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The Social Robot: A Study of the Social and Political Aspects of Automatic Milking Systems

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ABSTRACT

We explored social and political aspects of milking robot (automatic milking system; AMS) use and expansion in dairy farming. Over 30 % of dairy farms in Norway have an AMS, and the percentage is rapidly increasing. We interviewed 26 dairy farmers with AMSs in the county of Rogaland, Norway. Primary motives for investing in milking robots are a more flexible workday, reduced physical work, and a desire to join the perceived future standard of dairy farming. Although farmers are motivated by social factors, AMS is a key element in a structural change driven by political, economic, and social factors.

Key words: *milking robot; AMS; dairy farming; Norway*

Introduction

Dairy farming, a key sector in contemporary agriculture, has experienced major technological developments with several associated innovations. One of the most important is the introduction of milking robots or automatic milking systems (AMSs). Researchers have studied AMSs extensively within the fields of engineering, veterinary science, dairy technology, and, to some degree, management and agricultural economics. A milking robot is a device associated with increased efficiency and productivity, and consequently profitability in dairy farming. However, these issues are only a part of the picture. Social and political factors are also important to understand the proliferation of AMSs and their consequences.

It is estimated that more than 35,000 AMSs operate on dairy farms around the world (Salfer et al., 2017). Norway has one of the highest relative numbers of AMSs: more than one-third of the milk produced in Norway is milked by a robot. The first AMS was installed in Norway in 2000. In 2006, there were 170 robots, and by end 2015 there were 1,610 robots (Ministry of Agriculture and Food, 2016). Currently, more than 30 percent of dairy farms have installed an AMS, and the percentage is rapidly increasing. Approximately 200–250 AMSs are installed in Norway each year. This development is accompanied by substantial structural changes.

At the farm level, AMS have altered farmers' quality of life, and affected health, the environment, and safety. The introduction of AMSs has also affected socio-cultural aspects, such as household labor division and work-

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hour flexibility. There are various reasons for adopting AMS, and there are also benefits of using AMS. The primary arguments for investing in AMSs involve reduced labor and improved cow welfare, as reviewed by Drach et al. (2017). In a review of AMS studies, Jacobs and Siegford (2012) reported a decrease in labor by as much as 18 percent. However, other authors found little difference in labor use, but there were differences in task and work flexibility (Steeneveld et al., 2012). Similarly, Butler et al. (2012) found that although AMS reduced the need for labor in the milking parlor, farmers' labor changed rather than decreased.

According to Hansen (2015), farmers who invest in AMS emphasized the following main benefits: less time spent on milking, more interesting farming, more stable treatment of the cows, and less need for relief in the cow house. To achieve these benefits, farmers must succeed in implementing AMSs. Successful implementation depends on the motivation level of the farmers and whether they can adapt the new technology to their specific needs (op. cit.). AMSs may also have disadvantages for farmers, such as being constantly on call and information overload (op. cit.).

The aim of this paper is to explore the social and political aspects of the adoption and expansion of milking robots in dairy farming. Our research questions are:
What motivates farmers to invest in AMS?; How does AMS change the workday and family life at the farm?; and What are the political implications of the AMS expansion?

We answered these questions by studying AMSs in Norwegian dairy farming. We explored the social and political background for the current transformation of dairy farming, and we analyzed the resulting social consequences of introducing AMS into daily life on dairy farms.[1] First, we briefly present the method and the data upon which our analysis rests. Thereafter, we summarize and present the main findings on motivation, changes in everyday life, and some changes in the approach to being a dairy farmer. We continue by discussing these findings together at the farm level, and by discussing the aggregated effects of the AMS expansion.

Methods and data

The questions in this study are explored through a qualitative approach built on interviews. We interviewed farmers and other household members about why they invested in AMSs, and their experiences after the investment.

Our study is based on 26 interviews with dairy farmers who have AMSs in the county of Rogaland in Norway. The interviews were conducted in 2014 as part of a study of 36 dairy farmers who had built or renovated their cowsheds over the period of 2007–2010. Twenty-six of these farms had installed an AMS. Part of the interviews with these farmers was related to AMSs, and included questions such as why the farmers invested in AMSs; how the introduction of the new system worked for them and for their herd; how and to what extent they used the information from the AMS; what other related technology they used; and how the AMS influences farm management, the farmers' daily life, and their quality of life. The study is documented in Nærland (2015)[2].

Norwegian dairy farming has some structural and economic features that need to be outlined to make the context clear. The agricultural sector in Norway is oriented towards domestic production, and key productions

[1] This study is part of the Norwegian R&D project "New approaches for management and breeding of dairy cows, in automatic milking systems (AMS)" coordinated by the Norwegian University of Life Sciences and funded by Norwegian Research Funding for Agriculture and Food Industry, GENO, TINE, and DeLaval.
[2] The interviews were conducted by Torfinn Nærland. We are grateful to him and the individuals who granted us access to the interviews.

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such as dairy are supported by trade barriers and relatively high subsidies. This, in turn, has to do with agronomic and topographic considerations, and national policy preferences as a non-member of the European Union (EU). In a European context, Norwegian agriculture is small scale. The average farm unit is approximately 23 hectares, and the average herd size is approximately 26 cows. Although the average size is increasing, only 3 percent of the dairy farms have more than 70 cows (Budsjettnemnda for jordbruket, 2016). To understand why this structure prevails, it is necessary to be aware that the average piece of land is one hectare, and agricultural land may be rather scattered. This means that while economics of scale may be developed in-house, it is difficult to obtain the economics of scale in for fodder production.

The farmers in our study invested to renew their production and production facilities. They are also located in a part of Norway that is considered to be more production-oriented and intensive than many other regions in Norway. Thus, our sample of farmers represent more a future trend than a typical farmer in Norway, and that is why they were sampled. The introduction of AMS involved a significant increase in milk production on all 36 farms. On average, their milk quotas increased by 79 percent. From 216 tons 1 year before the investment (range, 71–444 tons), the average rose to 386 tons (range, 170–759 tons) 4 years later (Nærland, 2015). Because of heavy investment in new technology, we assume that the expansion of the 26 dairy farms with AMSs was considerably above average.

Of the 26 interviews, eight were with a husband and wife together, two were with a husband, wife and son together, five were with two individuals representing the farm (such as a joint farm, or an accountant), 10 were with male farmers, and one was with a female farmer. Altogether, 41 people were involved in the interviews, ranging in age from 24–65 years. Most individuals were in their 40s, and two-thirds were agronomists. In total, 19 of the farms were joint farming operations, where several independent dairy farmers work together and cooperate with a common herd and cowshed. Eight farmers also had sheep, eight had pigs, and four had poultry.

The interviews were taped, transcribed and analyzed using NVivo (QSR International).

Results

We present the results related to the two first research questions on farmers' motivations for investing in AMS and how the AMS changed their work and daily life. The last research question on policy aspects is answered in the Discussion.

Farmers' motivations for investing in milking robots

Investing in AMSs is often associated with a new or renovated cowshed and introduction of other robotic technology. However, the question in Table 1 was particularly related to AMS. We asked the farmers why they invested in milking robots. The question was open with no pre-formulated answers. The results are listed in Table 1.

Table 1. Farmers' motivations for investing in AMS

Category of motivation	**n=26***
More flexible working day	12
To be free of milking and related work, less physical strain	7
AMSs are the future, one must keep pace with the development	6
To make it attractive for the next generation (succession)	3
To expand production without depending more on other family members or hired labor	3

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To expand or maintain a working partnership	2
To improve animal welfare	1

* Some farmers had more than one motive.

The most frequently noted motivation was achieving more flexibility in work and in everyday tasks.

> That <a milking robot> was the future, and reduced the input of work and increases the flexibility, that you didn't have to go in the cowshed at fixed times. If there is some activity to join with the kids, we can go in the cowshed afterwards. You are more flexible, right. (Farmer)

Other farmers emphasized the physical work and their desire to take better care of their health and welfare.

> We thought of us ourselves who take care of and manage the farm, and found this a pleasant way of farming. Thinking about walking up and down milking X times a day <milking parlor>, and hip and knee and such things, and if we were to keep up as farmers, I felt this was the right way to do it. (Farmer)

A third important motivation is to have state-of-the-art technology and participate in development of dairy farming. A common opinion is that if you do not invest in AMS, there is a danger that you will fall behind technologically, weakening your business position.

> Well, I suppose it was … that one needed to follow the dance, you might say <keep pace with the times>, and not get the feeling of lagging behind. We wanted to take part in the things that happened, and at that time some new cowsheds were built, it was a way to renew yourself. (Farmer)

An important element of keeping pace with developments was to make dairy farming more attractive to potential successors. As one farmer said: "Our son gave us a clear message that we had to choose <the> robot." In some cases where succession is an issue, parents consider the milking robot to be a way to make the future as dairy farmers more attractive.

To invest in AMS is not always a straightforward process; some need time to consider the idea:

> I didn't want robot because I thought you lose all contact with the cows. I had <the impression that> the farm would become a factory. This was how I thought in the beginning. Then I saw, in the Cow Club I take part in, there are others who have invested in milking robots, so I just needed some time to become familiar with the idea. (Farmer)

Some farmers are very clear that specific motives prompted them to invest in AMS. Others have broader justifications for their motives, as this response illustrates:

> We have now a much better working situation. We have eliminated quite a lot of strain injuries when leaving that kind of work to the milking robot, and less bothersome, less lifting and such things. And the animals too, they become older now as compared to what they did in the old cowshed. They too have a better life down here, so in the long run this will still be the right way to go. And I think for the next generation it will be easier to take over when you have a complete and simple cowshed, than to keep on struggling with the patchwork up there <in the old cow house>, to put it that way. (Farmer)

There are various motives for installing milking robots. Most of the motives are related to working conditions and quality of life. However, nobody mentioned the economy as a motivation for investing in AMS. As one

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farmer said: "We didn't do this out of the economy because we knew it wouldn't become better." Thus, this study confirms that expectations of increased profits is not a motivation for investing in AMS.

In the next sections, we show how the farmers experience the new workday in practice. First, we present the new work situation for farmers. Then, we focus on how this new situation influences their quality of life from a household perspective.

A new workday

AMS radically changes the daily work routines in the cowshed. The changes are even more pronounced for farmers who simultaneously move their cows from a tie-stall barn to a loose-housing barn. The scope of the change also depends on how much additional computer technology farmers install along with the AMS. As one farmer said:

> Earlier you in a way did everything <in the cow shed> yourself, you gave concentrate, did the milking, and controlled everything. Now it is more about interpreting data and more office work. (Farmer)

From the interviews we identified changes in daily working activities that can be related to two categories: computer work and herd management.

Computer work: Facing data flow from computers

> Yes, the computer system has loads of information, tables and such. You can just go to the computer and watch the yield the last days. It is enormous volumes of information. (Farmer)

There are many data options to follow up and study depending on the type of AMS, and whether farmers possess other robots such as feeders. The most important options include consecutive milk production, activity measuring, cows in heat, consumption of concentrate, register of dry cows, the birth of calves, and a prognosis of total milk production. Much of these data were, and still are, registered in retrospect in the Norwegian Dairy Herd Recording System (NDHRS). Farmers with milking robots can transfer data from the robots to the NDHRS. For daily herd management, they can use both reports from the AMS and the NDHRS. Altogether, there are several reports and registrations that the farmer can monitor.

There is more than one way to make use of the data, and how farmers use the data varies. From the interviews, we can analyze to what degree the farmers make use of the different options. We have identified two categories: high and low levels of data options used. A low level suggests using only the most necessary data options.

We also observed differences in farmers' attitude towards data and working with computers. These differences are related to the farmers' computer competence. However, we did not examine this competence explicitly in the interviews; we only gleaned this information indirectly during the interviews. Therefore, we cannot be explicit about computer competence. Our impression is, however, that farmers with more competence make more use of the different data options. We categorized the farmers' attitudes as positive, neutral, and frustrated toward computers (Table 2).

Table 2. Relationship between farmer's attitude towards data options and use of options from AMS (n=26)

Attitude toward data options	High level of data options in use	Low level of data options in use
Positive	4	0
Neutral	10	11

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Frustrated	0	1

Although we cannot generalize statistically, our study indicates that farmers who have a more positive attitude use more data options. Below, we explore more in depth the data options and how farmers use them.

Accessing all the data is a challenge for some farmers. As one said:

> In general, I have very little interest in data and computers, so that I am suffering for now. I have learned just the minimum I absolutely have to. I see it is not hocus pocus. But to make the most of the data from the milking robot, to make use of it as information and to use it as a tool, clearly I have a lot left. (Farmer)

Another farmer described the new situation:

> I do not use these data as much as I could have done. Regarding those things, my daughter is much cleverer than me, and she tried to teach me. There are unbelievably many things you can find <from the> information, and I use of some of them. (Farmer)

The last quotation is from a farmer with high computer competence who had brought his daughter into the working partnership. In other interviews, there is an indication that female partners take on more responsibility with the computer work.

These quotations also indicate that some of the farmers' make excuses for themselves for not using more of the data options. It is almost like some of them feel somewhat ashamed.

AMSs force farmers to think and work more systematically. The following dialogue reveals how some farmers change their working practices in the cowshed:

> Male farmer: When we got the robot, I said that we now had to think in new ways, think differently.
>
> Interviewer: In the way you manage?
> Male farmer: Yes, we must make notes. This will be much bigger and we must think quite differently.
> Female farmer: Now we always have pen and paper in the cowshed, and we make notes to have the overview. We did not do that before.

However, some farmers find this new situation difficult. As one farmer said: "I find it very hard to sit down <by the computer> and do the things that are needed. I feel there is no time for that."

Becoming more flexible does not necessary mean more freedom, as one farmer said:

> … what has changed is that you have to bring the mobile with you to bed. You have to bring it with you everywhere, because of the robot. If something should happen, you must get a message immediately and act immediately. (Farmer)

We observed that milking robots bring about new technology such as computerized and cell phone-based data flow. Similar to many other types of jobs, this situation changes the farmers' daily lives. Some consider this to be a benefit while others see this as a restriction of freedom and something that increases stress.

From single cow care to herd management

Investments in AMS suggest changes in how farmers think about their herd. One farmer described the biggest differences in daily management that resulted from AMS:

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> It is about transferring the work from milking to looking after that the cows have been fed and milked. Further, we must move our minds towards avoiding power outages, or whatever we have to look after. <You become> more like a caretaker. You have to be pro-active to make sure everything works. ….. you need a herd management system to be able to follow all the dairy cows because there are so many. … To spend time <after the obligatory tasks> is always profitable. A few minutes with your hands in your pockets just observing the animals, that's quite profitable. (Farmer)

Another farmer also focused on herd management:

> ….. it is much more <about> observations. In the new cowshed you have much better overview. While I walk around watching the cows I throw a glance at the heifers, I see them too. You can keep an eye on them in your peripheral vision, and thus you have complete control of the whole herd at same time. (Farmer)

Another farmer emphasized how herd management has improved:

> The herd management is extremely much better. We have much better control of the 60 dairy cows we have here, than the 25 we had in the old <cow house>. Extremely much better. It is like night and day. … We have much better contact with the animals, observe and know every single animal better now than we did in the tie-stall, because we have <the> robot. … Now we can watch immediately how they move and if there is something wrong. We put more attention <on> whether the animal feels comfortable or not. (Farmer)

The strategy of how to perform the herd management varies between farmers:

> I see that we have to replace some more <dairy cows> in a loose-housing barn than in a tie-stall. For example we had a cow that had problems with her legs, and some problems with the robot, so we had to cull her. The robot did not manage to milk her, so we had to put bricks under the hind legs to make the robot able to get under the udder. So there are things like that, and there are more replacements now than in the old cow house. (Farmer)

Several farmers also recounted stories of how they attempted to make their dairy cows more comfortable during milking to achieve a smooth production.

The farmers were concerned about how their dairy cows behaved in the new cowshed. Cows that do not fit in with other cows are not popular. Similarly, animals that become agitated in the AMS, or animals that repeatedly have illnesses such as mastitis and high cell counts, are unpopular. Additionally, udders and teats that deviate significantly from an average size and shape may cause problems in the AMS. A slow milking cow is also less popular in the AMS because a slow milker causes a queue in front of the robot. One of the farmers said: "Of course some <of the dairy cows> must be culled. They are difficult to milk <in the AMS> and then it goes too slow." The change is most problematic for herds that come from a tie stall.

It is necessary for farmers to acclimate the herd to the milking robots. At one farm, the farmer used to concentrate the calving in the autumn, which allows farmers to have time off in the summer. The farmers wished to maintain this practice, but after some time with the milking robots they encountered problems with high cell counts. Concentrated calving exacerbates these problems because the milking robots require a minimum amount of cow traffic to work properly.

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> We realized that we must try to keep the production running continuously. It is best for the robot that it operates all the time, and then we achieve a constant milk quality. (Farmer)

Several of the farmers emphasized the need to follow up the herd:

> Interviewer: In your opinion, what are the most important factors to succeed with production?
> Farmer: To emphasize the production and spend time on that. Try to keep as many animals as possible because then you can cull the poorest ones. Then you will succeed in the production, the yield will increase, you get rid of sick animals and the animals that cause trouble in the robot, and the everyday life becomes much easier. It's as simple as that.

Popular beliefs about "robotization" are often related to dehumanization and alienation. However, items such as the AMS shift towards herd management and observation of cow behavior may be seen as a paradoxical, albeit positive, development in this perspective.

Improved quality of life for the farm household

There is a shared opinion among farmers that milking robots have improved their quality of life (the main motivations are also compared in Table 1).

> Interviewer: Has the working situation become like you thought it would be?
> Farmer: Even better, I think. It is more attractive, comfortable, more peaceful, quiet, and great to be in the cowshed to see how they are doing, and things like that.

In the quotation above the effect from the AMS alone can be difficult to separate in practice. Additionally, there are some reservations to the improved way of life, as we have presented above.

If farmers do not need to milk cows at specific times they can more easily join in social activities outside the farm and be more available to their family. For dairy farmers, it is particularly important to be able to join their children in activities after school in the afternoon and evening:

> <Without the AMS> I would never have had so much time together with both the children and my wife. Now I can walk in at 2 pm when the children come home from school and ask them if they want some help to do the homework or something like that. (Farmer)

Because the number of dairy farmers is declining, the lifestyle in the rest of the rural community is less adjusted to dairy farm rhythms. Thus, farmers may have problems taking part in social activities in their communities. AMS can change this situation.

The AMS also makes it easier for farmers to take care of babies, and thus a farmer invested in AMS much earlier than planned:

> We were planning to invest in milking robot, let's say after a period of 10 years, but then it became a reality after only 2 years. We had the children in mind; I saw how it was when number two came <child>. It was OK with the first one because I just brought him with me in the cowshed. He slept in the baby buggy, and we also had a swing in the milking parlor. … When we expected number two it became different, it became much more difficult for me to do all of it myself. That was the real reason why we realized and recognized we had money to do it <invest in AMS>. (Farmer)

Milking robots improve the farmers' health, according some of the farmers:

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> The biggest gain is the milking robot, the health gain we achieved from the robot, the shoulders and the hard work, knees, carry milk, yes, the whole body!

The introduction of AMSs also influenced the allocation of work between genders. Several farmers noted that their female partners were more involved in farming after they introduced AMS. These farmers also noted that women were often more familiar with and competent using Information and Communications Technology (ICT). Thus, handling computers may become increasingly the responsibility of women working on a dairy farm.

> Interviewer: But you, Maria, also did a job to run the computer?
> Female farmer (Maria): Yes, he <the mate> is very impatient—he has little patience to search when there is something he can't find … <laughing>
> Interviewer: So he sends you to search and he himself does something else meanwhile ….
> Male farmer: … and then she teaches me afterwards.
> Interviewer: You are efficient, benefitting from each other's competencies, nice.

AMS also changes physical tasks in the cowshed that can have gender aspects. As a female farmer pointed out:

> I am even more involved and can <more easily> take care of <all> the work during one day. I milked before too but it was not with pleasure. And the milking parlor was a pest because I was too small and had to bring a bench with me. Obvious, I do much more now and therefore my husband is much more flexible to do other things which I don't do. (Farmer)

Based on our data, we cannot conclude that we see a reshaping of the gendered nature of farm work because of AMS. However, our findings indicate that AMSs raise interesting gender issues.

However, not everything has improved. For dairy farmers, it is necessary to have a substitute to be able to have time off work, e.g. for weekends or holidays. Some farmers find it more difficult to find a substitute when they have an AMS, because the substitute needs specific AMS competence. As one farmer said:

> Because it is a computerized thing. People must know what they are doing. Things can happen with that <the milking robot>, a small happening is a stop you can fix yourself, but if you hire <someone> that is not familiar with it, then it is not so easy. Often there will be many phone calls, fussing and so on … That was something I had not thought much about. I thought it should be much easier, but it isn't. (Farmer)

Overall, the farmers in this study experienced an increase in their quality of life after they installed AMS. In particular, they note the increased flexibility and the decreased need for physical work.

Choices at the farm level have consequences at the macro level

In practice, investment in AMS implies investing in a new or renovated cowshed. To afford a new cowshed the volume of milk produced is increased, and this has a significant impact on the daily life on the farm, as the dialogue below reveals.

> Interviewer: What are the biggest differences in the daily work after the investment?
> Male farmer: It's more of everything.
> Female farmer: It is another way of working. You do not milk the cows anymore, but still it's much the same. You have to feed the calves and so on, you are responsible for the same tasks, just more of each. I feel there is just as much job indoors now as it was before. But outdoors, it has increased because you have much more land, more cultivated land and more pasture,

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> and there is more manure to spread. At same time, the equipment and the machinery is better, but we work more hours now than we did before.

Farmers expected the change in work to include more flexibility. However, some of the farmers did not expect the expansion in the work load, and some called attention to the practical changes in work by, for example, an advisory service. In short, the working hours in-house remained approximately the same as before installation of the AMS and the expansion, but the working hours out of the house increased. As one said: "Maybe it has become busier cultivating the soil than I imagined. The spring work takes more time."

Investing in AMS, combined with farm expansion, does not reduce the workload. We asked the farmers how much time they spent in the cowshed and most of them provided rough estimates. In general, they do not spend less time in the cowshed than they did before. Instead, the farmers remark that they work differently. Instead of milking, they spend more time following up the herd and on the computer, and they spend more time handling cows and calves. The latter is not surprising because the number of animals increased significantly on most of the farms.

The number of working hours in the cowshed varied from 2.5 to 10 hours a day, with an average of approximately 6 hours. As one farmer said: "It is almost always people in the cow house." In addition the workload varies as a function of the systems for feeding and manure handling. Automatic feeding for both concentrate and roughage, and robotic manure removal reduces the workload. However, there is still a need for cleaning and monitoring, observing the herd and particularly the cows, preparing fodder for feeding, and solving problems as they occur. One or two people often do this work.

Some farmers are very conscious of the total amount of work. Instead of utilizing the capacity of the AMS maximally, about 70 cows or more per robot, and increase production and turnover, they prefer to have less work and take more time off. One of the farmers said:

> We don't have max on the robot. It is not 60–70 dairy cows, but 40–50 is more common for us, and then it doesn't have to operate all day and night. So we have some slack here. (Farmer)

Discussion

The farm level

Investing in AMS is mainly motivated by quality-of-life considerations. However, this choice is accompanied by unplanned consequences at the farm level and structural changes in dairy farming at the macro level.

Installing AMSs is often associated with other investments such as automatic feeders. Our findings reveal that the motivation for these investments is to increase flexibility, ease the physical workload, and adapt to what is viewed as the future standard of dairy farming. All of these motives are more related to quality of life than to profit. None of the farmers expect increased profits based on their investments in AMSs.

However, our findings also reveal that there is no precise relationship between motivational factors and the influence on quality of life, as we discuss below. Investment in milking robots is followed by a significant increase in volume of production (i.e. 79 percent on average in our study). Compared with other countries, this rate of expansion is substantial. A Canadian study showed that farms increased their herd size from a median of 77 to 85 lactating cows (Tse et al., 2017 in press).

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AMS makes it easier for farmers to join in family life, take care of their children, and take part in social activities in their local communities. Our findings are in line with what a female farmer Kine Efteland Vølstad said in a newspaper:

> Each day is a new day. I spend an equal amount of time in the cow shed now as I did before, but the flexibility is totally different. Now I can both take the children to kindergarten and pick them up, and find more time for other activities than before. (Wiker, 2015).

The value of these benefits depends on the farmers' individual preferences. However, in the long-term, we argue that these changes are more socially sustainable for farmers. Our argument is also consistent with farmers who argue that milking robots are "the future", and are necessary to ensure that dairy farming remains attractive to potential successors. For most farmers, to know that there is a successor who wishes maintain production contributes positively to their quality of life.

Our findings also indicate that there is a new workday developing for dairy farmers. Less strenuous physical work on a daily basis directly influences health in the long term, and accordingly, quality of life is also influenced. Thus, future studies could explore the relationship between AMSs and farmers' health.

Computer-based work and data flow is a crucial change in the daily tasks. We find that farmers often do not take advantage of opportunities to generate information from the AMS data flow. Over time, it is likely that this will improve, because of farmers' improved competency, partnerships with competent workers, and improved user-friendliness of the AMS. However, many farmers may not be overly eager to explore the possibilities that the computer offers. Increased flexibility is the primary motivation for investing in AMS. When this flexibility is achieved, there is little motivation to engage in further exploiting the data. Suppliers of AMS and advisory services should be aware of this finding. In principle, this shortcoming can be improved in two ways: by increasing competence among farmers, and by increasing the user-friendliness of the AMS reports and indicators. If suppliers and advisory services base these on the farmers with the highest interest and competencies related to computers and data, they may even strengthen the differences between the categories of farmers indicated in Table 2.

For some farmers, a complex and often confusing situation arises when they are presented with a large volume of data from the milking robots, automatic feeding systems, and activity measurers for cows. This confusing situation embraces the feeling that farmers have when they: 1) do not know what options they have; 2) have a strong feeling that if they do not make use of the options they will be unable to run their dairy farm in an efficient way; and 3) regard the data and computer as a black box.

An aspect related to the data flow is access and ownership of data. Suppliers of AMS possess the data, transform them to information, and present them to the farmers. However, there may also be other uses for the data. To develop new knowledge, it is also important that data from the AMSs are available to research institutions. Thus, it is crucial that the farmers obtain access to, and have ownership of, the data. This issue requires further exploration and research.

Our finding related to gender is somewhat paradoxical. The literature on the gendered nature of agricultural work and technology has described the modernization of agriculture in general as a masculinization process, even though dairy farming as family farm man and woman more often share the daily tasks (Haugen, 2013; Brandth, 2002). Introduction of the milking machine brought the male farmer more into the milking work and influenced the women's position in farming. According to Almås & Haugen (1991, :80): "This technological

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innovation forced women into a secondary position in this previously important female task." Our findings suggest a more nuanced picture in the case of the AMS. Does use of AMS in a family farming context suggest new gendered dynamics in the technological development of agriculture? This issue needs further exploration.

Introduction of AMS is also related to a debate on how technological innovations influence ethical aspects of animals in modern farming (Driessen and Heutinck, 2014). One of these aspects is how the farmer observes the cows and how much time farmers spend together with the cows. Our study is consistent with Butler et al (2012), and shows that farmers do not spend less time in the cowshed, but that how they spend the time is different. They spend less time on milking and are less hands-on physically with each individual cow, particularly the udder. Instead, they spend more time observing the "whole" cow and the herd. The farmer is facing a transformation from emphasis on tacit knowledge toward an increased importance of codified knowledge, from hands-on to analysis. This changes the relationship with the animals, but does not challenge the ethical standards; it is rather the opposite because an increased herd size may have ethical effects that we have not studied.

Finally, expanding production also has a large influence on farmers' daily work. Expansion is related first to the maximum capacity of one milking robot (i.e. approximately 70 dairy cows per 24 hours). This limit may be viewed as a target to make optimum use of the robots. Second, there is a question of covering costs. A higher milk volume reduces the fixed costs per liter. Factors such as more milk, more fodder, the need for more land, and more transportation all translate into more work.

An important issue here is whether the cost of milking robots will decline such that even smaller farms can afford a robot without expanding their production in a manner that outweighs the benefits of the robot. Some farmers note that they purposely kept a smaller number of cows to keep the level of stress low.

Farmers' actions aggregated into structural effects

The introduction of AMS and related technologies in modern dairy farming is a good case of technological change with mixed causes and substantial and far-reaching consequences. The technical breakthroughs related to advances in sensor and robot technologies are required preconditions for the technological change. However, there is no linear development from technical inventions to the spread and use of new technologies. For AMS, the technological development appears to be melded together with social, economic, and political forces, creating substantial structural changes.

Our study indicates that farmers seek to constantly "position" themselves for the future. Therefore, the investments seem to be driven partly by social motives and partly by expectations of the future development in farming. It would be incorrect, however, to ascribe the societal change to farmers' wishes and motives alone. Agricultural development tends to be highly political, and Norwegian dairy farming is no exception.

Milk production has, from the 1980s on, been regulated through milk quotas. Gradually, the quota system has opened for redistribution and structural change, i.e. become more dynamic. Beginning in 1997, the state could buy out quotas from farmers who wished to quit dairy production and redistribute parts of the quota to expanding farmers (Partssammensatt arbeidsgruppe, 2007). In 2003, farmers could also begin to sell and buy milk quotas on the private market within regional borders. In 2008, farmers were allowed to rent quota, which accelerated the structural change in dairy farming.

Another important politically regulated development in the Norwegian dairy business is the growth and decline of joint farming. Joint farming—independent farmers who join their resources to create one joint

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farming enterprise—has existed in Norway since the 1970s. However, the number of joint farming enterprises increased from 146 in 1995 to 1,973 in 2008 (Almås and Vik, 2015), partly because of extra subsidies for joint farming (Stræte and Almås, 2007). After 2008, because of the legalization of quota renting, the number of joint farming enterprises started to decline. Since 2015, the scheme for acreage support changed so that the financial incentives for joint farming disappeared. Therefore, the number of joint farming enterprises continued to decrease to 954 in 2016 (Norwegian Agriculture Agency, 2017).

The development of, and increase in, AMS intervened in this political development. When AMS was introduced on the Norwegian market, few single farm units had the resources and the quota basis to sustain the investment. Together with the economic support and the social advantages of joint farming, the possibilities of investing in AMS made joint farming a preferred organizational model for many farmers who needed to upgrade their farm. These preferences have now changed so that farmers choose single-farm solutions instead.

Investing in an AMS remains costly. Farmers need to increase their income after the investment and attempt to utilize most of the capacity of their robot(s). For most dairy farms in Norway, this change in capacity implies a substantial potential increase in production. The average number of cows per farm between 1979 and 1999 increased from 9.6 to 13.3. In 2015, the average number of cows per farm was 26. Most farmers who invest in a robot today plan for between 45 and 60 cows. Thus, AMS drives the average size rapidly upwards. Because the total amount of milk produced in Norway is relatively stable as a result of constraints in the domestic market, the development indicates a substantial structural change at the aggregated level. From 1999–2015, the number of dairy farms decreased from 26,468 to 8,287. AMS also tends to imply a substantial increase in milk yield per cow. From 1999–2016, the number of cows in Norway decreased by approximately 40,000. Because the Norwegian red breed is a combined breed, the result was a corresponding decrease in beef produced from the dairy farms.

Therefore, even though farmers are motivated by social factors, AMS is a key element of a structural change that is driven by political, economic, and social factors.

Conclusion

We have identified important social aspects of increased AMS distribution. Overall, these new adoptions and changes in dairy farming have affected the structure of dairy farming. The primary motives for investing in milking robots include a more flexible work day, reduced physical work, and a desire to join what is regarded as the future standard of dairy farming. Consequences of introduction of new technologies are identified for everyday work and quality of life. In addition to achieving increased flexibility, farmers face new opportunities and challenges related to data and computer work and in management of the herd. The investment in AMS most often includes a substantial expansion in milk production that necessitates an increased need for fodder, transport, and labor at the farm level. Data registration and implementation of the AMS and accompanying technology change the practices of farm management.

The implications of our findings are as follows: investing in robots stems from qualitative motives among the farmers. However, this investment is also associated with unplanned consequences at the farm level and structural changes in dairy farming on the macro level. The development indicates a substantial structural change at the aggregated level. AMSs are currently among the primary drivers of structural change in Norwegian dairy farming.

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