Revised paper for NJAS, special issue "Social responses to 'Smart Farming': emerging (re)configurations of practices and institutions"

The political robot – The structural consequences of automated milking systems (AMS) in Norway

Abstract

In this article, the aim is to explore how social aspects of the adoption and expansion of milking robots in Norwegian dairy farming are related to the political and structural changes in the sector. To explore the relationship between the implementation of automated milking systems (AMS) and structural developments, we used a qualitative methodology building on data from interviews with farmers, policy documents, statistics, and secondary literature. The structural change in the Norwegian dairy sector was substantial between 2000 and 2018. The average number of cows on each farm increased from 14.4 to 27.9, while the number of farms decreased from around 21,000 to less than 9,000. More than 47 percent of the milk produced in Norway now comes from a dairy farm with an AMS, and this percentage is rapidly increasing. We argue that the structural developments in milk production in Norway are neither politically nor economically driven, but are mainly an unintended consequence of farmers' aggregated investments in AMS – which are supposed to increase farmers' everyday quality of life – and reluctant regulatory changes to make investments in AMS structurally and economically viable.

Keywords: milking robot; automated milking systems (AMS); political responses; social responses; dairy farming; Norway

Introduction

Background and theme

Technological innovation and structural developments in agriculture are closely linked. The introduction and spread of automated milking systems (AMS) in Norwegian agriculture is no exception. Milking robots have become a significant feature in Norway, and the dairy sector has gone through rapid structural change over the last decades. Structural change includes changes such as number of farms, average size, regional concentration of farms, and so forth. Currently, Norway has one of the highest levels of AMS in milk production in the Nordic countries (NMSM, 2019). In 2016, Norway was first in front of Iceland in the proportion of total milk produced by milking robots (TINE, 2018). By the end of 2018, 47 percent of Norwegian milk production came through an AMS (TINE, 2019). The average farm size in terms of number of cows almost doubled from 14.4 in 2000 to 27.9 in 2018. Thus, the average size of a dairy farm is steadily increasing with AMS usage. However, although the correlation between new technology and structural change is not surprising, the underlying causality is uncertain.

The aim of this paper is to explore how the adoption and expansion of AMS in dairy farming are related to the political and structural changes in the sector. Our findings suggest that, at farm level, the drive toward investing in AMS cannot be explained by economic rationality alone. Economically, investments in AMS under Norwegian conditions show very mixed results (Hansen et al., 2018), and farmers who invest in AMS do not – in general – expect increased profits. Norwegian farmers' motives for investing seem to be of a more social character. Norwegian farmers invest in milking robots to improve their everyday life – socially and professionally – and they increase the production to finance their investment. Politically, for the parliament, it has not been a goal to stimulate structural change. However, there have been gradual and reluctant (until 2014) policy changes allowing for both individual and aggregated adaptations, from which structural change has resulted.

On the one hand, structural change is associated with increased productivity and improved economic conditions for farm households. On the other hand, structural change can have unwanted effects such as concentration of production in some regions, farming communities in decline in the less favored regions, increased renting of land, underutilization of arable land, increased fodder imports, and so forth (Arnoldussen et al., 2014; Forbord et al., 2014).

This may be seen as an illustration of what van der Ploeg describes as a macro–micro contradiction: "what is rational at the micro level emerges as irrational and counterproductive at the macro level – is typical of present day agriculture and especially, I would argue, for today's race to the bottom" (Van Der Ploeg, 2000, 506). Our study also indicates that there are micro–macro contradictions, although we would argue that there is more to this development than a race to the bottom. On both the micro and the macro level, the consequences of technological change are profound and mixed – positive *and* problematic.

The Norwegian context

Norway is a high-cost and wealthy welfare state. Living standards and labor costs are high, and access to capital and technology is relatively abundant. Land, on the other hand, is scarce (Forbord and Vik, 2017). Only 3 percent of Norwegian land is arable land, and, in a European context, Norwegian agriculture is relatively small-scale. In 2018, the average farm unit was 24.9 hectares and the average dairy herd size was 27.9 milking cows (Statistics Norway, 2019). Furthermore, agricultural lands are rather scattered, and the average discrete piece of land is only one hectare.

The agricultural sector in Norway is oriented toward the domestic market. As Norway is not a member of the European Union, the Common Agricultural Policy does not regulate Norwegian policy. Neither do Norwegian producers have free access to European markets. Nonetheless, the agricultural sector is highly regulated. There are five key elements in the Norwegian agricultural policy model (Almås, 2016): i) high trade barriers on products important for Norwegian farmers; ii) a high level of direct farm payments negotiated annually between the government and the farmers' organizations; iii) corporative market arrangements around key production areas such as dairy, meaning that farmers' cooperatives and agricultural authorities work together in the regulation of the market; iv) a regulated market for farm properties; and v) a geographically distributed production structure that is regulated by a mixture of diversified support schemes and quota regulations, which conserve a structure in which grain is produced in the best climatic zones and animal husbandry of various kind – e.g. dairy – is kept in the less favorable regions. For more than three decades, milk quotas per farm have regulated the supply side of the Norwegian market – a market where total domestic production has remained stable around 1,500 million liters a year (Budsjettnemnda, 2019).

Literature review

Dairy farming, a key sector in contemporary agriculture, has experienced major technological developments with several associated smart-farming innovations. The introduction of milking robots, or AMS, is in some countries among the most significant of these developments because it has fundamentally changed farmers' working day and farmer–animal relations (Butler et al., 2012; Holloway et al., 2014; Hårstad, 2019; Rodenburg, 2017). Currently, it is estimated that more than 35,000 AMSs operate on dairy farms around the world (Salfer et al., 2017), and AMS usage has achieved a substantial position in family-based dairy farming.

In Norway, the first AMS was installed in 2000 (Kjesbu et al., 2006). By the end of 2016, out of a total of 8,486 dairy farms, 1,726 had robots, and the number of AMS farms is increasing. Approximately 200–250 AMS units are installed in Norway each year.

The new technology has prompted a wide range of studies across various disciplines such as technology, veterinary, livestock, economic, and so on (Bentley et al., 2013; Hansen, 2015; Tse et al., 2018). AMS usage is regarded as a kind of precision farming (Eastwood et al., 2017) included in precision livestock technologies (John et al., 2016) and smart farming. Precision farming is about in-field efforts, and smart farming is "basing management tasks not only on location but also on data, enhanced by context- and situation awareness, triggered by real-time events" (Wolfert et al., 2017, p.70). For example, data generated from AMS are a crucial element in smart farming. Developing algorithms and/or tools for real-time monitoring and the accompanying decisions creates a strong smart-farm tool to improve farm management.

From a human–machine relations perspective, it is emphasized that this relation is a form of cooperation to manage and control for uncertainty and risk (Wessel et al., 2019; Hoc, 2000), but these human–machine relations also activate new debates about ethics, like how this technology influences "bovine freedom, autonomy and choice" (Holloway et al., 2014, p. 139). The complex human–machine relation has other aspects related to important motivations for farmers, such as their perceptions of their quality of life. At farm level, AMS usage has altered farmers' quality of life and affects their health, safety, and the environment. The introduction of AMS has also affected socio-cultural aspects that include household labor division and work-hour flexibility. AMS suppliers' primary arguments for investing in AMS involve reduced labor and improved cow welfare (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 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' workload changed rather than decreased. According to Hansen (2015), farmers who invested 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. Several studies imply that the main motivation for farmers to invest in AMS is not economic, but rather to improve their quality of life and achieve a more flexible working day (Hansen, 2015; Stræte et al., 2017; Hårstad, 2019; Rodenburg, 2017).

AMS usage is a stage in farmers' development, increasing their technical capacity and their economic scale. A milking robot is a device associated with increased efficiency and productivity and is therefore expected to have consequences for the profitability of dairy farming. Some studies find evidence that profitability increases (e.g. Tse et al., 2018), whereas others have mixed findings (Hårstad, 2019; Hansen et al., 2018). However, the consequences for profitability are likely to be highly context (and therefore country) dependent.

Investments in productivity-enhancing technologies may also be viewed as part of what has been called the agricultural treadmill (Ward, 1993) or the race to the bottom (Van Der Ploeg, 2000; Marsden, 1998) where the investments increase productivity and production, while farmers' margins decrease as a result of the reduced market price and increased costs and debts. In the literature, strategies of specialization/diversification are somewhat contested (de Roest et al., 2018; Halfacree 2007). In this study however, we examine at a more general level why dairy farmers invest in AMS. Is it a disruption in technology or production, or is it a path-dependent strategy? Barnes et al. (2016) hold that farmers tend to follow the pattern of action from the past, i.e. path dependency . Investment in technology and competence are examples of arguments for maintaining existing production methods. Burton (2004) argues that the cultural orientation among farmers in general indicates that being a 'good farmer' implies intensive agricultural production, although one may ask whether it is necessary to invest in AMS to continue being a good farmer. At another level, the momentum created by considering an investment in AMS may be a key nodal turning point (Wilson, 2007), also referred to as a 'trigger point', in the farm life cycle (Sutherland et al., 2012).

In general, the studies reviewed above do not address (or treat only implicitly) the relations between micro-level motives, expectations, and experiences on the one hand, and macro-level structural change on the other. Our study contributes to the field by exploring how farm-level adaptations to AMS technologies are related to macro-level political and structural change in the Norwegian dairy sector.

Outline

To explore the relationship between AMS implementation and structural developments, we used a qualitative methodology building on data from interviews with farmers, policy documents, statistics, and secondary literature. The rest of this paper is organized as follows. First, we describe our methodology and data, and thereafter we present our findings on structural change; farmers motives for, and experiences with, AMS; and agricultural policy developments. Finally, we discuss the relationship between the mentioned issues and sum up in a conclusion.

Methodology

In our study, we adopt a qualitative approach. Methodologically, we take a pragmatic stance and utilize an abductive logic (see e.g. Tavory and Timmermans, 2014). Below, we elaborate briefly what this means for our study. Pragmatism implies a modest approach and does not, according to Feilzer (2010, p. 13), "… require a particular method or methods mix and does not exclude others. It does not expect to find unvarying causal links or truths but aims to interrogate a particular question, theory, or phenomenon with the most appropriate research method." Whereas inductive logic starts with data and deduction starts with theory, abductive logic starts with a consequence and we (as scientists) construct reasonable causes that fit the available observations (Tavory and Timmermans, 2014, p. 37).

The practical consequence of the abductive line of reasoning is that we do not expect that one particular theoretical frame or approach is likely to *a priori* give a good representation of the linkage between the micro-level motives and expectations and the macro-level structural consequences. Such models (to our knowledge) do not exist. Our approach, therefore, is to explore the relationship in a pragmatic manner.

We have included different kinds of empirical data. We consulted the core policy documents and secondary sources to describe the Norwegian dairy production sector and related policy changes. We have also taken statistics from various sources to describe the structural changes in the sector. Together, these enabled us to describe the development of the dairy sector in Norway from late 1990 to 2018 in terms of production, policy, and structure. In addition, we conducted 26 interviews with dairy farmers who had installed AMS. These gave us useful insights regarding the motives for implementing AMS as well as experiences with the AMS way of being a dairy farmer. Our data sources are summarized in Table 1.

Table 1. Overview of data sources and uses regarding Norwegian agricultural policy

Type of data	**Source**	**Mainly used to**

Policy documents	White paper Meld.St. 11 (2016–2017) (Ministry of Agriculture and Food, 2016) White paper Meld.St. 9. (2011–2012) (Ministry of Agriculture and Food, 2011) White Paper St.Meld. nr. 19 (1999–2000) (Ministry of Agriculture and Food, 1999) Government strategy Agriculture Plus (Ministry of Agriculture and Food, 2005) The Sundvolden statement (Government, 2013) The Soria Moria declaration (Government, 2005)	Describe the political changes in Norwegian agricultural policy
Secondary sources	Almås (2016) Almås and Vik (2015) Grue (2014) Hårstad (2019) Stræte and Almås (2007) Vik et al. (2017)	Describe the political changes in Norwegian agricultural policy
Statistics	Statistics Norway (2019) NMSM (2019)	Describe structural changes
Interviews	Own interviews. See also Nærland (2015)	Describe motives and narratives of investments and development on farms and so on

The interviews were all held with farmers in the county of Rogaland in Norway; taped, transcribed, and analyzed using NVivo (QSR International); and anonymized. They were conducted during 2014 as part of a study of 36 dairy farmers who had built or renovated their cowsheds over the period 2007–2010. The farms were identified from the public register of farms that had received subsidies from governmental authorities and from information from municipalities, banks, and the dairy cooperative, TINE. Twenty-six of these 36 farms had installed an AMS. These make up the sample used in this study. Farmers were selected on the basis that they had been operating for at least three years in a new cowshed to be sure that they had sufficient experience with AMS.

Of the 26 interview participants, eight were husband and wife families, two were husband, wife, and son families, five were two individuals who represented the farm (such as joint farmers or an accountant), ten were male farmers, and one was a female farmer. Altogether, 41 people were involved in the interviews and ranged in age from 24 to 65 years. Most individuals were in their 40s, and two-thirds were educated agronomists. In total, 19 of the farms were joint farming operations in which several independent dairy farmers worked together and cooperated with a common herd and cowshed. Eight farmers also had sheep, eight had pigs, and four had poultry.

The farmers in our study invested to upgrade their production facilities for dairy farming. Furthermore, they are 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 does not represent all kinds of Norwegian farmers, as those who have not invested are not represented.

The questions posed to the farmers addressed their experience in planning and building or rebuilding a cowshed and included questions such as why the farmers invested in AMS, how the new system worked, how and to what extent they used the information from the AMS, what other related technology they used, and how the AMS influenced farm management, the farmers' daily life, and their quality of life. The study is documented in Nærland (2015) and Hansen and Nærland (2017).

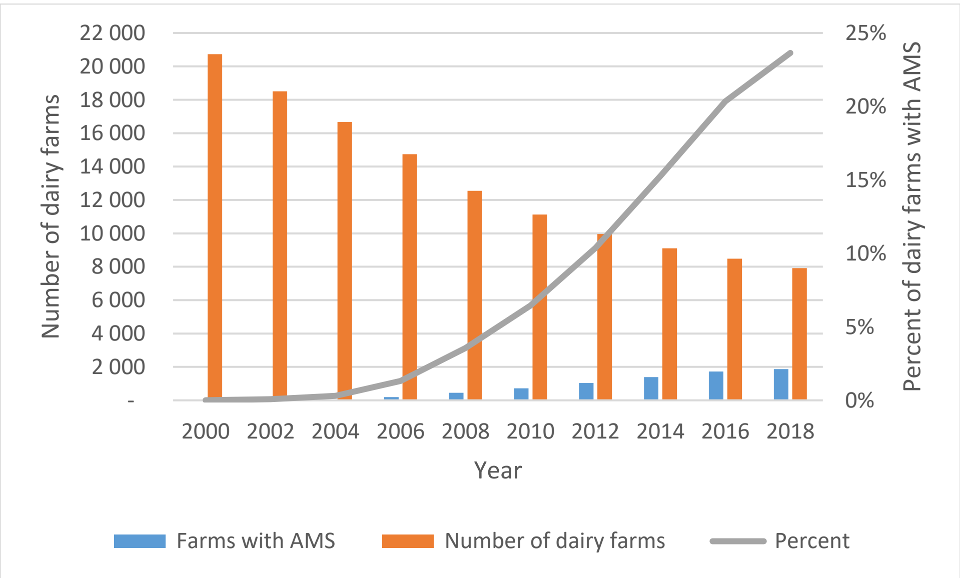
Results and analysis

In this section, we first present the structural changes that have taken place. Thereafter, we present a series of factors related to the introduction of AMS that may form part of an explanatory model of structural changes in the dairy sector. These are, first, factors at farm level, such as motivations, strategies, and needs of the farmers and farms households, and, second, political factors related to the changing regulative agricultural regime.

Milking robots and structural change in the dairy sector

The first milking robot in Norway was installed in 2000. Since then, there has been a rapid increase in the number of robots, particularly after 2006. By the end of 2018, there were 1,943 farms with AMS. This is close to 24 percent of all dairy farms, and these farms produce 47 percent of total milk production (TINE, 2019). Figure 1 illustrates this development.

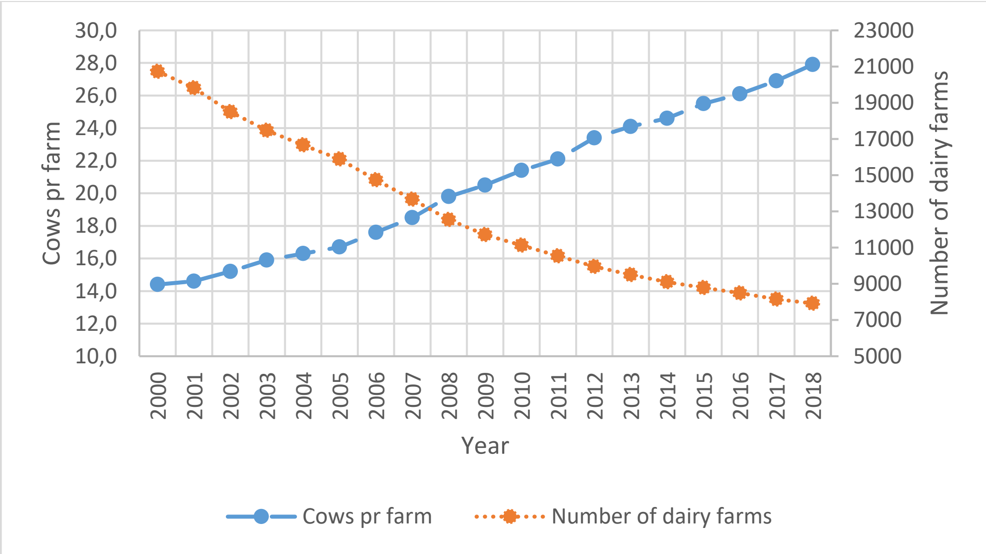
Figure 1. Dairy farms with AMS in Norway 2000–2018



Source: NMSM, 2019; Statistics Norway, 2019

The structural change in the Norwegian dairy sector was substantial over the period 2000–2018 (Figure 2). Figure 2 shows that the average number of cows on each farm has increased from 14.4 to 27.9. AMS usage and the upgrading of cowsheds also imply a substantial increase in milk yield per cow. Consequently, from 2000 to 2017, the number of cows in Norway decreased by approximately 30 percent, but production has remained stable.

Figure 2. Structural development in dairy farming in period 2000–2018, Norway



Source: Statistics Norway, 2019

As mentioned above, the Norwegian milk market is, with a few exceptions, a domestic market (see e.g. Almås and Vik, 2015; Vik and Kvam, 2017). This means that an average increase in the number of cows is accompanied by a corresponding decrease in the number of producers. The number of producers has declined from around 21,000 in 2000 to less than 9,000 in 2018. A milk quota system regulates production, and a quota trading system makes it possible for some farmers to expand while others can exit dairy farming. In addition, there is a limit on how many liters any one farm can produce per year. The quota system has become an integrated and important part of the corporative agricultural arrangements of Norwegian dairy sector (Almås and Brobakk, 2012; Almås and Vik, 2015; Grue 2014)

Clearly, the structural change pictured in Figures 1 and 2 is accompanied by a series of other developments and changes, besides the introduction of AMS. The regulatory framework has changed, production on individual farms has changed, and workload as well as productivity have changed. Below, we shed light, first, on the micro-level motives and experiences associated with AMS implementation and, thereafter, on the key elements in agricultural policy development from 2000 to 2018.

Farmers’ motivations for investing in milking robots

As we have seen, Norwegian farmers to a large degree embraced the new AMS technologies as they became available. But why? What is it with this technology that is so appealing? We now proceed to show how farmers themselves describe their motives and strategies for the changes that they have made. We asked the farmers an open-ended question as to why they invested in milking robots. The results are presented in Table 2.

Table 2. Farmers’ motivations for investing in automated milking systems

Category of motivation	**n=26[a]**
More flexible working day	12
To be free of milking and related work, less physical strain	7
AMS is the future, one must keep pace with developments	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
To expand or maintain a working partnership	2
To improve animal welfare	1

[a] Some farmers had more than one motive.

The answers summarized in Table 2 indicate that a more flexible working day and an improvement in the character of the work are the most widely held types of motivation. The next two types of motivations are about positioning for the future. To elaborate on the farmers’ reasoning in these matters, we present some of their statements.

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 increased the flexibility, … you didn't have to go into the cowshed at fixed times. If there is some activity to attend with the kids, we can go into the cowshed afterwards. You are more flexible, right. (Farmer)

Several farmers also emphasized the motivation to have state-of-the-art technology and participate in the development of dairy farming. A common opinion is that, if you do not invest in AMS, you are in danger of lagging 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 update yourself. (Farmer)

An important element of keeping pace with development is 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." Thus, in some cases, parents consider the milking robot to be a way to make the future of dairy farming more attractive.

Whereas 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:

> Now we have 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 ahead. 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)

Most of the motives are related to working conditions and quality of life; no one mentioned increasing profits as a motivation for investing in AMS. As one farmer said: "We didn't do this for economic reasons because we knew it wouldn't become better." Thus, this study confirms that an expectation of increased profit is not a main motivation for investing in AMS. This is in line with studies that revealed that Norwegian average-sized farms that have invested in AMS, at least in the short run, have lower profits than dairy farms with conventional milking systems (Hansen et al., 2018; Vasseljen, 2016). However, the fact that farmers do not mention economic motives does not mean that the motives may not be conceptualized and analyzed in economic terms if that is an aim. In the same way, the fact that the farmers didn't expect increased profit doesn't mean that profits will not be affected. Still, it is interesting that economic concepts and consideration is not mentioned as the motivational drive for investing in AMS by the farmers. This is a point that relates to Forbord and Vik (2017), that found that access to labor and land – but not capital – were limiting factors for farmers to increase production.

Improved quality of life for the farm household

All the farmers interviewed shared the opinion that milking robots in general have improved their quality of life, relating to both their farm work and their everyday life. The lifestyle in the rest of the rural community is less adjusted to dairy farm (without AMS) rhythms now, as dairy farmers make up a smaller part of the community. Thus, farmers sometimes face problems taking part in social activities in their communities. AMS can change this situation. If farmers do not need to milk cows at specific times, they can more easily attend social activities outside the farm and be more available to their family. For instance, they are able to join their children in activities after school in the afternoon and evenings:

> [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)

However, although AMS usage has clear benefits, not everything improves. Dairy farmers need to have a relief worker to be able to take time off work, e.g. at weekends or holiday time. 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 issue is a stop you can fix yourself, but if you hire [someone] who 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 of. 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, there was an increase in flexibility and a decrease in the need for physical work.

Expanding farm production

In practice, investing in AMS implies investing in a new or renovated cowshed. The interviews show that, for many, the investment is partly financed by increased production. To afford a new cowshed, the volume of milk produced must be increased, as the profit per liter is difficult to increase to a sufficient degree, and this has a significant impact on daily life on the farm. One farmer put it this way: “It’s more of everything.” His partner elaborated:

> It is another way of working. You do not milk the cows anymore, but still it’s much the same. You need 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 work indoors now as there was before. But outdoors, it has increased because you have much more land, more cultivated land and more pasture, and there is more manure to spread. At the same time, the equipment and the machinery are better, but we work more hours now than we did before.

Another farmer gave this short response “… the production in the new cowshed and with the milking robot is multiplied compared to the old cowshed, and the work is displaced from milking to feeding and feed production.”

Farmers expected the change in work to include more flexibility. However, some farmers did not fully account for the increased workload. In short, the working hours in-house remained approximately the same as before the installation of the AMS and the expansion, but the working hours outdoors increased.

Thus, investing in AMS, combined with farm expansion, increases workload. This is not surprising, because the number of animals increased significantly on most of the farms. On average, the farms increased their milk quotas by 79 percent (Hansen and Nærland, 2017).

Some farmers are very conscious of the total amount of work. Instead of utilizing the capacity of the AMS maximally, about 70 cows per robot, and increasing production and turnover, they prefer to have less work and 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."

Agricultural policies as a frame for dairy farming

Having addressed the micro-level aspects of the interviewed farmers' motivations and experiences, we now need to assess agricultural policies. A key question is whether the structural change may be ascribed to Norway's changing agricultural policy. To get a grasp on this, we went through the major developments and shifts in that policy in the period from 2000 to 2018. This aspect of our data collection is based on key policy documents from the period, as well as secondary literature. Table 3 describes the turning points and developments in Norwegian agricultural policy relevant to the dairy sector from 2000 to 2018.

<Table 3 around here>

Multifunctionality is the term used to describe the agricultural policy regimes in Norway and many other countries from the mid-1990s until the international food crisis in 2007/2008. Norway has had a quota regulation for milk production since 1983 (Almås and Vik, 2015), although gradually the quota system has been opened for redistribution and structural change. 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). However, the system was rather inflexible (Grue, 2014). This changed in 2002, when tradeable milk quotas were introduced on the private market (within regional borders). The maximum quotas for single farmers and for joint farming were also increased at that time. From 2008 on, the fact that farmers were allowed to rent quotas accelerated the structural change in dairy farming. These changes were politically contested, especially the opening of quota trading, and became important topics in the annual negotiations between the Ministry of Food and Agriculture and the farmers' organizations. The changes in quota regulations were responses to technological and organizational developments, rather than to some factor that was pushing change (Grue, 2014).

Another important, and politically regulated, development in the Norwegian dairy business was the growth and decline of joint farming. Joint dairy farming has existed in Norway since the 1970s. However, the number of joint farming enterprises started to increase in the early 1990s. It 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). For some farmers, the establishment of joint farming was a growth strategy. However, after 2008, thanks to the legalization of quota renting, growth became possible without establishing joint farming. The number of joint farming enterprises then started to decline. Since 2015, the scheme for acreage support has changed, so that there are no governmental financial incentives for joint farming. The number of joint farming enterprises has since continued to decrease and had reduced to 954 in 2016 (Norwegian Agriculture Agency, 2017).

Internationally, the agricultural policy discourse changed after the food crisis. Focus shifted from multifunctionality to neo-productivism. Although the content and consequences of both concepts are contested (Tomlinson, 2013; Wilson 2008; Wilson and Burton; 2015), the interest in increased production and food security peaked (e.g. Carolan, 2013). It took some time before the new food security focus appeared in Norwegian policy, but in a 2011 white paper (Ministry of Agriculture and Food, 2011) a new and more production-oriented line of thinking emerged. However, this did not manifest in policy until after a new Conservative/Right government came to power after the 2013 election. Then, policies changed in favor of the larger farms, in terms of both higher maximum quotas for dairy farmers and an increase in direct support for producers with more land and higher production (Vik et al., 2017; Ministry of Agriculture and Food, 2016).

Two key points are apparent from the development of Norwegian agricultural policy regarding dairy production. First, the policy changes caused milk production to take place on fewer and larger farms – there was a steady concentration of dairy production. Although this is in line with a policy focusing on productivity, it challenges the political goal of maintaining agricultural production all over rural Norway (Ministry of Agriculture and Food, 2011). Second, except for the changes in 2014 initiated by the new government, the policy changes regarding structural change were adopted rather reluctantly by policy actors (Grue, 2014).

Discussion

We have seen that investing in AMS is motivated mainly by quality-of-life considerations. Installing AMS is often associated with other investments, such as automatic feeders and modernized cowsheds, and the investments are partly financed by increased production. Our findings reveal that the motivations for these investments are to increase flexibility, ease the physical workload, and adapt to what is viewed by the mainstream dairy industry as the future standard of dairy farming. All these motives are more related to quality of life than to profit.

None of the farmers expects increased profits based on their investment in AMS. Yet, the farmers do, to some degree, use income from increased production to pay for the new AMS. AMS usage makes it easier for farmers to have more of a family life, take care of their children, and take part in social activities in their local communities. The value of these benefits depends on farmers' individual preferences. However, we argue that, in the long term, these changes make farming more socially sustainable for Norwegian farmers. Our argument is in line with the farmers who argue that milking robots are "the future" and pivotal for ensuring that dairy farming remains attractive to potential successors. For most farmers, knowing that there is a successor who wishes to maintain production contributes positively to their quality of life and job satisfaction (Hansen and Stræte, in review).

The spread of AMS may be seen as a part of the intensification of agriculture associated with several new productivist trends (Burton and Wilson, 2012. Yet, the farmers' focus on quality of life considerations rather than profit imply that what we observe – as do Mackay and Perkins (2019) – is far from an agro-business of "super-productivism" where profit maximization is the core element (Halfacree 2007).

Still, investment in milking robots is followed by a significant increase in the volume of production per farm. Compared to 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, i.e. a 10 percent increase (Tse et al., 2017). This difference in production increase may reflect the fact that, because Norwegian dairy farming is more small scale than Canadian dairy farming, it is necessary to increase more in order to utilize the robot's capacity. It is also important to note that so far, robotic milking seems to be a phenomenon that first and foremost is of relevance to a farm structure fitted for one to three robots (Hansen et al.

2018; Tse et al., 2017; Rotz, Coiner and Soder 2003). For larger herd sizes, other technologies may be more relevant. Nevertheless, within this range the macro-level consequence in a sector oriented toward the domestic market may be a substantial structural change.

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

Our study indicates that farmers seek to position themselves for the future. The future is not a constant though. Both the overall agricultural discourse and the realities of rural Norway influence the farmers' envisioning of the future, and their investments seem to be driven partly by social motives and partly by expectations for the future developments in farming. Basically, this is a household strategy used to prepare dairy farming for the coming years. However, investing in AMS remains costly. Most farmers need to increase their production after the investment and attempt to utilize most of the capacity of their robot(s). Even so, it is not clear, in the Norwegian case, whether investing in AMS is a strategy of specialization, or of diversification, which Valiant et al. (2017) identify as a method that will bring the younger generations into farming operations.

It would be incorrect 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. First, the Norwegian political economy, as an oil-fueled welfare state, has made it possible to support agriculture both through a protective trade policy and a high level of subsidies (Forbord and Vik, 2017). Evaluations of the Norwegian investment schemes has shown that investments are made possible both through substantial governmental subsidies and private subsidizing with income from diversification (Pettersen et al., 2009; Sand et al 2019). Second, there has been a political willingness both to use resources and to adapt the regulatory framework. The structural change would not have been possible without a changed regulatory framework. When AMS was introduced to the Norwegian market, few single farms 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 for investing in AMS made joint farming the preferred organizational model for many farmers who needed to upgrade their farm. These preferences have now changed so that farmers choose single-farm solutions, but with the production capacity of the joint farming enterprises. Lately, it seems that the regulation of the dairy sector has provided the changes necessary for adapting to a new technological reality, which possibly became a more active stance after 2014.

This Norwegian study indicates that investment in AMS is an important optional strategy for dairy farmers. The strategy is part of an overall plan for the survival and development of the family farm. The aggregated consequences of many farmers' decisions influence the structural development of dairy farming in general. Our study also indicates that the reduction in work caused by AMS is substituted by increased outfield work, particularly the production and transport of feed. Overall, investing in AMS means that dairy farmers achieve increased flexibility but end up with a greater workload than before because of their increased production.

To sum up, our model of change may be described as follows. The cowshed and milking system need to be renovated when worn out, normally after 25–30 years. If the household wants to stay in dairy farming and have a flexible modern social life, investment in AMS is seen as a good option. Therefore, farmers who invest in AMS are motivated by social factors, a wish to increase flexibility and quality of life, and to stay in dairy farming. To cover the investment costs, there is a drive to utilize the capacity of the AMS, i.e. to increase the volume of production. Thus, AMS usage is a key element of the structural changes that take place. The increase in production is a function of the need to finance the investment. To allow for these micro-level adaptations, policymakers have followed up with openings for buying and renting quotas.

Policy is shifting though: since 2014, the government has actively pushed farmers in the direction of structural change through a new distribution of governmental funding to benefit the larger producers (Vik et al., 2017). Increased attention on the structural consequences led to a shift in direction when agricultural policies in 2017 were adjusted by the Parliament (*Stortinget*) to give more support to small and medium-sized dairy farms (Stortinget, 2017).

The micro-macro contradictions addressed by, for example, van der Ploeg (2000, 506) are also evident in our study. However, the extent to which this represents a race to the bottom may be questioned. Our study suggests that, at farm level, improvements in everyday life point to increased social sustainability, although economically, in terms of increased profit, the investments seem uncertain. As shown, the aggregated changes in dairy farm structures challenge some of the policy objectives for agriculture in Norway, especially the objective of maintaining farming in all rural districts. However, farmers' associations and policymakers are aware of what is happening and seek to adjust policies in relation to challenges at both the macro and the micro level.

Conclusion

In this article, we have shown that Norwegian agriculture experienced substantial structural developments alongside the introduction of AMS in the dairy sector from 2000 to 2018. These structural developments are likely to be strongly influenced by the implementation of new technologies. Whereas the increase in the average number of cows per farm in the 20 years between 1979 and 1999 was less than four cows (from ten to around 14) (Committee of Budget for Agriculture, 2017), the increase in the next 18 years was 14.4 cows to 27.9 cows (Statistics Norway, 2019). Most farmers who have rebuilt their cowsheds and invested in a robot have, until recently, planned for between 40 and 60 cows. Thus, AMS usage has driven the average size rapidly upwards. Because the total amount of milk produced in Norway is relatively stable consequent to constraints in the domestic market, this development reveals a substantial structural change at the aggregated level. Between 2000 and 2018, the number of dairy farms decreased from 20,734 to 8,150 (Statistics Norway, 2019). However, in the last couple of years, even small and medium-sized dairy farms have invested in AMS. Supported by a recent change in governmental policy (active from 2018 onward), the structural change at the aggregated level may be less in coming years than in the period from 2000 to 2018.

Following abductive logic, we have discussed various factors related to this development. The primary motives for investing in milking robots relate to quality of life, including a more flexible workday, reduced physical work, as well as a desire to achieve what is regarded as the future standard of dairy farming. Investment in AMS most often includes a substantial expansion in milk production that entails an increased need for fodder, transport, and labor at farm level. The domestic political framework has not pushed the observed structural developments; rather, policy has adapted to them. Neither are the structural developments pushed by farmers' need or wish to increase incomes. Farmers' motives are more of a social character, and their modest economic expectations are supported by experiences and economic results.

However, the described structural and political changes must be seen in light of both the ideational shift in the direction of neo-productivism (e.g. Mackay and Perkins 2019; Wilson and Burton, 2015), and the context of the Norwegian political economy (Forbord and Vik 2017). The situation, however, seems to be that the structural developments resulting from the introduction of robotic milking in Norwegian agriculture are a series of unplanned consequences of farm level strategies, political adaptations, technological characteristics, and milking robot capacities.

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Statement of author contribution

NN1 was responsible for the policy approach of the article (regarding the structure) and contributed to other parts such as the Introduction, Discussion, and Conclusion sections. NN2 interpreted the farmers' interviews, contributed to other parts of the manuscript, and edited the manuscript. NN3 and NN4 designed the study and the interview guide. NN3 interpreted interviews with farmers and contributed to the writing. NN4 carried out interviews with farmers and added some information regarding other parts of the manuscript. All four authors have contributed to the manuscript and are equally responsible. The order of the authors reflects the work done in writing this article.

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Table 3. Norwegian agricultural policy developments 2000–2018

Year	**← 2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018 →**
Government	**Labor 2000 to 2001**	**Center/Right, 2001 to 2005**		**Labor/Center, Oct 2005 to 0ct 2013**				**Right (H/Frp), from Oct 2013**		
International focus in agricultural policies	Multifunctional perspectives				Food crises and food security			New overproduction problems		
Official agricultural policy documents and *Key perspectives*	White Paper St.Meld. nr. 19 (1999–2000) *Multifunctionality (and moderate structural development in dairy production)*		Government strategy Agriculture + (in 2003) *Diversification*	New government platform The Soria Moria declaration *Multifunctionality*			White paper Meld.St. 9. (2011–2012) *Food security Increased national production while upholding distributed agriculture*	New government platform The Sundvolden statement *Cost-effective agriculture*	White paper Meld.St. 11 (2016–2017) *Efficient production while upholding distributed agriculture*	
New/changed funding schemes			Increased investment funds to diversifying farmers					Increased support for high production levels (meat, milk, land)		
Milk quota regulation	Governmental trade with quotas since 1997	Tradeable quotas (effective from 2003)			Possible to rent quota (effective from 2009)		Increased flexibility in milk quota trade system			
Max quota	Increased maximum quota from 170,000 to 400,000 liters for single farms and from 400,000 to 750,000 liters for joint farms							Increased maximum quota to 900,000 liters		
Joint farming	Extra subsidies for joint farming		Extra subsidies removed							

Source: Grue, 2014; Almås and Vik, 2015; Vik et al., 2017; Almås, 2016; Government, 2005, 2013; Ministry of Agriculture and Food, 2005, 2011, 2016, 1999