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Loose housing-nothing to lose? Exploring the on-farm profitability and agricultural policy consequences associated with a tie stall ban on dairy farms

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Due to stricter animal welfare regulations, in Norway tie stalls for dairy cows are banned from 2034 onwards. The aim of this paper is to explore the profitability and agricultural policy consequences associated with the transition from tie stalls to loose housing. Data on farm economics and investments were collected from farm enterprise budgets on 66 farms that have built new cowsheds in recent years in Vestland county. In Norway, many medium or large sized farms have already renewed or built new cowsheds with loose housing. However, many dairy farms have less than average and often scattered farmland, which makes it challenging to make investments in new cowsheds profitable. To demonstrate the challenge facing these farms, Vestland was chosen because on average it has the smallest dairy farms in Norway, with 45 percent of the herds having less than 20 cows. To analyze profitability, we compared different farm sizes based on their expected rates of return, required investment, and anticipated revenue over time. The findings show that irrespective of herd size, to continue farming with an upgraded tie stall is more profitable than to invest in new loose housing. For farms with less than 30 cows, investment in new loose housing is on average not profitable. Unless the Governmental investment grant is significantly increased, the tie stall ban will have large consequences for farm structure and conflict several agricultural policy goals. Farmland in less favored areas may go out of production, making it more difficult to reach the policy goals of increasing food production, agriculture across the country, reduced greenhouse gas emissions, biodiversity and rural viability. Our findings are of interest to policymakers in countries where one considers stricter animal welfare regulations, as well as planners and farmers who consider investing in new loose housing dairies.

Key words: cattle housing, animal welfare, small dairy farms, farm expansion, profitability

Introduction

As a result of stricter animal welfare regulations, Norwegian famers will be required to keep cows and cattle in loose housing from 2034 onwards, and further use of tie stalls will be banned. Yet almost 60 percent of Norwegian dairy farms have tie stalls and these farms produce one third of the Norwegian milk production (Mikalsen et al. 2021). These are mainly small and medium-sized farms, with 18 dairy cows on average (Mikalsen et al. 2021). In addition to the loose housing requirement, by 2024 all dairy farms must have a minimum of one calving pen per 25 cows, a minimum of 16 weeks of summer grazing if conditions allow it (otherwise reduced to 12 weeks), and the opportunity to free movability the rest of the year (Lawdata 2004). In the next decade considerable investments are needed on small and medium- sized farms to adapt to these regulations. However, many farms with limited farmland are not able to make investments profitable given today's governmental financial support scheme (Jensen and Larsson 2020).

Dairy farming is going through a process of structural change. In many regions of Norway agricultural land is scattered, and the survival of farms in marginal and remote areas has been heavily supported by Government payments. The transfers to farmers are payments for production of public goods, positive externalities and services valued by the society but not paid for in the market. Without such payments, many of these farms would not exist, and their continuation heavily depends on the agricultural policy. Norwegian agriculture is small-scale, except from some significant regions in Østlandet, Jæren and Trøndelag. However, farms located outside these regions make up a considerable proportion of production and land use. The last two decades many Norwegian dairy farmers have invested in automated milking systems (AMSs) to obtain a more flexible lifestyle (e.g. Hansen 2015, Burton and Farstad 2020). To achieve economies of scale farms with sufficient farmland have expanded farming and invested in loose housing and AMS. Today, more than 56 percent of the milk produced in Norway comes from dairy farms with AMS, and the percentage is increasing (Mikalsen et al. 2021). Sand et al. (2019) claim that for an investment in AMS to be profitable, a farm needs to have at least 30 cows, and therefore few small and medium sized farms have invested in loose housing (Sand et al. 2019). When interpreting this figure, one

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one should consider that in a European context agriculture in Norway is small scale. Moreover, to understand why this structure prevails, one must be aware of that the average field size is one hectare, and agricultural land may be rather scattered. To fund investments farmers usually need to increase their production level, but for many small and medium-sized farmers this is not possible or desirable, typically due to lack of farmland in the vicinity. Overall, the need for large investments in loose housing has left many farmers on small and medium-sized farms with tie stalls uncertain about the future (AgriAnalyse 2016). Small to medium-sized dairy farms are important for the maintenance of farming in rural communities – both economically, socially, and culturally. They also contribute to food security and preparedness in Norway through production (Bjørkhaug and Rønningen 2014) and keeping the landscape open (Almås 2004). Marginal agriculture in Norway also contributes to preservation of biodiversity and cultural heritage (Shucksmith and Rønningen 2011). The importance of smaller farms in economic terms, has also been demonstrated in Europe (Pinter and Kirner 2014, McDonagh et al. 2017). While in some European countries, retailers have considered to stop selling milk from tie stall barns in unprocessed food, that has not yet been discussed in Norway.

According to Halland et al. (2021), Norwegian dairy farmers need to invest in total between 18 and 22.8 billion NOK to adapt to the loose housing regulation. In this study we explore the consequences of the tie stall ban in Vestland county. In a recent study very similar to ours, (Haukås et al. 2022), 43% of the dairy farmers in Vestland reported that they will exit farming before 2034 due to the loose housing regulation and the new regulations requiring separate calving cubicles from 2024 on. Vestland embraces coastal and inland areas in Western Norway, and is characterized by high mountains, fjords and islands. The farmland typically consists of small and distant plots, some of it relatively steep. For example, the average land plot size in Voss, one of the main dairy farming municipalities in Vestland, is 1.6 ha (Stokstad et al. 2020). The fragmented structure puts limits on farm expansion, without heavily increased emissions and transport costs. We chose Vestland because on average, it has the smallest dairy farms in Norway, and 70 percent of all cowsheds are tie stalls (Mikalsen et al. 2021). As compared to the rest of Norway, the number of farms and hectares of farmland in Vestland has declined faster (Johnsen and Smedshaug 2016). In Vestland the farmland has declined by 11 percent in recent years, and studies have shown that some of this land will most likely go out of operation (Johnsen and Smedshaug 2016). Haukås et al. (2022) also report that some farmland in Vestland will most likely go out of production due to the tie-stall ban. The reason is that the remaining farmers do not always have the capacity to operate the vacant farmland in addition to their own farmland due to small field sizes and high transportation costs. In Norway, dairy production and beef production constitute one system, rather than separate beef and dairy systems. More than 95 percent of dairy cows are of the breed Norwegian Red Cattle (NRF), which combines both beef and dairy into one breed (Bonesmo et al. 2013). Despite many good reasons to keep up small to medium-sized combined dairy and beef farming in Norway, these farms will face huge challenges of adapting to the loose housing regulation. While the figures in Halland et al. (2021) illustrate the economic consequences of a tie-stall ban at the sector-level, in this study we aimed to explore the consequences at farm level. Our research questions are: 1) How profitable is it to invest in loose-housing in Vestland county, and 2) How is profitability associated with herd size? To answer our research questions, we analysed 66 enterprise plans on farms that have invested in loose housing between 2016 and 2020.

The current situation in other Nordic countries and in Switzerland

As in Norway, in Denmark and Sweden loose housing is mandatory for all new-built cowsheds (Retsinformation 2017, Jordbruksverket 2019). However, to the best of our knowledge, except Denmark and Norway no other countries have introduced an order that all existing farms should keep cows in loose housing. In Denmark, loose housing is mandatory from 2022 (Retsinformation 2017), yet almost 95 percent of all dairy cows in Denmark are already in loose housing (Mejeriforeningen 2021). Furthermore, the herds in Denmark are significantly larger compared to Norway, with on average 227 cows (RYK 2020). Therefore, loose housing is the only practical solution.

In Sweden around 40 to 50 percent of the cow herds are in tie stalls, which amounts to approximately 20–30 percent of all cows (Jordbruksverket 2019). However, on farms with less than 50 cows, approximately 95 percent are in tie stalls (Jordbruksverket 2019). With respect to animal welfare, research from Sweden (Gustafson 1993) has shown that for cows in tie stalls, health in general was significantly and positively influenced by exercise, reducing the need for veterinary treatments. Moreover, cases of non-infectious leg and hoof disorders were also notably more frequent in the control group without exercise Gustafson (1993). However, Bergsten (2001) reported that foot and leg disorders that resulted in lameness were more frequent in loose housing compared to tie stalls. In a recent report The Swedish board of agriculture has explored possible consequences of a ban of tie stalls

(Jordbruksverket 2019). According to the report about 1600 dairy farmers and 177 000 cows will be affected by a possible ban. The costs for all existing farmers to adhere to a possible ban is estimated to between five and seven billion SEK (Jordbruksverket 2019). However, it is expected that instead of re-investing in a new cowshed, many farmers will instead cease dairy farming. This may result in less biological diversity, less viable rural communities, and reduced self-sufficiency in milk (Jordbruksverket 2019). Therefore, other incentives than regulations should also be considered, such as e.g. financial support and advisory assistance (Jordbruksverket 2019). Furthermore, what are considered small and medium sized farms with less than 50 cows in remote areas will be affected the most, and the need for transitional provisions and exceptions is highlighted (Jordbruksverket 2019). At the moment of writing the report is with the Swedish Government.

Switzerland has somewhat similar production conditions and average herd size as in Norway, with about 22 cows, varying from less than 20 in the hill region to more than 30 in the plains (Agristat 2019). Tie stalls are common (Odermatt et al. 2019), and loose housing is not mandatory. However, organic farms are obliged to let their cows outdoors at least 13 times per month, even during winter. To promote the provision of animal- friendly housing, a pull strategy with economic incentives and information is preferred over a push strategy involving demands and regulations. On small farms it is considered that tie stalls work well because the close relationship between farmer and cow, e.g. with regular brushing of each cow. Two governmental programs exist to promote the provision of more animal-friendly husbandry and management. The BTS program requires that farms have a loose housing system, lying area separated from the feeding area, feeding area with solid flooring and deep litter and soft mattresses in cubicles (Odermatt et al. 2019). The other program, the RAUS, requires that cows receive regular exercise in an outdoor run in the winter together with a minimum of space per cow, and at least 26 days per month on pasture from May 1st to October 31st. Furthermore, at least 25 percent of the dry matter should come from pasture (Odermatt et al. 2019). Participation in both the BTS and RAUS programs have resulted in a 10% cost reduction and indicates that the implementation of higher welfare standards can have a positive effect on farm economics (Odermatt et al. 2019).

Finally, in Finland a country with farming conditions similar to Norway, in 2019 there were about 6350 dairy farms in Finland with on average 41.3 cows per farm (Eläinten-hyvinvointikeskus 2021). A rapid structural change is ongoing, and in the period 2014 to 2019 the number of dairy farms decreased by 6.9 percent annually (IFCN 2020). The number of cows in tie stalls is declining steadily. In 2013 more than 50 % of the dairy cows registered in the herd recording, covering 80 % of all cows, were in tie stalls but in 2021 this number was reduced to 31 %. With respect to animal welfare, research from Finland (Kivinen et al. 2007) has shown that clean cows, healthy hoofs and proper dimensions of the cubicle are important for the functionality of the cowshed. As a result of this research new larger dimensions for cubicles and manure alleys were cows can move free were suggested. AMSs have some positive effects on udder health as compared to conventional milking systems. Thus, Hovinen et al. (2009) compared cows transferred from tie stalls and loose housing to conventional or automatic milking systems. Cows transferred from tie stalls and loose housing to automatic milking systems had slightly better udder health in terms of risk for high somatic cell count than those transferred to conventional milking systems. Since 2019 no government investment grants have been given to any new tie stalls for dairy cows or heifers. There are also plans to change the investment grants so that in free stalls, the cows must have access to either a walking area outdoor or grazing. A new animal welfare law is currently sent for consultation among all stakeholders. In the draft there is a ban for building new tie stalls. The old tie stalls may however still be used, without any deadline. The new law is coming to the Parliament at earliest spring 2022 and will come into act from beginning of 2023.

The Norwegian context

The Norwegian agricultural policy is multifunctional (Vik et al. 2019). Besides providing food, the agriculture produces public goods like biological diversity, tourism, experiences, welfare services, value creation across the country, cultural landscape and cultural monuments (Ministry of Agriculture and Food 2016). These services are provided in rural areas that depend heavily on an active agriculture, with dairy farming as the main pillar. The four goals of Norwegian agricultural policy are to provide food safety, agriculture in all parts of the country, increased value creation, and sustainable agriculture with lower emissions of greenhouse gases (Innst. 251 S (2016–2017). Moreover, in the policy platform of the present Government increased self-sufficiency from 34% at present to 50% is high-lighted as an overall goal (Hurdalsplattformen 2021). Norwegian dairy farmers mainly produce goods for the domestic market, and to achieve the agricultural policy goals the farmers receive substantial producer support, mostly through import tariffs and government payments.

While The Government states that the resource base in Norway is scattered and the conditions for agriculture vary, it is emphasized that "The Government wants a strong and competitive agriculture across Norway" (Ministry of Agriculture and Food 2016). To reach the goal of agriculture across the country forage and grazing based livestock is decisive (Directorate for Agriculture 2021).

Although the number of dairy farms in Norway is more than halved from 2000 to 2019, the total milk delivered to dairy is reduced by about five percent only (Table 1).

Table 1. Number of dairy farms, dairy cows, milk yield per cow and milk delivered to dairy in Norway from 2000 to 2019 (Statistics Norway 2022)

Year	Number of dairy farms	Number of dairy cows	Average cows per farm	Milk yield per cow in kg ECM	Milk delivered to dairy (liters)
2000	20 493	301 199	14.7	6 094	1 558 242
2010	11 529	245 001	21.3	7 373	1 505 981
2019	7598	215 063	28.3	8 602	1 480 683

Thus, the reduced number of cows and farms are almost fully compensated by the strong increase in milk yield per cow (Table 1). This development is accompanied by a rapid increase in number of AMS in recent years (Vik et al. 2019) and less restrictive milk quotas. From the first AMS was introduced in year 2000, in year 2010 there were 718 AMS and in 2019 the number had increased to 2025 (Vik et al. 2019).

According to Statistics Norway (2022), in 2020 only 36.9 percent of the dairy farms in Norway had 30 cows or more, while 39.9 percent had less than 20 cows. Thus, Vestland is not the only county in Norway with small and medium-sized herds, and the loose housing legislation represents a challenge in several regions (Table 2).

Table 2. Number and distribution of herds over different sizes in five selected counties in 2020. Data collected from the national dairy herd recording comprising 98 percent of all herds (Mikalsen, Österås and Roalkvam, 2020).

	Number of farms	Number of dairy cows per herd, percentage distribution					
		< 10	10–14.9	15–19.9	20–34.9	35–49.9	≥ 50
Vestland	778	15.9	25.1	20.8	21.3	9.5	7.4
Innlandet	1050	5.6	17.4	21.9	29	13	13.1
Agder	146	11.6	23.3	19.9	28.1	11.6	5.5
Møre and Romsdal	478	6.7	13.8	19	28.5	14	18
Rogaland	541	3.9	9.6	15.5	35.7	21.4	13.9

The percentage of farms with less than 35 cows is above 64 in all five counties (Table 2). One should also keep in mind that 3.5 percent of all herds do not report data to the national herd recording, and these farms are typically smaller than average. In Norway in 2020, 56 percent of the cowsheds are tie stalls, while 35.1 percent of the cows only were in tie stalls. This suggests that tie stalls have fewer than average cows per herd. In Vestland, 66.9 percent have tie stalls and the corresponding figure for Innlandet is 59.9 (Mikalsen et al. 2021).

Methods, material and empirical application

Net present value calculations

Innovasjon Norge (INN) is the governmental funder of new cowsheds in Norway. For traditional dairy farming, INN offers investment grants up to 35 percent of calculated investments costs, with an upper limit of two million NOK (INN 2020). This upper limit reduces the percentage share of grant on large investments. For buildings in wood there is an extra investment grant of maximum 400 000 NOK (INN 2020). In 2021 small and medium-sized dairy farms between 15 and 30 cows are prioritized for financing. To allocate funding of new cowsheds, INN requires an enterprise plan. The enterprise plan is set up by a farm advisor or a farm accountant and includes a detailed economic overview and a liquidity budget. The grant from INN is considered decisive by most farmers for investments in new cowsheds to be profitable, and the amount applied for is stated in the enterprise plan. We got access to these plans, and they were our main source of information to calculate profitability.

In literature, net present value (*NPV*) is widely accepted as the preferred method to calculate profitability (Brealey et al. 2004). In our study, expected *NPV* was calculated as

$$E(NPV) = -I + IG + \sum_t^N E(C_t)/\,(1+k)^t. \quad (1)$$

In (1), *I* is investment costs, *IG* is investment grant *T* is point in time (Year), *N* is expected lifetime of the investment, *C* is expected annual net cash-flow and *k* is the required rate of return. A positive net present value indicates that the projected earnings generated by an investment exceeds the anticipated costs. An investment yielding a positive *NVP* is profitable, while an investment yielding a negative *NVP* will result in a net loss. Although widely used among researchers and consultants, when interpreting the results from the *NPV* calculations one should keep in mind that *NPV* is not necessarily a widely used decision support tool among farmers. Thus, in practice investment decisions may be different than what the *NPV* calculations suggest. Moving cows from a tie stall to loose housing is beneficial in terms of working conditions for the farmers and time spent on milking. However, unfortunately in this study we were not able to include these benefits in the profitability calculation, because the data needed were not included in the enterprise plans. Investment costs in our case consists of a main investment in the loose housing barn itself, included technical equipment, typically AMS and feeding equipment. In addition, farmers often do investments prior to the main investment, such as e.g. milk quota, farmland, tractors and farm machinery. In this study we included such investments in the last years prior to the main investment, and the first years after in *I*. However, it might be that we failed to include all investments associated with the farm expansion. To show the importance of *IG*, we calculated *NVP* both with and without *IG* .

The expected lifetime for buildings and technical equipment depends on choice of technology and maintenance throughout the lifespan. Technical equipment clearly has shorter lifetime than the building itself, and therefore we first divided the investment in two parts, and the depreciation period for the total investment was calculated by weighting total cost according to the share that each of the two parts constitute. After discussions with experienced building advisors and planners we decided to use two alternative lifetimes in the analysis, 25 and 30 years. No salvage values were assumed, neither for technical equipment nor the building itself. In some cases, the investment in a new barn included space for other livestock productions, such as e.g. sheep or hens. In these cases, we contacted the planners to assess roughly the share that should be allocated to other livestock and subtracted this from the total investment cost. The planners also help us to estimate and remove the budgeted contributions from these productions.

To calculate annual *C* we applied the equation

$$C = GM - FC - FI - LC\,. \quad (2)$$

The data needed to calculate *C* were collected from the enterprise budgets, which is part of the enterprise plan. The enterprise budget includes all fixed and variable costs and all returns five to seven years ahead. The gross margin *GM* includes all returns, mainly milk, beef and livestock together with direct payments, and variable costs like seed, concentrate, fertilizer and lime, veterinary and AI- costs, advisory services, sundry etc. Fixed costs (*FC*) include costs associated with maintenance of buildings and machinery, fuel, electricity, insurance, book-keeping, hired labor, contracting, administration etc. Fuel and energy can also be considered variable costs, but we included them in the fixed costs because this is common practice in the Norwegian FADN and in the enterprise plans. We did not include depreciation in *FC* since it is already built-in in the definition of *NPV*. In the years after the main investment farmers often recognize that farm expansion requires some follow-up investments (*FI*). Thus, studies have shown that farm expansion incurs *FI* in machinery, technical equipment etc. resulting from significantly increased production volume and labor burden, particularly in forage production (Hansen and Nærland 2019, Halland et al. 2021, Haukås et al. 2022).

In *NPV* calculations in other sectors labor costs are usually included as salaries paid to employees. However, in agriculture the decision maker is most often the main employee. Therefore, we decided to include family labor costs in the *NPV* calculations. While we recognize that farms get larger and farmers become more professional, it is well established in literature that most farmers still have goals and objectives that go beyond constrained revenue maximization. Moreover, from one of the authors' experience with farm planning most farmers who want to invest in new cowsheds are fully aware of that they could have earned more money in other occupations. Based on these assessments, we chose not to use opportunity costs of family labor. A similar approach is used in Haukås et al. (2022). To assess farmer familys labor costs (*LC*) in each of the four size groups we analyzed, we collected return to all family labor from the farm accountancy survey (Norwegian FADN) in 2018 in Vestland (NIBIO 2019).

The accountancy survey for Vestland contained average number of working hours and average return to labor for four size groups based on the number of cows, 14, 21.7, 26.1 and 49.2. To calculate return to family labor for the average number of cows in each size group in the paper, we used linear approximation based on these four groups. Return to labor was calculated for the size groups the farms expanded to, and not the size groups they expanded from.

According to theory, the expected rate of return should be comparable to an investment with similar risk (Brealey et al. 2004). However, to simplify, we decided to use the same interest rate as NIBIO uses in the survey of account statistics for assets in agriculture in 2019, namely 2 percent (NIBIO 2019). This interest rate is supposed to reflect a level between the interest rates on long-term loans and long-term bank deposits, to reflect a mixture of equity and long-term debt (NIBIO 2019). Since the cash flow was estimated in fixed monetary value, we apply a real interest rate.

To assess the *NPV* associated with adapting to the loose housing regulation we considered two different scenarios. In the new loose housing (NLH) versus upgrade (UG) scenario we presupposed that it is possible to upgrade the existing tie stall for an amount of 1.5 mill. NOK, and continue with tie stalls also after 2034. This sum is an anticipated average cost for necessary upgrading of existing cowsheds, determined in discussions with experienced farm building planners at Tine SA. The upgrading just includes necessary maintenance and new purchase to be able to maintain production. To illustrate the profitability of the change, the NLH-UG scenario was calculated as the *NPV* of NLH less the *NPV* of UG. The two alternatives are mutually exclusive, and according to theory the alternative with the largest positive net present value is the best choice. Based on current legislation this is of course a hypothetic scenario, but the reason we explored it was to better understand the full economic consequences of the tie stall ban. Moreover, it should also be mentioned that the NLH alternative entails some advantages compared to the NLH-UG alternative, but only the economic consequences are examined here. Finally, to further explore how *NPV* relates to different farm characteristics, we also ran an OLS-regression.

Results

Descriptive statistics

A general trend is that farmers expanded production during the investment, and on average the milk quota increased by 73 000 liters or approximately 42 percent (Table 3). We notice a large variation in investment costs between the different size groups, and particularly within each group (Table 3). One reason is that the figures represents both refurbishments of existing buildings and new buildings. Furthermore, the average enterprise plan suggests a relatively strong increase in milk yield per cow (Table 3).

To assess whether our results are representative for Vestland county, we compared the figures for our sample with the figures in Vestland. In our sample the average number of cows prior to and after investment was 21 and 31 respectively, as compared to the average herd of 22 cows in Vestland (Mikalsen et al. 2021). The sample average farmland prior to investment was 31.3 ha, increasing to 34.1 after. On collaborative dairy farms, the farmland is often registered on each of the participating farms, and not on the collaborative farm. Therefore, we did not have access to the average farmland for dairy farms in Vestland. Therefore, to estimate the average farmland, we used ratio-estimation (Lohr 2019) with the average number of cows as the auxiliary variable. Thus, when estimating the average farmland in Vestland, we assumed that the ratio between the number of cows and ha of farmland in the study sample was equal to the same ratio in Vestland. This premise can of course be discussed, but in similar situations with no exact knowledge, ratio-estimation is a widely used method (Lohr 2019). The average farmland in Vestland was estimated to 26.5 ha, somewhat lower than the sample average prior to investment. Thus, in our sample farms with more than 30 cows are somewhat over-represented compared to farms with fewer than 30 cows. This reflects that large farms are more likely to expand their farming than small farms.

I varies considerably within all size groups, and most plans involve a significant increase in milk quotas and milk yield per cow (Table 3). Particularly in the two largest groups, the plans also presuppose increased farmland (Table 3), which indicates that more farmland is available within reasonable driving distance.

Table 3. Farm net result prior to depreciation after investment, together with investment costs, number of cows, investment cost in total and per cow, farmland, milk quota and milk yield per cow prior to and after investment for the farms in our sample. The farms are grouped according to number of cows after investment.

	Number of cows	Herd size groups				
		≤ 19	20–29	30–39	≥ 40	All
	N	10	19	23	14	66
Farm net result prior to depreciation (1000 NOK)	Mean	520	793	1030	1207	922
	St.dev.	114	96	195	301	294
	Median	530	764	1037	1104	875
	Min	266	601	742	856	266
	Max	646	983	1386	1840	1840
Investment cost in total (1000 NOK)	Mean	5714	7633	8700	8452	7888
	St.dev.	1888	2443	2440	2977	2642
	Median	5860	6850	9099	8787	8186
	Min	1828	3435	5035	3680	1828
	Max	8564	12545	15650	14271	15650
Investment cost per cow (1000 NOK)	Mean	324	329	259	175	271
	St.dev.	121	97	68	45	100
	Median	324	329	269	185	269
	Min	102	137	158	82	82
	Max	504	463	454	232	504
Number of cows prior to investment	Mean	13	19	23	28	21
	St.dev.	5	6	6	8	8
	Median	15	20	22	28	20
	Min	0	0	11	14	0
	Max	19	31	35	42	42
Number of cows after investment	Mean	17	24	33	48	31
	St.dev.	2	3	3	11	12
	Median	18	24	33	44	30
	Min	14	20	30	40	14
	Max	19	29	39	75	75
Farmland prior to investment (ha)	Mean	15.2	27.1	37.7	37.8	31.3
	St.dev.	6.2	11.5	14.6	11.5	14.5
	Median	12.7	25.8	40.0	39.8	27.9
	Min	8.7	13.6	14.3	22.5	8.7
	Max	27.8	65.0	78.4	60.1	78.4
Farmland after investment (ha)	Mean	15.2	27.4	39.9	44.6	34.1
	St.dev.	6.2	11.8	14.9	12.1	16.5
	Median	12.7	25.8	39.9	43.8	28.8
	Min	8.7	13.6	16.8	24.7	8.7
	Max	27.8	65.0	78.4	66.6	78.4
Milk quota prior to investment (1000 liters)	Mean	93	160	181	232	172
	St.dev.	31	43	55	98	74
	Median	95	159	191	213	158
EUR	Min	47	70	70	103	47
	Max	134	226	284	388	388

Milk quota after investment (1000 liters)	Mean	124	188	263	378	245
	St.dev.	11	29	29	92	97
	Median	123	188	258	351	240
	Min	100	144	190	300	100
	Max	140	239	308	600	600
Milk yield per cow prior to investment (Kg energy corrected milk)	Mean	6371	7447	7346	7144	7174
	St.dev.	1172	756	773	625	877
	Median	6562	7488	7500	7150	7403
	Min	4091	4787	5345	6131	4091
	Max	7767	8300	8750	8333	8750
Milk yield per cow after investment (Kg energy corrected milk)	Mean	7341	7915	8019	7903	7862
	St.dev.	488	558	449	323	510
	Median	7421	7847	8000	7900	7881
	Min	6349	7143	6979	7500	6349
	Max	7950	9000	8875	8372	9000

At the time of writing (May 2021), NOK1 was approximately equivalent to 0.101 EUR.

The *NPV* calculations

The for NLH-UG is negative for all groups irrespective of depreciation period and grant (Table 4).

Table 4. *NVP* for NLH-UG (upper half) and NLH (lower half) with and without *IG*. The figures are averages for herds of different sizes and two different depreciation periods, 25 and 30 years. All figures are in 1000 NOK.

	NVP, *IG* ncluded		*NVP*, *IG* excluded	
Depreciation period	25 years	30 years	25 years	30 years
NLH-UG				
Number of cows ≤ 19	–1 126	–882	–2 887	–2 643
Number of cows 20–29	–2 610	–2 287	–4 491	–4 168
Number of cows 30–39	–1 709	–1 023	–3 471	–2 785
Number of cows ≥ 40	–1 726	–1 043	–3 348	–2 664
NLH				
Number of cows ≤ 19	–2 619	–2 423	–4 404	–4 208
Number of cows 20–29	–1 305	–651	–3 319	–2 665
Number of cows 30–39	10	1 064	–1 768	–714
Number of cows ≥ 40	202	1 289	–1 389	–303

This means that it is more profitable to continue with an upgraded tie stall than to invest in NLH. For NLH the *NVP* included grant is positive for herd sizes of 30 cows and above irrespective of depreciation period. However, for herd sizes less than 30 cows, on average investments in NLH is still not profitable.

To further explore the relationship between *NPV* and farm size, we ran an OLS-regression including the whole sample with *NPV* included *IG* as dependent variable, and number of cows, milk quota, milk yield per cow, investment cost per cow and farmland prior to and after expansion as possible predictors. Both second order and interaction terms were tried. Although cow number and farmland are strongly correlated, ha of farmland after expansion explains most of the variation in *NPV*, with an adjusted R^2 of 26.8 (Fig. 1). Considered that the model contains only one explanatory variable, this is a high value.

Table 5. OLS regression with NPV as dependent variable and farmland as independent variable (N=66).

	Coefficient	Std.dev.
Intercept	–3372.978***	788.448
Farmland after farm expansion (ha)	10.534***	2.133

*** $p < 0.001$

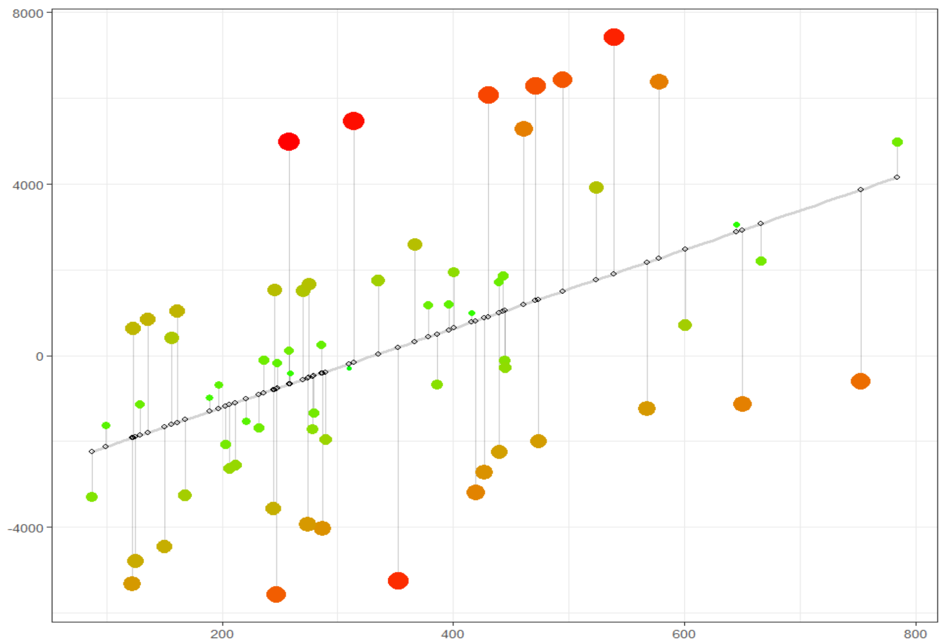

Fig. 1. OLS regression line for all farms with 0.1 ha of farmland on the x-axis, and included and depreciation period 30 years on the y-axis. Each dot represents a farm, and the size indicates the deviation from the regression line. The vertical lines are the projections onto the regression line.

With a depreciation period of 30 years and included *IG* the *NPV* depicted by the regression line increases linearly with available farmland after expansion, but the variation is large (Fig. 1). On average, to be profitable farms need to have approximately 32 ha of farmland after investment, represented by the intersection between the regression line and the abscissa.

Discussion

For farms with less than 30 cows, investment in new loose housing cowsheds is on average not profitable. Thus, our findings show that the loose housing regulations represent a huge challenge for small dairy farms in Vestland. There is reason to believe that other regions with similar farm structure, both in and outside Norway, will face similar challenges. Two reasons why the SMALL group is worse off than MEDIUM is that the investment costs per cow for SMALL is more than one hundred thousand NOK higher, while the milk quotas are smaller (Table 3). To be profitable, on average farms need a minimum of 32 ha of farmland after investment, or 5.5 ha more than today's estimated average. However, we notice that the variation in profitability between similar-sized farms is large (Fig. 1). Because the farmland in Vestland is scattered, some farmers simply do not have access to extra farmland within reasonable transportation distances. For some farmers, quitting dairy farming may therefore be the only option. For others, the need for extra land will lead to increased transportation costs and increased CO_2 emissions. The simulations support the results from the *NPV* calculations and the OLS-regression, and clearly illustrate the importance of herd size for investments to be profitable. They also show that today's grant scheme is insufficient to make investments in less than 30 cows profitable. One million NOK extra is needed to make investments on farms with 20 to 24 cows as profitable as on farms with 30 to 34 cows (Fig. 2). Furthermore, for farms with less than 20 cows the *NPV* is considerably lower, and the corresponding necessary amount of grant correspondingly higher. In 2020, in Vestland the two groups with less than 15 cows constitute 41 percent of all dairy farms (Table 2). Although a share of these farms is likely to cease dairy farming before 2034, in debates about the loose housing requirement this group is seldom mentioned. With approximately the same investment costs per cow and 67 000 liters smaller quota as compared to farms with 20–29 cows (Table 1), the situation for these farms is challenging.

Similar to our findings, Haukås et al. (2022) conclude that farms in Vestland need at least 35 cows to invest in new loose housing. Moreover, data from the Norwegian FADN also show that the economy is weak on farms that have invested in recent years (Haukås et al. 2022). Our sample is collected from farms that have already invested in loose housing. We do not know whether the farmers in our sample differ from farmers in Vestland that have not yet invested, with respect to farm economy, farmer education, attitude towards risk etc. Thus, there is a risk that our sample is not fully representative of the farmers in Vestland. What we do know is that our sample farms have somewhat larger than average farmland, and thus our results may be valid for larger than average farms only. Furthermore, in the regression analysis it would have been desirable to have more farms. However, to analyze and discuss 66 enterprise budgets in detail with planners was time consuming, and unfortunately the time allocated to this project did not allow for more. A weakness is that most enterprise plans included accountancy figures for the last year prior to investment only. There is of course a risk that this year did not yield a representative picture of the farm economy, and accountancy figures for more years could possibly have contributed to a more correct calculation of the NLH-UG alternative. However, to reassure that the figures were representative for “going concern”, we discussed these accountancy figures with the planners and excluded enterprise plans where the figures did not give a correct picture. Another weakness of our study is that we did not have access to the time saved on milking when moving from conventional to robotic milking. Especially in small dairy herds, opportunity costs for labor are a major cost factor. Moreover, while *NPV* calculations for 20 years or more are susceptible for changes in interest rates, in this study we did not perform sensitivity analyses. However, Haukås et al. (2022) showed that an increase in the interest rate from two to four percent on farms in Vestland yielded negative *NPV*s in all alternatives. Based on our experience an interest rate of four percent in this study would probably have yielded similar results. Finally, while we focused on profitability, future studies could also analyze the cash flows in the early years of the investment to check that the investment is financially feasible. In the enterprise plans we used the financial feasibility had been rated by the INN.

Based on our calculations we claim that given today’s investment grant scheme, the loose house regulation conflicts current agricultural policy goals in several parts of the country. Particularly this holds for Vestland and Agder, where 65.8 and 56.4 percent of farms respectively have less than 20 cows. However, counties like Innlandet and Møre and Romsdal will also face large challenges, as will remote parts of Rogaland county. Thus, the consequences for farm structure apply to large parts of agriculture in less favorable areas. This was also acknowledged by The Parliament already in 2003: “If the costs are too high, many small farms will cease production, and only larger farms will afford to keep up dairy farming. The Government should have financial readiness to support transition to loose housing” (Parliament 2003 p. 10). Furthermore, it was stated that “It is important that the industry’s costs and competitiveness are emphasized when considering new measures for increased animal welfare. On areas where we want to go further than our neighbor countries, such matters should be carefully considered” (Parliament 2003 p. 5). Based on our findings, eighteen years later these statements are still highly relevant. For example, our findings show that unless the investment grant is significantly increased for small farms, both the total amount and the percentage of the investment, the goal of agriculture across Norway will be put at stake. And in section 1.1. we also concluded that currently we are about to go further than comparable countries to promote animal welfare.

Agriculture in rural areas contributes to maintain vibrant rural communities, and value creation and employment in rural areas (Directorate for Agriculture 2021). Furthermore, agriculture in rural areas also contributes to maintain the cultural landscape and biological diversity (Directorate for Agriculture 2021, Sæterbakk 2015). Our findings show that given the existing grant-scheme, the loose housing regulation will conflict with many of these functions. There is a risk that if small farms cease dairy farming, milk production will move to the areas with best natural conditions. Then farmland in less favorable areas may go out of production (Sæterbakk 2015), and this will make it more difficult to reach the goal of increasing food production in line with the increase in population (Ministry of Food and Agriculture 2011). A concentration of dairy farming in the best areas of Norway only, will also make agriculture more vulnerable to climate changes. Agriculture is more exposed to weather than most other industries, and climate changes represent a global and regional threat to food security (Ministry of Agriculture and Food 2011). This was evident in summer 2018, when there was severe drought in large parts of southern Norway, resulting in shortage of both forage and grain. Taken together, our findings support the worries for small and medium sized farms of possible loose housing regulations posed by Swedish authorities (Jordbruksverket 2019). Our findings are also in line with the findings in Halland et al. (2021) and Haukås et al.(2022).

There is a risk that increased Government funding for new cowsheds in its entirety will not end up with the farmers concerned, because companies that sell equipment for loose housing may be tempted to increase their prices of products and services correspondingly (Jordbruksverket 2019). This was also one reason why ibid. recommended other alternatives than a tie stall ban in Sweden. We agree that this risk exists, however, given that the ban is already decided on in Norway, we see few other options. Our calculations are heavily based on current conditions regarding agricultural policy including milk quotas, farm structure, national need for milk and beef, milk yield per cow, building solutions and costs etc. Although farm expansion requires a few years to plan and obtaining extra farmland and quota, 2034 is still a relatively long way ahead, and significant changes in any of these factors may yield other results. For example, new building solutions may influence investment costs, and the efforts to reduce building costs must continue. Similarly, a change in the milk quota regulations or removal of quotas prior to 2034 may affect farm structure and the division of milk production between regions. Moreover, transition to loose housing often results in somewhat increased milk yield per cow, and this will reduce the need for future investments. The demand for milk also affects the need for investments in loose housing, and depends e.g. on development in population, per capita consumption of milk and how imports of dairy products develop. A strength of this study is that we demonstrate the implications of loose housing on single farms. While loose housing is debated in several countries, to the best of our knowledge few studies have explored possible economic consequences of a tie stall ban at farm level. Therefore, our study could be of interest in countries that consider new housing regulations like e.g. Sweden and Finland.

Conclusions

Given today's investment grant scheme, investment in loose housing is not profitable on farms with less than 30 cows, and less profitable than to upgrade existing tie stalls irrespective of herd size. Thus, given today's farm structure, the loose housing requirement has far-reaching consequences for farm structure and conflicts several goals in current agricultural policy, such as farming across the country, vibrant rural areas, open cultural landscape and biological diversity. To avoid these goal conflicts in the agricultural policy, for farms with less than 30 cows a significant increase in the investment grant is decisive.

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