensive pasture use, but only whether grazing is utilized. Increased interest in pasture-based dairying has emerged due to increased demand for "natural" milk products and the fact that some pasture-based operations may qualify as organic with additional management changes.

Three Times Milking Daily. To more efficiently utilize parlors and increase production per cow, some farmers milk cows three times daily. Studies have shown a 6 to 19% increase in production associated with a third milking (Amos et al., 1985; DePeters et al., 1985; Gisi et al., 1986). Erdman and Varner (1994), however, found that the increase in yield due to increase in milking frequency is by a fixed amount rather than a percentage increase.

Parlor. Milking facilities are generally one of three types, namely parlor, flat barn and tie stall (stanchion) barns. In a parlor system, cows enter stalls for milking, generally on a raised platform. Arrangements may include herringbone, parallel, swing, side opening, polygon and others. In most large-scale and some smaller dairies, milking is conducted in parlors. The flat barn system and stanchion systems tend to be more labor intensive, physically demanding and in most cases result in lower cow throughput per hour than a comparable parlor system, but are less expensive to build and equip than a milking parlor facility. For small farms, the cost of stanchion technology is generally lower than that of parlor technology (Tauer 1998, Katsumata and Tauer 2008).

MATERIALS AND METHODS

This study uses data from the 2000 and 2005 Agricultural Resource Management Survey (ARMS) dairy version, conducted by USDA National Agricultural Statistics Service (NASS) and Economic Research Service. The 2000 and 2005 datasets include 870 and 1,814 observations, respectively. The minimum size for inclusion was 10 cows, so as to limit the sample to commercial observations. States covered include AZ, CA, FL, GA, ID, IL, IN, IA, KY, ME (2005 only), MI, MN, MO, NM, NY, OH, OR (2005 only), PA, TN, TX, VT, VA, WA, and WI.

The survey collects information on farm operator and financial characteristics, production costs, size, commodities produced, and technology use. Sample dairy farms are selected from a list maintained by NASS. Sampling is stratified, with sampling probabilities varying by farm size and state to achieve more reliable estimates of production and expenses. Each sample farm represents a number of like farms in the population, and expansion factors allow for extrapolation to the dairy population of the 24 states where the survey was conducted (90% of the U.S. dairy population). Estimates for 2000 and 2005 are comparable due to consistency in

surveying and processing the data: collected by the same organization in a similar format using hand enumeration, involving a complex sampling scheme, and representing the same population with broad national coverage.

We report findings in Tables 1 and 2. Table 1 reports comparisons of adoption rates for each of the 11 technologies in 2000 and 2005. Because dairy production is skewed toward the largest farms, we report adoption rates in two ways, as the proportion of farms adopting a technology and as the proportion of production covered by farms using a technology (i.e., the latter weighted by production). In Table 2, we compare adopters and non-adopters of each technology, management practice, or system in each of the two years. In each table, we consider (1) farm size (number of milk cows); (2) clustering of technologies—the extent to which adopters and non-adopters use each of the other 10 technological innovations, management practices, or production systems; and (3) dairy enterprise performance measures milk yield and net return over total costs.

Pair-wise, two-tailed t-tests utilizing the delete-a-group jackknife estimation procedure are used to determine whether significant differences exist between adopters and non-adopters. Using the jackknife, there are 15 replicates and 28 degrees of freedom. For greater detail on this estimation procedure using ARMS, the reader is referred to Dubman (2000).

Dairy enterprise net returns are the difference between gross returns and costs. Gross returns include the value of milk sold, revenues from sales of culled cattle, the implicit fertilizer value of manure produced, and other income from the dairy. Operating costs include feed (including the implicit value of homegrown feed), veterinary and medical, bedding, marketing, custom services, fuel, lube, electricity, repairs, other operating costs and interest on operating costs. Allocated overhead costs include: hired labor, opportunity cost of unpaid labor, capital

recovery of machinery and equipment, opportunity cost of land (rental rate), taxes and insurance, and general farm overhead.

RESULTS

Tables 1 and 2 show differences in dairy farm adoption of technologies, management practices, and production systems. In cases where there was a disclosure issue for a particular factor (too few observations), means are not included.

Adoption Diffusion

Significant adoption diffusion is found for four technologies or production systems from 2000 to 2005. The percentage of farms adopting: (1) ATOs increased from 24.4% in 2000 to 37.5% in 2005, (2) genetic selection increased from 64.3% in 2000 to 81.5% in 2005, (3) three times milking daily increased from 3.4% in 2000 to 6.9% in 2005, and (4) parlors increased from 38.2% in 2000 to 49.9% in 2005. It is noted that the two latter production systems were particularly associated with the adoption of many of the other technologies, a subject of further discussion later when technically complementary relationships are discussed.

Of note is the technologies, management practices, and production systems for which percentages of farms adopting did not change significantly over 2000-2005: holding pens with udder washers, rBST, computerized feeding systems, computerized milking systems, use of a nutritionist, DHIA membership, and grazing. The lack of change in rBST and grazing may be partially explained by increased consumer demand for milk with specific attributes, such as rBST-free, organic, etc., trends not expected to greatly influence the other technologies.

Adoption and Farm Size

We also report the percentage of production covered by farms using the technology in Table 1. Since larger farms are typically greater technology adopters, these weighted adoption

rates are expected to exceed those for farms alone. In general, that is true, with the exception of grazing. Particularly large differences in adoption rates appear for milking systems (use of holding pens with udder washers, ATOs, computerized milking systems, parlors, and milking frequency). This pattern suggests significant economies of size with the more capital-intensive technologies. Referring to Table 2, larger farms were greater adopters of all technologies, management practices, and production systems with the exception of grazing.

Complementary Relationships among Technologies

In most cases, adopters of technologies, management practices, and production systems were more likely than non-adopters to have also adopted all other technologies, management practices, and production systems, with the exception of grazing.

A number of examples from 2005 are particularly noteworthy. Adopters of holding pens with udder washers had adoption rates of at least 47 points higher than non-adopters for ATOs and a parlor. Adopters of ATOs had an adoption rate of 46 points higher than ATO non-adopters for a parlor. Of genetic selection adopters, 51.8% were members of DHIA versus 17.0% of non-adopters. Adopters of rBST had adoption rates of at least 32 points higher than non-adopters for ATOs, a parlor, and DHIA membership. Computerized feed delivery system adopters had adoption rates of at least 32 points higher than non-adopters for ATOs, rBST, and a parlor. Computerized milking system adopters had adoption rates of at least 38 points higher than non-adopters for ATOs and a parlor. Of DHIA members, 56.8% used a nutritionist versus 16.7% of DHIA nonmembers. Farmers milking three times daily had adoption rates of at least 39 points higher than those milking twice daily for ATOs, rBST, and DHIA membership. Of parlor adopters, 59.4% used ATOs while only 15.7% of parlor non-adopters used ATOs. Grazers had

lower adoption rates of all but two technologies, with differences of at least 18 points between adopters and non-adopters for ATOs, use of a nutritionist, parlor, and DHIA membership.

What makes particularly strong impressions about these lists is that, for each technology, management practice, and production system, correlations of adoption rates are not only statistically significant, but the magnitude of the differences are in many cases quite large, with adoption rates for a technology being in some cases three times greater if a second technology was adopted. Highly complementary appear to be: parlor and ATO adoption, rBST and three-times daily milking, three-times daily milking and ATO adoption, use of a nutritionist and DHIA membership, ATO and computerized milking system adoption (both of which may be integrated into the same machine), computerized feed delivery system and ATO adoption, holding pen with udder washer and ATO adoption, and holding pen with udder washer and parlor adoption. In many cases, more than one technology and/or management practice is likely to be adopted as part of an overall production system.

Adoption and Its Relationship with Productivity

Productivity was significantly associated with all technologies, management practices, and production systems. While readers are cautioned to not ascribe "cause and effect" interactions among the variables since this analysis is not multivariate in nature, we particularly warn against this with the net returns analysis primarily because, as seen in the preceding section, technologies, management practices, and production systems are often adopted as packages, so ascribing an increase in profitability and productivity to one technology, management practice, or production system without considering others in a suitable multivariate framework would be invalid. Considering this cautionary note, examination of the measures on the whole can provide significant insight into the effects of technology adoption. Adopters of all

technologies, management practices, and production systems other than grazing realized higher milk production per cow than did non-adopters.

The profitability measure included here, net returns over total costs per hundredweight of milk produced, is negative during both years since fixed costs such as cost of land and buildings were also included in total costs. Adopters of each of the technologies, management practices, and production systems other than grazing realized higher net returns over total costs per cow in at least one of the years. Considering the technically complementary nature and indivisibility of impacts of each of the technologies and associated economies of size, these results generally show evidence of greater profitability associated with the adoption of advanced technologies, management practices, and production systems.

Additional Measures of Structural Change – 2000 to 2005

Table 1 provides additional insight into dairy industry structural change during 2000-2005. Dairy farms grew from averages of 112 to 154 cows. Average milk produced per cow increased from 15,611 to 16,894 pounds. Overall, five-year trends show increases in farm size and increases in productivity per cow.

CONCLUSIONS AND DISCUSSION

Changes in the U.S. dairy industry have been significant whether examined using farm numbers, farm size, productivity, or technology adoption. From 2000 to 2005, average dairy farm size grew by 37.5% in number of cows, and cow productivity increased 8.2%. Thus, the figures show not only growth in farm size, but also imply increased intensity, as cow productivity increased while the land input was de-emphasized.

Particularly striking are adoption trends. Over the period, increases were seen in the use of ATOs, milking three times daily, genetic selection, and parlors. Somewhat surprising is that

no significant changes were found in other technological innovations, management practices, and systems, such as udder washers, rBST, computerized feed delivery systems, computerized milking systems, the use of a nutritionist, DHIA membership, and grazing, though many increased in terms of percentage of milk produced as small farms exited while large adopters continued farming. Reasons beyond the scope of this study explain why each of these remained relatively stable over the period of study, each likely to deserve significant research to determine influences on farm profitability and/or other reasons preventing more farmers from adopting.

Adopters of each of the technologies, management practices, and production systems (besides grazing) tend to be adopters of the other technologies, practices, and systems. This suggests at least a couple of things. First, the technologies complement one another and may be used in an overall systems approach. Second, each was used more extensively by larger farms, so there appear to be significant economies of size associated with adoption of each. This suggests that as farm sizes continue to grow, the larger farms will be the adopters of these technologies, whether or not they are truly technically complementary with one another.

For dairy industry researchers determining the impact of a particular technology or management practice on profitability or productivity, it is clear from this analysis that singling out a particular innovation and evaluating its impact on profitability or productivity will lead to upward bias unless accounting for the impact of other technologies using proper selection bias corrections. Each of the technologies and management practices was associated with higher milk cow productivity and enterprise net returns, but adopters of a particular technology were also the adopters of other technologies and management practices, so sorting out the influence of a particular technology provides significant challenges. Thorough examinations that adequately isolate the technology of interest are vital to fully understanding the dynamics of adoption.

Table 1. USDA agricultural resource management survey estimates, by year, 2000 and 2005.

Item	2000	2005
Number of Farms	71,300 [a]	52,237 [b]
Size and Productivity		
Number of milk cows	111.9 [b]	154.0 [a]
Milk per cow, cwt/year	156.109 [b]	168.941 [a]
Technologies and Management Practices, % of US Farms Adopting		
Holding pen with udder washer	0.054	0.065
Milkers with automatic take-offs	0.244 [b]	0.375 [a]
Genetic selection	0.643 [b]	0.815 [a]
rBST	0.173	0.166
Computerized feeding system	0.081	0.071
Computerized milking system	0.061	0.053
Nutritionist used	0.669	0.716
DHIA membership	0.447	0.454
Grazing	0.685	0.645
Milk 3 times/day	0.034 [b]	0.069 [a]
Parlor	0.382 [b]	0.499 [a]
Percent of US Milk Produced by Farms Utilizing Technologies and Management Practices		
Holding pen with udder washer	0.268	0.315
Milkers with automatic take-offs	0.583	0.730
Genetic selection	0.762	0.890
rBST	0.350	0.400
Computerized feeding system	0.216	0.283
Computerized milking system	0.197	0.227
Nutritionist used	0.832	0.877
DHIA membership	0.570	0.585
Grazing	0.460	0.369
Milk 3 times/day	0.190	0.302
Parlor	0.700	0.838

Source: 2000 and 2005 USDA Agricultural Resource Management Survey.

Based on 2,684 observations. Pairwise two tailed [H0:B1=B2] delete –a-group Jackknife *t*-statistics at the 90 percent confidence level or higher with 15 replicates and 28 degrees of freedom were used.

*[a-b] : Means within a row with different superscripts differ ($p < 0.10$)

Table 2. USDA agricultural resource management survey estimates, by different technologies, 2000 and 2005.

Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
----------Holding Pen with Udder Washer----------				
Number of Farms	67,455[a]	3,845 [c]	48,833 [b]	3,404 [c]
Size				
Number of milk cows	88.4 [d]	524.8 [b]	115.9 [c]	700.3 [a]
Technologies and Management Practices				
Milkers with automatic take-offs	0.210 [c]	0.844 [a]	0.344 [b]	0.817 [a]
Genetic selection	0.642 [bd]	0.666 [d]	0.817 [a]	0.782 [a]
rBST	0.169 [c]	0.233 [b]	0.159 [c]	0.258 [a]
Computerized feeding system	0.071 [b]	0.261 [a]	0.061 [b]	0.215 [a]
Computerized milking system	0.049 [b]	0.260 [a]	0.042 [b]	0.203 [a]
Nutritionist used	0.667 [b]	0.703 [ab]	0.709 [b]	0.824 [a]
DHIA membership	0.446 [b]	0.460 [ab]	0.447 [b]	0.560 [a]
Grazing	0.697 [a]	0.465 [b]	0.668 [a]	0.318 [c]
Milk 3 times/day	0.029 [d]	0.122 [ab]	0.062 [b]	0.169 [a]
Parlor	0.352 [d]	0.910 [a]	0.466 [c]	0.971 [a]
Productivity				
Milk per cow, cwt/year	155.59 [c]	165.24 [bc]	167.88 [b]	184.11 [a]
Net returns over total costs / cwt	-14.81 [a]	-3.76 [c]	-10.14 [b]	-2.49 [c]
----------Milkers with Automatic Takeoffs----------				
Number of Farms	53,921 [a]	17,380 [c]	32,634 [b]	19,603 [c]
Size				
Number of milk cows	65.1 [c]	257.3 [a]	77.1 [b]	281.9 [a]
Technologies and Management Practices				
Holding pen with an udder washer	0.011 [d]	0.187 [a]	0.019 [c]	0.142 [b]
Genetic selection	0.618 [c]	0.721 [b]	0.777 [b]	0.879 [a]
rBST	0.120 [b]	0.335 [a]	0.083 [b]	0.304 [a]
Computerized feeding system	0.048 [b]	0.183 [a]	0.026 [c]	0.146 [a]
Nutritionist used	0.620 [b]	0.821 [a]	0.636 [b]	0.851 [a]
DHIA membership	0.405 [b]	0.576 [a]	0.377 [b]	0.582 [a]
Grazing	0.742 [a]	0.507 [b]	0.713 [a]	0.533 [b]
Milk 3 times/day	0.010 [b]	0.108 [a]	0.008 [b]	0.172 [a]
Parlor	0.246 [c]	0.803 [a]	0.324 [b]	0.791 [a]
Productivity				
Milk per cow, cwt/year	150.92 [c]	172.23 [b]	155.39 [c]	191.50 [a]
Net returns over total costs / cwt	-17.07 [a]	-5.37 [b]	-12.98 [a]	-4.09 [b]

Table 2 continued

Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
---------- Genetic Selection----------				
Number of Farms	25,440 [b]	45,861 [a]	9,664 [c]	42,573 [a]
Size				
Number of milk cows	81.9 [c]	128.6 [b]	116.2 [b]	162.5 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.051	0.056	0.077	0.063
Milkers with automatic take-offs	0.190 c	0.273 [b]	0.246 [bc]	0.405 [a]
rBST	0.090 [b]	0.218 [a]	0.040 [c]	0.195 [a]
Computerized feeding system	0.035 [b]	0.107 [a]	0.027 [b]	0.081 [a]
Computerized milking system	0.027 [b]	0.080 [a]	0.037 [b]	0.056 [ac]
Nutritionist used	0.497 [b]	0.764 [a]	0.461 [bc]	0.774 [a]
DHIA membership	0.220 [b]	0.573 [a]	0.170 [b]	0.518 [a]
Grazing	0.760 [a]	0.643 [b]	0.683 [ab]	0.637 [b]
Milk 3 times/day	0.016 [c]	0.044 [b]	0.020 [bc]	0.081 [a]
Parlor	0.424 [b]	0.359 [c]	0.615 [a]	0.473 [b]
Productivity				
Milk per cow, cwt/year	142.30 [c]	163.77 [b]	132.76 [c]	177.16 [a]
Net returns over total costs / cwt	-17.16 [a]	-12.59 [b]	-15.02 [abc]	-8.42 [c]
----------Recombinant Bovine Somatotropin (rBST)----------				
Number of Farms	58,991 [a]	12,309 [c]	43,569 [b]	8,668 [d]
Size				
Number of milk cows	91.9 [d]	207.9 [b]	119.8 [c]	325.5 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.050 [b]	0.073 [ab]	0.058 [b]	0.101 [a]
Milkers with automatic take-offs	0.196 [d]	0.473 [b]	0.313 [c]	0.688 [a]
Genetic selection	0.608 [c]	0.813 [b]	0.787 [b]	0.956 [a]
Computerized feeding system	0.065 [b]	0.159 [a]	0.043 [b]	0.213 [a]
Computerized milking system	0.044 [d]	0.141 [a]	0.036 [b]	0.137 [a]
Nutritionist used	0.609 [b]	0.955 [a]	0.670 [b]	0.950 [a]
DHIA membership	0.381 [b]	0.762 [a]	0.392 [b]	0.764 [a]
Grazing	0.727 [a]	0.481 [b]	0.683 [a]	0.455 [b]
Milk 3 times/day	0.014 [c]	0.128 [b]	0.021 [c]	0.311 [a]
Parlor	0.366 [c]	0.459 [b]	0.444 [b]	0.778 [a]
Productivity				
Milk per cow, cwt/year	148.799 [d]	191.141 [b]	158.670 [c]	220.568 [a]
Net returns over total costs / cwt	-15.86 [a]	-6.34 [c]	-10.90 [b]	-3.31

Table 2 continued.

Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
----------Computerized Feed Delivery System----------				
Number of Farms	65,527 [a]	5,774 [c]	48,446 [b]	3,791 [d]
Size				
Number of milk cows	95.7 [d]	296.2 [b]	124.1 [c]	536.0 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.043 [b]	0.174 [a]	0.055 [b]	0.195 [a]
Milkers with automatic take-offs	0.217 [d]	0.552 [b]	0.344 [c]	0.770 [a]
Genetic selection	0.625 [c]	0.846 [ab]	0.807 [b]	0.921 [a]
rBST	0.158 [b]	0.339 [a]	0.140 [b]	0.493 [a]
Computerized milking system	0.034 [c]	0.369 [a]	0.041 [c]	0.207 [b]
Nutritionist used	0.644 [b]	0.949 [a]	0.702 [b]	0.902 [a]
DHIA membership	0.431 [b]	0.621 [a]	0.436 [b]	0.679 [a]
Grazing	0.694 [a]	0.574 [b]	0.668 [ab]	0.351 [c]
Milk 3 times/day	0.028 [c]	0.101 [abc]	0.058 [b]	0.213 [a]
Parlor	0.350 [d]	0.746 [b]	0.471 [c]	0.862 [a]
Productivity				
Milk per cow, cwt/year	155.505 [c]	162.964 [bc]	165.922 [b]	207.527 [a]
Net returns over total costs / cwt	-14.76 [a]	-8.07 [b]	-10.12 [b]	-3.49 [c]
----------Computerized Milking System----------				
Number of Farms	66,965 [a]	4,335 [c]	49,482 [b]	2,755 [d]
Size				
Number of milk cows	95.4 [d]	366.8 [b]	129.5 [c]	592.3 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.042 [b]	0.230 [a]	0.055 [b]	0.251 [a]
Milkers with automatic take-offs	0.208 [c]	0.800 [a]	0.345 [b]	0.923 [a]
Genetic selection	0.630 [b]	0.842 [a]	0.812 [a]	0.872 [a]
rBST	0.158 [b]	0.399 [a]	0.151 [b]	0.430 [a]
Computerized feeding system	0.054 [c]	0.492 [a]	0.059 [c]	0.284 [b]
Nutritionist used	0.654 [b]	0.897 [a]	0.706 [b]	0.904 [a]
DHIA membership	0.442	0.520	0.447	0.583
Grazing	0.701 [a]	0.426 [b]	0.660 [a]	0.379 [b]
Milk 3 times/day	0.023 [d]	0.193 [b]	0.053 [c]	0.368 [a]
Parlor	0.355 [c]	0.801 [a]	0.479 [b]	0.859 [a]
Productivity				
Milk per cow, cwt/year	155.414 [c]	166.850 [bc]	167.080 [b]	202.376 [a]
Net returns over total costs / cwt	-14.83 [a]	-4.79 [c]	-10.08 [b]	-1.75 [d]

Table 2 continued.

Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
----------Whether a Nutritionist Is Used----------				
Number of Farms	23,613 [c]	47,687 [a]	14,812 [d]	37,425 [b]
Size				
Number of milk cows	65.9 [d]	134.7 [b]	83.2 [c]	182.0 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.048 [ab]	0.057 [a]	0.041 [b]	0.075 [a]
Milkers with automatic take-offs	0.132 [c]	0.299 [b]	0.197 [c]	0.446 [a]
Genetic selection	0.459 [c]	0.735 [b]	0.648 [b]	0.881 [a]
rBST	0.023 [b]	0.247 [a]	0.029 [b]	0.220 [a]
Computerized feeding system	0.013 [b]	0.115 [a]	0.020 [b]	0.091 [a]
Computerized milking system	0.019 [b]	0.082 [a]	0.018 [b]	0.067 [a]
DHIA membership	0.215 [b]	0.561 [a]	0.167 [b]	0.568 [a]
Grazing	0.795 [a]	0.630 [b]	0.821 [a]	0.576 [b]
Milk 3 times/day	0.004 [c]	0.048 [b]	0.010 [c]	0.093 [a]
Parlor	0.355 [b]	0.396 [b]	0.442 [ab]	0.522 [a]
Productivity				
Milk per cow, cwt/year	132.993 [c]	167.556 [b]	132.961 [c]	183.181 [a]
Net returns over total costs / cwt	-21.39 [a]	-10.67 [b]	-16.23 [ab]	-7.03 [c]
----------Membership with DHIA----------				
Number of Farms	39,445 [a]	31,856 [b]	28,523 [b]	23,714 [c]
Size				
Number of milk cows	92.1 [c]	136.5 [b]	126.1 [b]	187.5 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.053 [b]	0.056 [ab]	0.053 [b]	0.080 [a]
Milkers with automatic take-offs	0.187 [c]	0.314 [b]	0.287 [b]	0.481 [a]
Genetic selection	0.497 [d]	0.824 [b]	0.719 [c]	0.931 [a]
rBST	0.074 [b]	0.295 [a]	0.072 [b]	0.279 [a]
Computerized feeding system	0.055 [b]	0.113 [a]	0.041 [b]	0.107 [a]
Computerized milking system	0.053 [ab]	0.071 [a]	0.040 [b]	0.068 [ab]
Nutritionist used	0.530 [c]	0.840 [b]	0.567 [c]	0.896 [a]
Grazing	0.712 [ab]	0.651 [b]	0.727 [a]	0.547 [c]
Milk 3 times/day	0.015 [c]	0.057 [b]	0.023 [c]	0.125 [a]
Parlor	0.390 [b]	0.373 [b]	0.481 [a]	0.521 [a]
Productivity				
Milk per cow, cwt/year	140.883 [c]	174.962 [b]	150.648 [c]	190.94 [a]
Net returns over total costs / cwt	-17.78 [a]	-9.80 [b]	-12.67 [b]	-6.00 [c]

Table 2 continued.

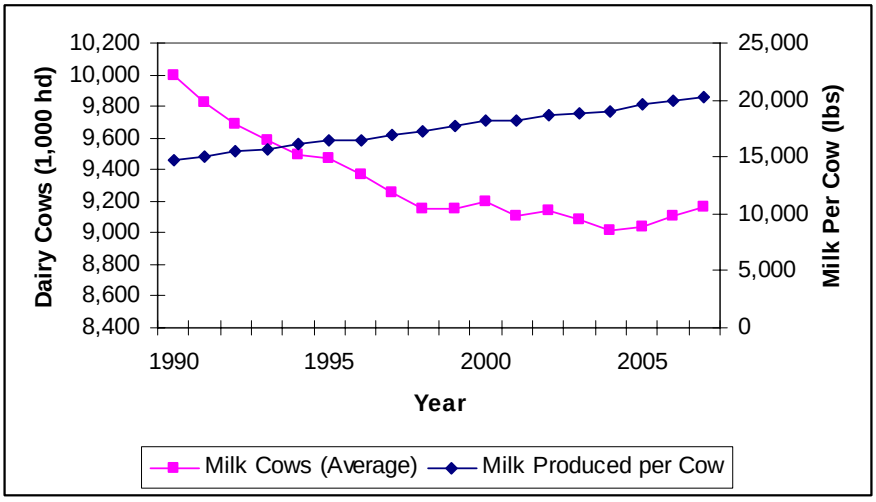
Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
----------Grazing----------				
Number of Farms	22,481 [c]	48,819 [a]	18,525 [d]	33,712 [b]
Size				
Number of milk cows	185.4 [b]	78.1 [d]	259.1 [a]	96.2 [c]
Technologies and Management Practices				
Holding pen with udder washer	0.091 [c]	0.037 [a]	0.125 [b]	0.032 [a]
Milkers with automatic take-offs	0.381 [b]	0.181 [c]	0.494 [a]	0.310 [b]
Genetic selection	0.728 [b]	0.604 [c]	0.835 [a]	0.804 [ab]
rBST	0.284 [a]	0.121 [b]	0.255 [a]	0.117 [b]
Computerized feeding system	0.109 [a]	0.068 [b]	0.132 [a]	0.038 [c]
Computerized milking system	0.111 [a]	0.038 [b]	0.092 [a]	0.031 [b]
Nutritionist used	0.785 [b]	0.615 [c]	0.857 [a]	0.639 [c]
DHIA membership	0.494 [ab]	0.425 [bc]	0.580 [a]	0.384 [c]
Milk 3 times/day	0.063 [c]	0.021 [b]	0.118 [a]	0.043 [bc]
Parlor	0.475 [b]	0.340 [c]	0.642 [a]	0.421 [b]
Productivity				
Milk per cow, cwt/year	167.803 [b]	150.725 [c]	183.440 [a]	160.974 [bc]
Net returns over total costs / cwt	-8.22 [c]	-16.98 [a]	-6.04 [c]	-11.62 [b]
----------Milking Three Times Daily----------				
Number of Farms	68,890 [a]	2,411 [c]	48,609 [b]	3,628 [c]
Size				
Number of milk cows	95.0 [c]	596.9 [a]	123.1 [b]	567.8 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.049 [b]	0.195 [a]	0.058 [b]	0.159 [a]
Milkers with automatic take-offs	0.225 [d]	0.781 [b]	0.334 [c]	0.929 [a]
Genetic selection	0.637 [b]	0.833 [ac]	0.805 [c]	0.947 [a]
rBST	0.156 [b]	0.651 [a]	0.123 [b]	0.742 [a]
Computerized feeding system	0.075 [b]	0.241 [ab]	0.060 [b]	0.223 [a]
Computerized milking system	0.051 [b]	0.348 [a]	0.036 [b]	0.279 [a]
Nutritionist used	0.659 [b]	0.958 [a]	0.698 [b]	0.958 [a]
DHIA membership	0.436 [b]	0.757 [a]	0.427 [b]	0.817 [a]
Grazing	0.694 [a]	0.417 [b]	0.664 [a]	0.397 [b]
Parlor	0.363 [c]	0.915 [a]	0.476 [b]	0.808 [a]
Productivity				
Milk per cow, cwt/year	154.719 [d]	195.846 [b]	163.825 [c]	237.484 [a]
Net returns over total costs / cwt	-14.69 [a]	-0.79 [c]	-10.31 [b]	-0.65 [c]

Table 2 Continued.

Item	Non-adoption, 2000	Adoption, 2000	Non-adoption, 2005	Adoption, 2005
			Parlor	
Number of Farms	44,054 [a]	27,246 [b]	26,157 [b]	26,080 [b]
Size				
Number of milk cows	57.1 [c]	200.6 [b]	55.9 [c]	252.3 [a]
Technologies and Management Practices				
Holding pen with udder washer	0.008 [b]	0.128 [a]	0.004 [b]	0.127 [a]
Milkers with automatic take-offs	0.078 [d]	0.512 [b]	0.157 [c]	0.594 [a]
Genetic selection	0.668 [b]	0.604 [c]	0.858 [a]	0.772 [a]
rBST	0.151 [c]	0.208 [b]	0.074 [d]	0.259 [a]
Computerized feeding system	0.033 [b]	0.158 [a]	0.020 [b]	0.123 [a]
Computerized milking system	0.020 [c]	0.127 [a]	0.015 [c]	0.091 [b]
Nutritionist used	0.654 [b]	0.693 b	0.684 [ab]	0.749 [a]
DHIA membership	0.454	0.436	0.434	0.474
Grazing	0.732 [a]	0.608 [b]	0.747 [a]	0.544 [b]
Productivity				
Milk per cow, cwt/year	154.990 [b]	157.920 [b]	162.998 [b]	174.902 [a]
Net returns over total costs / cwt	-17.37 [a]	-9.11 [bc]	-12.62 [ab]	-6.65 [c]

Source: 2000 and 2005 USDA Agricultural Resource Management Survey.
Based on 2,684 observations. Pairwise two tailed [H0:B1=B2] delete –a-group Jackknife *t*-statistics at the 90 percent confidence level or higher with 15 replicates and 28 degrees of freedom were used.
*[a-d]: Means within a row with different superscripts differ ($p < 0.10$)

Figure 1: Total U.S. Dairy Cows and Milk per Dairy Cow, 1990-2007



Source: USDA-National Agricultural Statistics Service

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