The Profitability of Automatic Milking on Dutch Dairy Farms

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ABSTRACT

Several studies have reported on the profitability of automatic milking based on different simulation models, but a data-based study using actual farm data has been lacking. The objective of this study was to analyze the profitability of dairy farms having an automatic milking system (AMS) compared with farms using a conventional milking system (CMS) based on real accounting data. In total, 62 farms (31 using an AMS and 31 using a CMS) were analyzed for the year 2003 in a case control study. Differences between the years 2002 and 2003 also were analyzed by comparing a subgroup of 16 farms with an AMS and 16 farms with a CMS. Matching was based on the time of investment in a milking system (same year), the total milk production per year, and intensity of land use (kg/ha). Results from 2003 showed that the farms with an AMS used, on average, 29% less labor than farms with a CMS. In contrast, farms using a CMS grew faster (37,132 kg of milk quota and 5 dairy cows) than farms with an AMS (–3,756 kg milk quota and 0.5 dairy cows) between 2002 and 2003. Dairy farmers with a CMS had larger (€7,899) revenues than those with an AMS. However, no difference in the margin on dairy production was detected, partly because of numerically greater (€6,822) variable costs on CMS farms. Dairy farms were compared financially based on the amount of money that was available for rent, depreciation, interest, labor, and profit (RDILP). The CMS farms had more money (€15,566) available for RDILP than the AMS farms. This difference was caused by larger fixed costs (excluding labor) for the AMS farms, larger contractor costs (€6,422), and larger costs for gas, water, and electricity (€1,549). Differences in costs for contractors and for gas, water, and electricity were statistically significant. When expressed per full-time employee, AMS farms had greater revenues, margins, and gross margins per full-time employee than did CMS farms. This resulted in a substantially greater (but not statistically signifi-

cant) RDILP per full-time employee (€12,953) for AMS farms compared with CMS farms. Depreciation and interest costs for automatic milking were not available but were calculated based on several assumptions. Assuming larger purchase costs and a shorter depreciation time for AMS than for CMS, costs for depreciation and interest were larger for AMS farms than for CMS farms. Larger fixed costs should be compensated for by the amount of labor that has become available after introducing the milking robot. Therefore, farm managers should decide whether the extra time acquired by automatic milking balances against the extra costs associated with an AMS.

Key words: automatic milking, economics, profitability

INTRODUCTION

In 1992, the first automatic milking systems (AMS) were installed in the Netherlands, with a primary goal of replacing labor. In 2004, more than 2,200 farms worldwide were using AMS (de Koning and Rodenburg, 2004). Today, the reasons for investing in an AMS can be divided into social and economic reasons. The most important social reasons for investing in an AMS are that they allow more free time, provide more flexibility, and require less heavy labor—in general, offering a better quality of life (Mathijs, 2004). The economic benefits of automatic milking are mainly the savings in labor and increased production per cow (Wade et al., 2004).

In a model study, labor savings by using an AMS were estimated to be 38% (Sonck, 1995). More recently, Mathijs (2004) conducted a survey among 107 farmers who had invested in an AMS and found, on average, 18% (17 h/wk) of savings in labor. On the other hand, van 't Land et al. (2000) concluded from different studies that labor savings depended on the management capacities of the farmer, and in some cases, introduction of an AMS led to increased labor. Wirtz et al. (2004) reported that milk production could increase up to 20% if cows were milked 3 times daily with an AMS, whereas Wade et al. (2004) found an average increase of only 2% after the introduction of an AMS.

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Several studies have been published on the economic consequences of automatic milking (Arendzen and van Scheppingen, 2000; Hyde and Engel, 2002; Rotz et al., 2003). With some exceptions, the general trend in these studies was that automatic milking has negative effects on the economic performance of the farm when compared with conventional milking. The results of these studies differed substantially. Wade et al. (2004) described a difference of more than €16,000 in labor income. Others (Dijkhuizen et al., 1997; Hyde and Engel, 2002) found a break-even point of €140,000 for a herd of 125 cows and \$374,000 for a herd of 120 cows, respectively, making automatic milking economically beneficial. The actual investment for Dijkhuizen et al. (1997) was larger than the calculated break-even points, making the investment in automatic milking not cost effective. The break-even value in the model of Hyde and Engel (2002) was above the costs of the units, indicating that the investment in automatic milking was cost effective. Armstrong and Daugherty (1997) stated that on large farms, a robotic system must sell for less than \$21,000 to compete with a conventional milking system (CMS). Rotz et al. (2003) reported losses in annual net return of \$0 to 300/cow, depending on farm size. In the latter study, the economic life of an AMS and a CMS were assumed to be equal. Arendzen and van Scheppingen (2000) showed, for a farm with a milk quota of 1,000,000 kg of milk, that the room for investment in an AMS depended on a decreased labor requirement and an increased milk yield—a difference that could be up to €189,091 (0% decrease in labor and no increase in milk yield vs. 30% decrease in labor and 15% increase in milk yield).

The economic studies conducted to date have been based on normative models in which the advantages of automatic milking (labor savings and increased production) were compared with increased costs (depreciation, maintenance, and interest). Introduction of an AMS will not only change the milk production and labor requirements but those of the whole operational management (van Vugt, 2005). It is not possible to study this complete change in farm management in a model study. A study on the economic aspects of automatic milking based on actual farm data is still needed. Therefore, the objective of this study was to analyze the profitability of dairy farms with an AMS in comparison with farms using a CMS based on actual farm data.

MATERIALS AND METHODS

Data

Data for this study originated from a Dutch accounting agency (Alfa Accountants en Adviseurs, Wageningen, the Netherlands). This agency is one of the

largest bookkeeping agencies in the Netherlands and has customers throughout the country.

A database of 1,400 dairy farms, which contained 57 farms with an AMS, was available for this research. Because not all data for 2004 were yet available, 2003 was used as the year of comparison. Adoption of an AMS is often accompanied by start-up problems; therefore, installation of the AMS must have occurred before 2003. Nine farms installed their AMS in 2003 or 2004 and had to be excluded for this reason. Two other farms were excluded because they used both an AMS and a CMS. Moreover, data from 5 farms were incomplete and incorrect (not verified by an auditor) and could not be used.

A case control method was used in this study. Each farm with an AMS was matched with a farm that had invested in a new CMS during the same year. Dairy farms with a CMS were selected out of the same database. Matching was based on the year of investment in a milking system, the total milk production per year (maximum difference of 10%), and the intensity of land use (defined as milk production/ha, with a maximum difference of 1,000 kg/ha). Ten farms could not be matched based on the chosen criteria. This resulted in a total of 31 farms with an AMS (referred to as AMS31) and 31 farms with a CMS (referred to as CMS31) used in the study. The principal occupation of these farms was dairy production. On these 31 farms, 55 milking units were in use, an average of 1.77 milking units per farm. Twenty-seven farms (46 units) used a Lely Astronaut (Lely Industries NV, Maasland, the Netherlands), 2 farms (4 units) used a Delaval VMS (De Laval VMS, Tumba, Sweden), 1 farm (3 units) used a Zenith (Zenith GM BV, Emmeloord, the Netherlands), and 1 farm (2 units) used a Liberty (Liberty, Zutphen, the Netherlands).

Technical and financial data on the 62 farms (AMS31 and CMS31) were available for the year 2003. To monitor differences in performance over the years, data from previous years were used. Data from 2002 for 16 of the 31 farms with an AMS (referred to as AMS16) and the matching 16 farms with a CMS (referred to as CMS16) could be used. No 2001 data were available.

In total, 244 variables were analyzed in this study. Data on the structure of the farm (labor, land, and livestock) and on the dairy production (revenues, feed costs, livestock costs, and costs of land) were all specified. By using these data, the gross margin could be determined. The nonaccountable costs (costs not directly associated with cattle husbandry or land use, such as contractor costs; costs for gas, water, and electricity; and maintenance and insurance costs of the machinery, equipment, land, buildings, and installations) were used to calculate overall farm profitability.

The most important variables are presented in this article.

The economic results of the 2 groups in absolute amounts were shown to give an indication of the total profitability. In addition to these absolute economic figures, the economic results were also expressed per 100 kg of ECM to reflect the performance of the farm relative to the farm size. The ECM value was used because in the Netherlands, the price of milk is based on the kilograms of fat and protein. The ECM value was calculated as follows (Hemmer et al., 2004):

$$\text{ECM} = [0.337 + (0.116 \times \%F) + (0.06 \times \%P)] \times M,$$

where M is the true milk yield (in kg), %F is the fat percentage, and %P is the protein percentage.

The farms were financially compared based on the amount of money that was available for rent, depreciation, interest, labor, and profit (**RDILP**). The RDILP was calculated as the gross margin minus the total nonaccountable costs (excluding labor). Rent, depreciation, interest, and labor were regarded as fixed costs and were therefore excluded when judging the performance of the farm. The purchase cost of an AMS is known to be greater than the purchase cost of a CMS for the same size of farm. Because AMS have been commercially available since 1992 and the improvements during the past years have been considerable, no data exist to suggest the economic lifetime of an AMS in relation to the economic lifetime of a CMS. Because of the greater level of complexity of an AMS (more electronics and precision mechanics), most economic studies assume a shorter economic lifetime of an AMS than a CMS (Armstrong and Daugherty, 1997; Cooper and Parsons, 1999; Hyde and Engel, 2002). Larger purchase costs and a shorter depreciation time of the AMS would have a negative impact on the financial outcomes of AMS farms. Therefore, the RDILP should be a good indicator of the dairy farm performance. However, depreciation and interest costs differ between milking systems and are important in economic performance. Unfortunately, the costs for depreciation and interest could not be estimated based on the available data, because the available bookkeeping data were meant for fiscal use. The resulting estimates for depreciation and interest could therefore not be used for a business economic purpose. Moreover, because AMS have been available on commercial dairy farms since 1992, no good estimate of their depreciation time exists. Therefore, per farm, the depreciation and interest for milking equipment were calculated normatively (based on assumptions). For an AMS farm, the number of milking units on that farm was multiplied by the purchase costs of 1 AMS unit. The purchase costs of 1

AMS unit (including building costs) were assumed to be €100,000. For a CMS farm, the investment in a milking parlor (including building costs) was estimated using the following function:

$$Y_i = 65,500 \times \log_e (X_i) - 225,000$$

where, Y_i denotes the total costs (including the building costs) of a milking parlor for farm i , and X_i denotes the herd size of farm i , with $40 < X_i < 200$.

The logarithmic function used gives credit for the decreasing marginal costs (euros per milking cow) of a milking parlor for increasing herd sizes. For an AMS and a CMS, salvage values of 10 and 5%, respectively, of the purchase value were assumed. The economic lifetimes were assumed to be 10 and 15 yr, respectively, for an AMS and a CMS. An interest rate of 5% was used.

Data Analysis

A descriptive analysis was carried out by using SPSS 13.0 for Windows (SPSS, 2005). For all variables, the standard deviation of the mean was larger than 50%, from which we concluded that none of the variables were normally distributed. To test the null hypothesis of no difference between AMS and CMS farms, a non-parametric test of 2 related samples, the 2-tailed Wilcoxon test, was used (Field, 2000). The 2-tailed Wilcoxon test calculates differences in matched pairs of observations. These calculated differences were ranked, based on the absolute values of the difference. The rank sums of the negative and positive differences were compared and used to determine the statistical significance of the difference between AMS and CMS farms. The AMS31 and CMS31 farms were analyzed for the year 2003. To monitor the development of the farms, the AMS16 and CMS16 farms were analyzed for the year 2002 and differences in the AMS16 between the years 2002 and 2003 and differences in the CMS16 between the years 2002 and 2003 were analyzed.

RESULTS AND DISCUSSION

Study Design

The year of investment in a milking system for a CMS farm was similar to the year of investment in a milking system for the comparable AMS farm. Table 1 shows the similarities in farm structure between the AMS and CMS farms in 2003. Total milk quota and land use did not differ between the AMS and CMS farms. However, the average milk quota of the farms was larger (almost 400,000 kg of milk) than the average milk production (442,904 kg of milk per farm) in The

Table 1. Average structure of 31 farms using an automatic milking system (AMS) and 31 farms using a conventional milking system (CMS) in 2003

Item	AMS	CMS	P
Total land use, ha	60.0	61.7	0.906
Pasture, ha	44.29	48.96	0.170
Milk quota, kg	828,761	853,620	0.196
No. of dairy cows	105	110	0.681
Total labor FTE ¹	1.45	1.87	0.001
Entrepreneurial labor FTE	1.07	1.62	0.001
Family member labor FTE	0.19	0.07	0.024
Employee labor FTE	0.19	0.18	0.737
Dairy cows/family FTE ²	85	65	0.001
Milk/family FTE, kg	674,642	508,017	0.001
ECM ³ /family FTE, kg	703,702	534,681	0.001
Dairy cows/total FTE	74	59	0.001
Milk/total FTE, kg	586,241	459,117	0.001
ECM/total FTE, kg	611,493	483,215	0.001
Milk/cow, kg	8,011	7,894	0.845
ECM/cow, kg	8,361	8,298	0.938

¹FTE = Full-time employee.

²Family FTE is the sum of entrepreneurial and family member FTE.

³ECM = Fat- and protein-corrected milk.

Netherlands (CBS, 2003). These data indicate that farms investing in an AMS are not average farms.

We examined the performance of the farms only after investment. It would have been preferable to make a “before and after” analysis. In that way, the impact on farm results of investing in an AMS could have been monitored. Because data from the accounting agency were available for only the most recent years, a “before and after” analysis was not possible. By using a case control design, the differences between farms were made as small as possible. Therefore, the farms were comparable and the results would be useful. Selection of data was done very strictly. If maximum differences in the matching criteria had been broadened, the number of farms included in the study could have increased. However, it was more important to have correct matching data instead of a larger number of farms.

The data originated from only 1 accounting agency. Using data from more accounting agencies also would have increased the number of farms, making the research more reliable. The disadvantage of using different agencies was that each agency has its own way of accounting, thus making it more difficult to make a comparison.

Structure of Farms

Table 1 shows the structure of the farms used in the study. The total amount of labor, expressed as full-time employee (FTE) equivalents, was smaller ($P < 0.001$) on the AMS31 than on the CMS31 farms. Gustafsson (2004) found 19% labor savings when using an AMS.

In our study, the AMS31 used, on average, 29% less labor ($P < 0.001$) than the CMS31. Labor costs for external workers were expected to be smaller for the AMS31 because less labor should be needed. However, in our study the use of external workers was almost equal between the groups. This meant that less home labor was used. This was also shown by the costs for external workers: the AMS31 was €7,982 and the CMS31 was €8,438. In our definition, 1 FTE of family labor equaled 2,540 h of labor (approximately 50 h/wk). One FTE of family labor is therefore not equal to 1 member of the family. When a member of the family works hard, he or she can work more than 2,540 h/yr. This family member often will be counted for >1 FTE. On average, 1,067 more ($P < 0.001$) hours of labor (approximately 20 h/wk) were required on the CMS31 than on the AMS31 farms. A hard-working family on a farm can compensate for this by working longer hours each day.

The range of the entrepreneurial FTE for the AMS31 (0.5 to 1.6) indicated that the majority of AMS farms were run by a single family, whereas the range for the CMS31 (1.0 to 2.5) indicated that some of the CMS31 farms were run by more than 1 family. This means that farm income must be divided. Because this information was not available, this can only be assumed.

As a consequence of less use of labor, the efficiency of the AMS31 was better. On farms with an AMS, more ($P < 0.001$) cows were held and more ($P < 0.001$) milk was produced by a single FTE, both for total FTE and for family FTE. No differences in milk production per cow were detected between the 2 types of farms. Although more cows per FTE were held on the AMS farms than on the CMS farms, average milk production per robot was 494,442 kg of milk. Because the capacity of 1 robot lies approximately between 600,000 and 750,000 kg of milk/yr (De Koning and Ouweltjes, 2000), the full capacity of the AMS on the farms in this study was not fully realized. For better economic results, it is important that the machine be used to its full capacity.

In Table 2, results of the AMS16 and CMS16 are shown, including differences between years. Between 2002 and 2003, the CMS16 farms grew, with greater ($P < 0.01$; 37,132 kg) milk quotas and 5 more ($P < 0.01$) cows, compared with the growth of the AMS16. As a consequence of differences in the growth in milk quotas and dairy cows, the efficiency per FTE (total FTE as well as family FTE) also was greater ($P < 0.01$).

The growth of the CMS16 and the stability of the AMS16 might be explained by the fact that dairy farmers using a CMS were able to grow stepwise within the existing farm structure. Annual investments would be in terms of milk quotas, whereas the farmers using an AMS must make large investments to grow (e.g., an additional automatic milking unit and a large quota

Table 2. Average structure of 16 farms having an automatic milking system (AMS) and 16 farms using a conventional milking system (CMS) in 2002 and differences in the structures of these farms between 2002 and 2003

Item	2002		<i>P</i>	Difference of 2003 – 2002		
	AMS	CMS		AMS	CMS	<i>P</i>
Total land use, ha	56.63	54.94	0.679	1.33	0.70	0.701
Pasture, ha	41.11	45.21	0.326	1.85	0.25	0.281
Milk quota, kg	779,420	763,357	0.379	–3,756	37,132	0.010
No. of dairy cows	95.97	96.03	0.756	0.47	5.00	0.009
Total labor FTE ¹	1.44	1.83	0.11	0.01	–0.07	0.078
Entrepreneurial labor FTE	0.98	1.51	0.003	0.00	–0.01	0.655
Family member labor FTE	0.24	0.08	0.168	0.01	–0.01	0.102
Employee labor FTE	0.23	0.23	0.733	0.00	–0.05	0.281
Dairy cows/family FTE ²	79.39	60.45	0.013	–0.76	20.06	0.003
Milk/family FTE, kg	646,351	470,154	0.001	–7,409	187,862	0.000
ECM ³ /family FTE, kg	683,697	484,632	0.002	–7,191	192,577	0.000
Dairy cows/total FTE	67.88	52.57	0.013	–0.76	5.73	0.008
Milk/total FTE, kg	553,942	399,854	0.001	–7,409	53,675	0.004
ECM/total FTE, kg	579,243	421,074	0.002	–7,191	55,022	0.004
Milk/cow, kg	8,249	7,711	0.255	–24	214	0.148
ECM/cow, kg	8,620	8,113	0.352	–15	189	0.196

¹FTE = Full-time employee.²Family FTE is the sum of entrepreneurial and family member FTE.³ECM = Fat- and protein-corrected milk.

amount). However, on average, dairy farms in our study were not utilizing the full capacity of the milking units. This indicates that there is space to grow within the existing capacity of the AMS. Another explanation could be that the farmers using an AMS already grew substantially after introducing the milking unit (average of 4 yr previously) and that farmers using a CMS were gradually catching up.

Economic Results

Descriptive Overview. Table 3 shows the averages and the 5th and 95th percentiles of revenues, costs, margins, nonaccountable costs, and RDILP. The calculation methods also are shown in this table. Differences between the systems are discussed later.

Dairy Production. Table 4 shows milk production on the AMS and CMS farms. The protein percentage was greater ($P < 0.02$) for farms using a CMS. Cows on the AMS31 were kept inside more often (van Vugt, 2005) and may have consumed less fresh, high-protein roughage. The ECM tended ($P = 0.065$) to be larger for the farms using a CMS. In Table 5, revenues, costs, and margins are given for the whole farm and are expressed per 100 kg of ECM. Because of the quota system and the greater prices of milk quotas in The Netherlands, the production capacity is made up by the milk quota. Milk payments are based on the amount of fat and protein delivered. To compare farms, the economic performance per 100 kg of ECM is important. A difference was shown in milk revenues (Table 5), both abso-

lute ($P = 0.003$) and per 100 kg of ECM ($P = 0.002$), between the AMS and CMS farms. The milk price was the same for the 2 farm types, but because of the larger protein and fat percentages, the ECM price was larger ($P = 0.002$) for the CMS31 farms. However, this difference was not expressed in the total revenues because of the numerically larger miscellaneous revenues of the AMS31. No difference was detected in costs. The margin on dairy production per 100 kg of ECM was nearly identical.

Growth of the CMS16 (monitored in Table 2) also is shown in Table 6. The difference in milk revenues (absolute) between years was greater ($P < 0.011$) for the CMS16 than the AMS16 farms. Costs did not differ. As a consequence, no difference in the absolute margin on the dairy was detected. When looking at the differences in milk revenues per 100 kg of ECM between years, no differences were found. Both systems showed a decrease in milk revenues compared with the previous year. This can be explained by an average decrease in the milk price in the Netherlands of €1.03 per 100 kg of ECM (Alfa, 2004).

Profitability. Costs for contractors and costs for gas, water, and electricity were greater ($P < 0.05$) for farms with an AMS than for those using a CMS (Table 7). Under Dutch circumstances, the contractor costs consist mainly of costs accrued to hire contractors for such things as harvesting. The larger contractor costs on an AMS farm might be explained by a different feeding strategy on these farms. On farms with an AMS, cows are more often held inside near the milking unit (van

Table 3. Average, 5th, and 95th percentiles of revenues, costs, margins, nonaccountable costs, and RDILP¹ (all in euros) for 31 farms having an automatic milking system (AMS) and 31 farms using a conventional milking system (CMS) in 2003

Item	AMS			CMS		
	Average	5th percentile	95th percentile	Average	5th percentile	95th percentile
Revenues						
Milk	274,556	145,863	445,676	287,333	149,436	422,934
Payment milk quota surplus	-1,013	-6,011	0	-808	-2,372	43
Milk quality penalties	-45	0	0	-52	-24	61
Livestock	18,243	5,548	29,865	17,629	-3,131	36,966
Miscellaneous	7,506	133	21,531	3,046	0	14,782
Total (a)	299,248	170,300	455,178	307,147	172,287	456,512
Feed costs						
Concentrates	40,718	20,316	68,686	44,057	22,152	71,548
Substitutes for concentrates	5,519	0	10,631	6,734	0	21,045
Roughage	3,414	-3,863	11,223	3,081	-10,099	14,570
Milk products	1,651	0	3,600	1,838	0	6,569
Other feed	2,901	201	7,220	1,410	114	4,185
Total (b)	54,202	27,067	87,178	57,120	28,803	102,021
Livestock costs						
Health	4,526	1,311	10,937	5,135	1,548	11,245
Medicines	3,036	0	7,932	3,078	0	8,542
AI and breeding	5,136	561	12,034	7,871	3,318	20,415
Miscellaneous	5,508	1,460	12,480	4,474	953	7,921
Total (c)	18,205	6,460	32,230	20,559	8,742	36,804
Costs of land use						
Fertilizer	7,443	2,462	13,711	7,048	3,130	12,410
Seed	1,991	0	6,595	3,699	336	9,465
Pesticide	1,169	0	4,779	1,810	0	4,776
Miscellaneous	794	0	1,768	391	0	1,040
Total (d)	11,396	4,497	24,969	12,948	4,476	27,379
Total costs (b + c + d)(e)	83,804	40,249	131,645	90,626	47,982	152,808
Margins						
Margin on dairy (a - e)	215,444	118,937	337,370	216,521	124,513	321,746
Margin other farm activities	3,286	0	14,638	2,651	-1,200	14,866
Other activities	12,813	0	41,302	13,347	779	37,173
Gross margin (f)	231,542	123,731	364,341	232,519	127,639	336,610
Nonaccountable costs						
Contractor	21,783	5,653	44,862	15,361	3,369	28,597
Maintenance and insurance of:						
Machinery and equipment	28,088	10,705	52,718	24,411	8,172	48,126
Land, buildings, installations	7,404	1,329	15,546	5,371	-748	14,594
Gas, water, and electricity	10,337	4,482	17,052	8,788	4,853	13,449
Other nonaccountable costs	12,002	6,395	17,883	11,093	6,561	16,044
Total (g)	79,614	42,934	125,890	65,025	29,829	102,327
Available for RDILP (f - g)	151,928	80,073	262,962	167,494	82,627	249,811

¹Rent, depreciation, interest, labor, and profit.

Vugt, 2005). Additional work flowing out of this change of feeding strategy might be carried out partly by contractors. The 29% lower labor requirement on AMS

Table 4. Average milk production, fat percentage, protein percentage, and ECM of 31 farms having an automatic milking system (AMS) and 31 farms using a conventional milking system (CMS) in 2003

Item	AMS	CMS	P
Milk production, kg/farm	836,095	847,057	0.203
Fat, %	4.33	4.37	0.264
Protein, %	3.42	3.47	0.017
ECM, kg/farm	870,585	891,057	0.065

farms (Table 1) might not necessarily be caused only by a reduced amount of labor for milking, but also could be caused by an increased use of contractors. For short-term (tactical) decisions, the margins are an important factor to consider. For long-term (strategic) decisions, the overall profitability of a farm is important. The net result (profit) of a farm is used many times. Although this is true for a specific farm, the net result is dependent on the financial structure of a specific farm. Comparing farms on the basis of the net result might therefore actually be merely a comparison of farm structures and not of farm management. The RDILP is therefore

Table 5. Average revenues, costs, and margins on dairy (in euros), absolute and per 100 kg of ECM, of 31 farms having an automatic milking system (AMS) and 31 farms using a conventional milking system (CMS) in 2003

Item	Absolute		<i>P</i>	100 kg of ECM		
	AMS	CMS		AMS	CMS	<i>P</i>
Milk revenues	274,556	287,333	0.003	31.53	32.27	0.002
Miscellaneous revenues	24,692	19,815	0.583	2.82	2.27	0.232
Total revenues	299,248	307,147	0.112	34.35	34.54	0.544
Concentrate costs	40,718	44,057	0.357	4.67	4.83	0.481
Total feed costs	54,202	57,120	0.290	6.47	6.33	0.845
Health costs	7,561	8,213	0.597	0.84	0.93	0.681
Total livestock costs	18,205	20,559	0.468	2.01	2.25	0.531
Land use costs	11,396	12,948	0.224	1.28	1.46	0.170
Total costs	83,804	90,626	0.164	9.76	10.04	0.505
Margin dairy production	215,444	216,521	0.597	24.60	24.50	0.953

a good measure to estimate the overall profitability independent of the farm structure. The RDILP represents the benefits and those cost factors that are not necessarily expenses. The RDILP was larger ($P < 0.05$) by €15,566 for CMS31 farms, caused by the smaller nonaccountable costs of the CMS31. The same results were found per 100 kg of ECM. No differences between the years 2002 and 2003 were detected for the CMS16 and AMS16 farms (Table 8). As a result of the growth of the CMS16, the RDILP increased, whereas the RDILP decreased in the AMS16. Because of the lower milk price, both systems decreased in RDILP per 100 kg of ECM.

When the most important profitability factors are expressed per FTE (Table 9), one can see that the AMS farms had greater ($P < 0.05$) revenues, margins, and gross margins per FTE than the CMS farms. The AMS farms had a numerically greater RDILP per FTE (€12,953) than the RDILP per FTE for the CMS farms. Because there was no difference in the use of external labor, this means that the farmers using an AMS do

not save money by reducing external work, but increase their opportunity costs by reducing their own labor. This is a clear advantage of automatic milking that might differ from farm to farm, depending on the opportunity costs of labor on a specific farm, which might vary from 0 to €21,840 (1,092 h at €20/h). In our study, opportunity costs of labor were not known. On the other hand, these findings show that AMS makes it possible for family farms to increase in size (in terms of total milk production per year, number of dairy cows, or both) without hiring additional personnel.

The results shown so far do not account for depreciation and interest. For several reasons, the exact depreciation of AMS and CMS are not known. Because AMS have been available on the market only since 1992, no reliable estimate of their economic life span exists. Moreover, the depreciation that is available in the bookkeeping system is the fiscal depreciation. Because of the Dutch fiscal system, yearly depreciation is set as large as possible to be able to deduct as much as possible for taxes. Because depreciation and interest are im-

Table 6. Average revenues, costs, and margins on dairy production (in euros), absolute and per 100 kg of ECM, of 16 farms having an automatic milking system (AMS) and 16 farms using a conventional milking system (CMS) in 2002 and the differences in structure of these farms between 2002 and 2003

Item	Absolute						100 kg of ECM					
	2002			Difference of 2003 – 2002			2002			Difference of 2003 – 2002		
	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>
Milk revenues	261,385	256,888	0.501	–3,203	11,392	0.011	32.17	33.62	0.001	–0.71	–1.04	0.278
Miscellaneous revenues	24,207	19,087	0.215	1,514	–817	0.501	2.83	2.41	0.326	0.22	–0.31	0.234
Total revenues	285,592	275,975	0.196	–1,689	10,575	0.098	35.00	36.03	0.255	–0.49	–1.35	0.056
Concentrate costs	36,431	35,346	0.605	516	991	0.301	4.56	4.60	0.796	–0.05	–0.16	0.918
Total feed costs	48,790	47,489	0.679	4,903	4,141	0.959	6.35	6.09	0.438	0.47	0.15	0.352
Health costs	6,549	6,532	0.796	4	1,040	0.134	0.77	0.87	0.352	0.02	0.10	0.379
Total livestock costs	17,562	16,717	0.569	–1,304	491	0.109	2.10	2.19	0.642	–0.18	–0.09	0.408
Land use costs	7,269	10,898	0.003	–83	478	0.255	0.91	1.43	0.004	–0.01	–0.07	0.756
Total costs	73,620	75,104	0.756	3,516	5,111	0.569	9.36	9.70	0.501	0.28	–0.00	0.501
Margin on dairy production	211,972	200,871	0.134	–5,205	5,465	0.063	25.64	26.33	0.501	–0.77	–1.35	0.469

Table 7. Average gross margins, nonaccountable costs, and available for RDILP¹ (in euros), absolute and per 100 kg of ECM, of 31 farms with an automatic milking system (AMS) and 31 farms with a conventional milking system (CMS) in 2003

Item	Absolute			100 kg of ECM		
	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>
Margin on dairy production	215,444	216,521	0.597	24.60	24.50	0.953
Gross margin	231,542	232,519	0.754	26.51	26.34	0.938
Contractor	21,783	15,361	0.004	2.55	1.81	0.003
Gas, water, electricity	10,337	8,788	0.021	1.24	1.01	0.007
Maintenance and insurance of:						
Machinery and equipment	28,088	24,411	0.136	3.15	2.72	0.078
Land, buildings, installations	7,404	5,371	0.104	0.88	0.60	0.122
Total nonaccountable costs	79,614	65,025	0.002	9.29	7.46	0.001
Available for RDILP	151,928	167,494	0.046	17.22	18.87	0.046

¹Rent, depreciation, interest, labor, and profit.

portant factors in the financial results of a farm business, we chose a normative approach toward depreciation and interest of the milking system. The average purchase value of the AMS (including costs for the building) was estimated to be €177,419, with a yearly depreciation of €15,968, and a calculated average yearly interest of €4,879. This resulted in average total equipment costs for an AMS, excluding maintenance (which was part of the data described above), of €20,847. The average purchase value (including costs for the building) of a CMS was estimated to be €78,210. Estimated yearly depreciation and average yearly interest were estimated to be €4,953 and €2,053, respectively. Average total yearly costs for a CMS were €7,006. This was €13,841 less than the estimated yearly costs for an AMS. In this respect, it should be noted that the AMS in our study were not used to full capacity, negatively influencing the depreciation and interest costs. Moreover, although most economic studies (Cooper and Parsons, 1999; Arendzen and van Scheppingen, 2000; Hyde

and Engel, 2002) use a shorter economic lifetime for an AMS, no reliable estimates exist on the economic life span of an AMS in comparison with a CMS. Because of the high-tech nature of the AMS, a shorter lifetime is assumed. However, this shorter lifetime may, in practice, be compensated for by a greater replacement rate of components of the AMS. The greater replacement rate of certain components can be found back in larger maintenance costs. In our study, we also found numerically greater maintenance costs for the AMS. The economic life span of the AMS is important because of its profitability relative to a CMS. If the economic life span of an AMS equaled that of a CMS, the difference in costs for depreciation and interest between the 2 systems would be €8,518 instead of €13,841. For future comparisons, it would be beneficial to gain more insight in the real economic life span of the AMS and CMS.

Given the present results, it is clear that profitability, in terms of money available for RDILP, is smaller in farms using an AMS. Moreover, farms with an AMS

Table 8. Average gross margins, nonaccountable costs, and available for RDILP¹ (in euros), absolute and per 100 kg of ECM, of farms with an automatic milking system (AMS) and 16 farms with a conventional milking system (CMS) in 2002, and the differences in the structure of these farms between 2002 and 2003

Item	Absolute						100 kg of ECM					
	2002			Difference of 2003 – 2002			2002			Difference of 2003 – 2002		
	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>	AMS	CMS	<i>P</i>
Margin on dairy production	211,972	200,871	0.134	–5,205	5,465	0.063	25.64	26.33	0.501	–0.77	–1.35	0.469
Gross margin	221,511	216,303	0.918	–4,092	4,188	0.098	26.90	28.39	0.121	–0.51	–1.73	0.121
Contractor	23,276	16,555	0.134	–3,535	–317	0.079	2.92	2.44	0.196	–0.41	–0.39	0.326
Gas, water, electricity	9,344	7,101	0.017	727	626	0.301	1.22	0.98	0.013	0.07	0.00	0.501
Maintenance and insurance of:												
Machinery and equipment	21,164	20,959	0.438	2,760	581	0.379	2.64	2.60	0.605	0.23	–0.06	0.134
Land, buildings, installations	9,103	5,856	0.017	272	–880	0.918	1.06	0.86	0.063	0.04	–0.28	0.679
Total nonaccountable costs	74,707	62,876	0.030	–449	–1,779	0.796	9.36	8.67	0.148	–0.14	–1.15	0.079
Available for RDILP	146,804	153,426	0.301	–3,643	5,966	0.148	17.53	19.72	0.121	–0.37	–0.58	0.717

¹Rent, depreciation, interest, labor, and profit.

Table 9. Average revenues, costs, margin on dairy production, gross margin, and money available for RDILP,¹ expressed for full time equivalent for labor (1 FTE = 2,540 h) for the difference between automatic milking system (AMS) and conventional milking systems (CMS) for the year 2003 and the difference between the years 2002 and 2003 within system (n = 16)

Item	Milking system		Milking system			
			AMS		CMS	
	AMS	CMS	2002	2003	2002	2003
No. of dairy farms	31	31	16	16	16	16
Total revenues	206,378	164,250 ^a	198,328	195,795	150,806	162,813
Total costs	57,796	48,463	51,125	53,197	41,040	45,577
Margin on dairy production	148,582	115,787 ^a	147,202	142,597	109,766	117,236
Gross margin	163,056	127,939 ^a	156,861	152,516	119,482	127,264
Available for RDILP	101,372	88,429	96,680	94,677	78,979	87,270 ^b

^aDifferent ($P < 0.05$) from AMS.

^bDifferent ($P < 0.05$) from 2002 within a milking system.

¹Rent, depreciation, interest, labor, and profit.

have larger depreciation and interest costs compared with farms using a CMS. This difference should be compensated for by using the amount of labor that has become available for the entrepreneur after installation of the milking robot. As calculated above, the maximum opportunity cost is, on average, €21,840 (1,092 h at a rate of €20/h). On average, this amount is insufficient to cover the increased costs of depreciation (€13,841) and the smaller amount of money available for RDILP (€15,566). This indicates that for many dairy farmers, adoption of an AMS system is more than just a purely economic decision, but a socioeconomic decision (Hogveen et al., 2004; Mathijs, 2004).

CONCLUSIONS

Our study is the first economic comparison of an AMS vs. a CMS using actual farm data instead of models. Thus, our results are unique and worthwhile. Results showed that farms with an AMS used, on average, 29% less (of their own) labor than farms using a CMS, whereas farms with a CMS grew more (37,132-kg milk quota and 5 dairy cows) than farms with an AMS (–3,756-kg milk quota and 0.5 dairy cows). Farms using a CMS had larger revenues (€7,899), but farms with an AMS had smaller costs, especially livestock (€2,354) and feeding costs (€2,918). Therefore, no differences in the margin were detected between the 2 milking systems.

Fixed costs (excluding labor, depreciation, and interest) were larger for the AMS farms than for the CMS farms (€4,589). Larger fixed costs were caused by larger contractor costs (€6,422) and costs for gas, water, and electricity (€1,549). Because of these larger costs, the farms using a CMS had more money available for RDILP.

When expressed per FTE, the AMS farms had greater revenues, margins, and gross margins per FTE than the CMS farms. The AMS farms did have a numerically greater RDILP per FTE (€12,953) than did CMS farms. Although depreciation and interest were not available in our study, normative calculations showed larger depreciation and interest costs for the AMS. When deciding between investment in an AMS or a CMS, dairy farmers must weigh decreased labor needs for the AMS against increased fixed costs of milking with an AMS.

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