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Structural change in the dairy sector: exit from farming and farm type change

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Abstract

This paper analyses the factors driving structural change in Swiss dairy farming. We focus on the most important farm type in Switzerland, dairy farms, to examine which factors contribute to a farmer's decision to abandon farming or change to suckler cow farm type. Swiss dairy farming is characterised by a high proportion of farms with animal welfare programmes and extensive use of grassland. This farm sector can therefore provide a blueprint for sustainable dairy farming, especially in mountain regions. Using administrative data from the agricultural policy information system, the results from logistic regression show that age is a major reason for farm exit. Interestingly, dairy farms that are more specialised reveal higher exit probabilities, whereas farm size in terms of employees and the number of dairy cows as well as the adherence to organic or animal welfare standards reduce the exit probabilities. Changes to the farm type suckler cow occur rather at younger age and by farms that are acquainted with organic and free-range animal husbandry. Finally, there are factors that differently influence farm exit and farm type change. These findings allow for the adjustment of policy instruments to better control structural change of the Swiss dairy farm sector. Given the partly conflicting economic and environmental objectives in agricultural policy, a profound understanding and control of structural development in the agricultural sector is pivotal.

Keywords: Structural change, Farm exit, Farm type change, Dairy farm, Switzerland

Introduction

Structural change in agriculture is ubiquitous and persistent. Some farms cease operations; the released land usually is taken over by other farms, which allows them to grow in size (Storm et al. 2015). Some farms specialize in certain farm enterprises, whereas others diversify into new farm enterprises or farm-related businesses. Around 30% of Swiss farms belong to the dairy farm type (Zorn 2020). It is the most important branch of Swiss agriculture with a share of over 20% to the output value of the agricultural sector (FSO 2019a; Oeschger 2013). However, the Swiss dairy market is characterised by decreasing added value (Bokusheva et al. 2019). Structural change is particularly pronounced in Swiss dairy farming, contributing to a relatively high decline of the number of farms compared to other farm types (Agristat et al. 2019). While the number of dairy cows is shrinking, the number of suckler cows is steadily increasing (Rüssli 2019).

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Suckler-based systems require less labour, are considered animal-friendly but imply higher environmental impacts per unit of product than dairy-based systems (de Vries et al. 2015).

This analysis of structural change in the Swiss dairy farm sector considers two specific developments in parallel, dairy farm exit and dairy farms changing their business orientation to suckler cow farming. Which characteristics of dairy farms go along with farm exit, which factors work on farm type change and which conclusions can be drawn from a comparison of both trajectories? Representing these different structural developments and understanding what exactly happens in the farming sector is of high importance with regard to the future development of agricultural, animal welfare, land use and environmental policies.

Previous analyses of structural change in agriculture focus on factors explaining general farm exit (Breustedt and Glauben 2007; Katchova and Ahearn 2017; Kazukauskas et al. 2013; Roesch et al. 2013; Saint-Cyr et al. 2019), some of which specifically consider dairy farms (Thiermann et al. 2019). Only recent studies shed light on the structural development of farm types (Neuenfeldt et al. 2019; Saint-Cyr et al. 2019; Storm et al. 2016). Storm et al. (2016) reveal different exit probabilities and growth rates between farm types. Neuenfeldt et al. (2019) point to the relevance of farms' 'historic specialisation' for structural change at regional level. Accounting for spatial interactions in the analysis of farm exit, Saint-Cyr et al. (2019) also find considerable variation between farm types.

The share of suckler cow farms in Switzerland steadily increased from a share of 3.1% in the year 2000 to 8.4% in 2018 (Zorn 2020). This is the only farming type that considerably grew during this period; all other farming types' shares shrunk or remained roughly constant. This growing importance of suckler cow farming in Switzerland is explained by farmers in the mountain regions shifting from capital-intensive dairy to beef production (Stöcklin et al. 2007) and consumer demand for meat from animal-friendly livestock husbandry (Briner et al. 2012). This development is supported by animal welfare and biodiversity payments (OECD 2015) and diverse labelling schemes (Boessinger and Hoffet 2018; Pusch 2015) in Switzerland. Anecdotal evidence suggests that many small- and medium-sized dairy farms resign from milk production and change to suckler cows. This is explained by barriers to growth and the relief of labour from the burden of milking (Jäger 2019). Furthermore, if young dairy farmers' situation does not allow specialisation, they alternatively often diversify their farm business (Krammer et al. 2012).

Swiss agriculture can provide a relevant blueprint for neighbouring European regions. First, Switzerland leads the way in terms of animal welfare legislation and in linking private animal welfare schemes with agricultural policy programmes (Vogeler 2017). This allows differentiating animal products accordingly at retail level. Second, this development is in line with the preferences of the Swiss society that highly values environmental benefits and animal welfare (OECD 2015), which is also an ongoing trend in neighbouring food markets (Naspetti et al. 2021). Finally, Swiss agriculture is a prime example for

investigating the effects of structural change on dairy farms in mountainous regions, in which agricultural production is based on grassland and ruminants.[1]

We contribute to the literature by empirically analysing and also *comparing* farm exit and farm type change, i.e. switches from milking to the related farming branch of suckler cow husbandry. This issue is relevant as the structural development of dairy farms is linked to questions of the intensity of agricultural production (e.g. in case of specialising, dairy farming may be accompanied with farm growth, cf. Kimura and Sauer 2015). Furthermore, the change to a less labour-intensive farm enterprise often involves issues of household income diversification (e.g. release of labour from farming in case of less intensive farming like suckler cow husbandry, cf. Mack 2012). Structural changes finally affect related policy areas such as spatial planning (maintaining decentralised settlement, keeping the landscape open), the environment (impact on natural resources, cf. Jan et al. 2019), and food policies (food production and self-sufficiency). Therefore, the identification and distinction of factors that relate to structural change with regard to farm exit and farm type change is of high relevance for the elaboration of precise agricultural and adjacent policies.

This paper is structured as follows: The next section provides an overview of prior studies and proposes hypotheses on factors that are related to structural change of dairy farms. The third section describes the data and presents descriptive findings before the methodological approach is explained. "Results" section presents the regression analysis results and allows to compare the estimated models. "Discussion" section discusses these results, and the final section offers conclusions.

Literature review and hypotheses

This literature review focuses on studies related to dairy farms' development. Our specific interest lies on the one hand in farm exits and, on the other hand, in farm type changes (i.e. farms leaving specialised dairy farming in favour of other farm types). Based on the review of the empirical literature, we develop hypotheses based on factors influencing dairy farm exits and farm type changes. The literature on the adoption of suckler cow farming is sparse. Table 1 provides an overview of our proposed hypotheses.

Zimmermann et al. (2006) identify in a literature review technological progress, price relations (between production factors), market structure, human capital, demographic development, employment of household members (on- vs. off-farm work), and agricultural policies as general drivers of structural change. Regarding the farm household, a higher age of the farm operator is supposed to increase the exit probability (Gale 2003), while the existence of a family farm successor is expected to decrease this probability (Dong et al. 2016). Moreover, with larger family size, the probability of having a farm successor increases since incentives and labour resources for farm growth are available (Weiss 1999). Furthermore, more family farm workers imply a higher dependence of the family on farm income. Hence, we expect a lower exit probability with an increasing number of family members.

[1] Milk production and cattle farming is the most important sector of agricultural production in the mountain region of Switzerland, accounting for 51% of the value of agricultural production in the year 2018 (FSO 2019b).

Table 1 Variables, corresponding hypotheses, and explanations of the expected effect on farm exit and farm type change ("+" increases, "−" decreases the probability)

Variable	Exit	Change	Exit	Change
Number of family workers	−	−	The more family members are working on a farm, the higher the farm household's dependence on agricultural income and the lower the probabilities to exit farming and to change to a less labour-intensive form of production such as suckler cow The higher the number of family workers, the higher the probability that a farm family member takes over the farm business	
Age	+	−/+	Older farmers quit farming shortly before or after exceeding the age limit to receive direct payments. This is the case if there is no successor (no children; children do not want to do farming or take over the farm—for economic or other reasons)	Changing the focus of production could occur either before handing over the farm (at higher age) or after taking over (by younger farm successor); therefore, a two-sided hypothesis is formulated
Herd size (number of dairy cows)	−	−	The larger dairy herd size, the more profitable is this enterprise and the lower the probability to exit (change). Larger farms can better implement technical progress and hence increase labour productivity or improve working conditions	
Intensity of production (stocking rate)	−/+	−	A higher stocking rate can constitute farm specialisation, which could involve higher profitability (lower exit probability) On the other hand, a high stocking rate could result from scarcity of land and hereby mirror barriers of growth, which then could increase the exit probability	High stocking rates illustrate high intensity of production; under such circumstances, we would expect a lower change probability to extensive methods of production such as suckler cow production
Organic production	−	−	Organic production can relatively easy be implemented in dairy production and allows higher added value. Hence, exit (change) probability decreases	
Animal welfare housing system	−	−	Animal welfare housing systems involve investment in stables, which allows higher added value. Hence, exit probability decreases	
Animal welfare: outdoor keeping	−	−/+	Keeping dairy cows outdoor allows higher added value. Hence, exit probability decreases	Keeping dairy cows outdoor allows higher added value. Hence, exit probability decreases. However, the existence of grassland area around the farm could pave the way to grassland-based suckler cow production
Specialisation (Herfindahl–Hirschman-Index)	−/+	−/+	Higher specialisation goes along with a stronger focus and professionalization (higher profitability). However, the more specialised a farm, the less diversified are farm risks. Hence, the relation to the exit (change) probability is theoretically ambiguous	
Direct payments total	−	−	Direct payments (DP) contribute to farm income and hereby foster the given situation. The higher DP total, the larger a farm and the higher a farm's profitability. Hence, with increasing DP we expect a decreasing probability of farm exit (change)	
Dependency from direct payments (share of DP in farm's standard output)	+	+	We interpret the dependency from direct payments measured as the ratio of DPs in relation to a farm's standard output as inverse of a farm's market orientation. The higher the dependency from DPs (and the lower the market orientation) of a farm, the higher the exit (change) probability	
Milk price	−	−	The better the milk price (measured as three-year average), the lower the probability of farm type exit (change)	

Table 1 (continued)

Variable	Exit	Change	Exit	Change
PDO cheese region with above average milk prices	−	−	Protected designation of origins helps to establish specific quality traits with links to the place of production. This qualitative differentiation contributes to added value. Raw milk for cheese production receives higher prices than milk for direct consumption. The milk prices for Gruyere and Raclette—both very successful cheeses in export—are particularly high within cheese milk. Therefore, we expect lower exit (change) probabilities for farms located in the corresponding PDO regions	
Comparison salary	+	+	The higher the opportunity cost of working outside farming, the higher the probability to exit farming and the higher the probability to reduce farm labour requirements by stopping to milk and change to labour-extensive enterprises, such as suckler cows	
Unemployment rate	−	−	The lower regional unemployment, the higher the opportunity cost of working outside farming and the higher the probability to exit farming and to change to labour-extensive enterprises	
Difficulty of farm production	+	+	Swiss agricultural policy differentiates three regions according to climatic conditions (length of vegetation period), topography/relief (steep slopes), and transport infrastructure. With increasing difficulty of production, we expect an exit (change) probability increasing effect	

Additionally, several studies consider farm size and structure as drivers for farm exits. In case of dairy farms, farm size is measured by the number of cows (Thiermann et al. 2019). With an increasing number of cows, the exit probability is supposed to decrease (Bragg and Dalton 2004). Given the relatively small herd sizes of Swiss dairy farms compared to neighbouring countries, larger farms may benefit from considerable economies of scale. A high stocking rate can increase dairy profitability (Ma et al. 2020) and can be considered as an indicator of farm growth and correspondingly lower exit or change probabilities (Zimmermann and Heckelei 2012); conversely, it could also indicate growth barriers due to scarce farm land. Farm specialisation in terms of concentration on fewer, major farm enterprises (proxied by the Herfindahl–Hirschman index, cf. Piet 2016) could either result in a higher dairy profitability and stability or increase income volatility (Bragg and Dalton 2004). Thus, theory predicts either a decrease or an increase in the probability of farm exit or farm type change.

Another important factor for dairy farms' development is their orientation in terms of product differentiation, i.e. quality labels. A prominent share of organic milk characterises the Swiss milk market. Organic farming allows dairy farms in particular to increase the selling price and to reduce farm vulnerability (Bouttes et al. 2019; Hofer 2002). Organic dairy farms in Switzerland attain higher incomes despite smaller herd sizes (Hoop et al. 2019). In Swiss agriculture, animal welfare standards offer further potential to differentiate: the schemes 'animal welfare through housing system' (BTS) and 'regularly keeping animals outdoors' (RAUS) are subsidised. In that context, we expect a lower exit probability. However, the adherence to the requirements of RAUS can also form a growth barrier since its fulfilment could be more challenging for larger farms. Besides, farms adhering to RAUS have access to pasture; this could allow to change to pasture-based suckler cow farming easily.

Generally, Swiss producers receive higher prices for cheese milk; special quality cheeses such as Gruyère and Raclette can further benefit from protected designation of origin (PDO) and above average cheese milk prices (FOAG 2020). In regions in which Gruyère and Raclette cheese can be produced (see Fig. 1a), we expect on average a higher profitability of dairy farms (AND International and Ecorys 2020) and lower exit and change probabilities.

During the period of analysis, the Swiss milk market and the dairy sector underwent different reforms of the agricultural policy framework. These reforms liberalised cheese trade with the EU, abolished domestic and export subsidies and the milk quota system. This liberalisation of market forces between 2002 and 2009 is expected to foster structural change in any dimension in the dairy sector. The last reform in 2014 involved a shift from headage payments to area payments and hereby could provide incentives to decrease the stocking density and the intensity of livestock production (OECD 2015). This development could especially support farm type changes from dairy to extensive suckler cow production.

Swiss agriculture is highly subsidised (OECD 2019). To reflect the farms' dependency on direct payments, we expect a stabilising effect from the sum of direct payments a farm receives (Breustedt and Glauben 2007; Hofer 2002). Furthermore, the relation of direct payments to a farm's standard output[2] allows further insights into the strategic

[2] The standard output is the average monetary value of agricultural production at producer prices (Eurostat 2018). The standard output considers the costs of production but excludes direct payments.

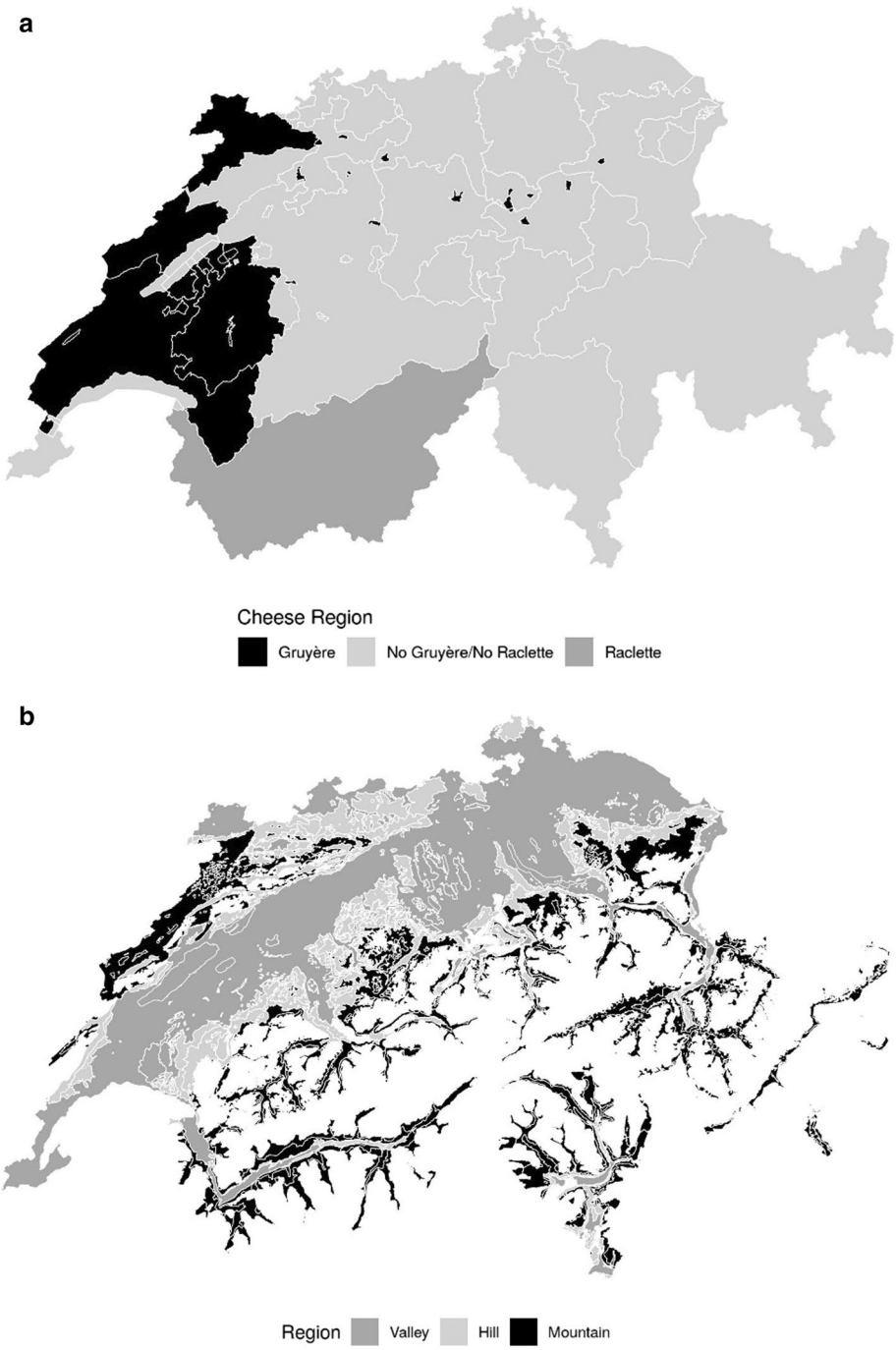

Fig. 1 Regional characteristics. **a** Switzerland's cheese regions, **b** Switzerland's agricultural regions. *Source*: Authors' illustrations using data from https://map.geo.admin.ch/

orientation on direct payments (e.g. by farms focusing on extensive production and biodiversity payments) versus a more pronounced market orientation. With decreasing dependence on public subsidies, we expect a lower exit and change rate.

Structural change can considerably differ between regions (Huettel and Margarian 2009; Zimmermann and Heckelei 2012). The administrative differentiation in valley, hill and mountain regions allows considering regional effects (see Fig. 1b for a graphical representation). These regions are delimited based on fields' climatic conditions, surface conditions (slope), and the infrastructure (remoteness); these criteria reflect the difficulty of farm production. Political instruments and corresponding direct payments are differentiated according to the difficulty of production conditions (FOAG 2008; Schweizerischer Bundesrat 1998). Across farm types, Swiss farm exit rates increase with more difficult production conditions in the mountain region as opposed to the valley region (Zorn 2020). We expect a corresponding effect for dairy farms (Hofer 2002).

Off-farm comparative income reflects the attractiveness of off-farm job opportunities. This is relevant for both farm exits as well as part-time work. With increasing opportunity costs of staying in the agricultural sector due to higher off-farm incomes, we expect a higher exit rate as well as a higher rate of change to less labour-intensive farm types such as suckler cows. Lips et al. (2016) observed a high preference to stay in the business of dairy farming. By the means of a discrete choice experiment, they quantify the necessary yearly income compensation for changing from dairy to suckler cows at around 50,000 CHF. Generally, the empirical effect of off-farm labour on farm exit is not clear (Ramsey et al. 2019). Finally, the unemployment rate at cantonal level is considered to represent the labour market conditions; the higher the unemployment rate, the lower the expected probability of farm exit and labour input-reducing farm type changes.

Data and methods

We used annual panel data on the farm level for the years 2000 to 2018 from the Federal Office for Agriculture (FOAG) to empirically test the proposed hypotheses. The FOAG collects the data in the context of the management of direct payment programs, called agricultural policy information system (AGIS). The dataset represents a general farm register, so it corresponds to a census of all Swiss farms. The use of administrative data typically involves a larger sample size (in contrast to surveys) and less potential for measurement errors.

Since our focus is on dairy farms, we consider only farms which have been classified as specialised dairy farm at least once according to the Swiss typology (Meier 2000) during the period of observation (2000–2018), and farms which received direct payments for at least one year.

To avoid distortions caused by extremes at the lower tail of the distribution, we refer to the definition of an agricultural holding used by the Federal Statistical Office (FSO). This definition is based on a minimum farm size (such as one hectare of farm land area, 30 areas of special crops or minimum animal numbers, cf. FSO 2016). Farms that do not meet these minimum standards are excluded from the analysis. In accordance with the selection criteria used by the Swiss farm accountancy data network (FADN), year-round farms and group farming are considered for the present analysis (Renner et al. 2019). Hereby, we exclude summering farms where animals

Table 2 Outcome definitions for farm exit and farm type change. *Source*: Authors' illustration

Identifier	Year	Direct payments (CHF)	Farm type	Farm exit	Farm type change
1	2000	25,650	Dairy	0	0
1	2001	26,410	Dairy	1	0
2	2000	40,520	Dairy	0	0
2	2001	40,340	Dairy	0	1
2	2002	44,870	Suckler cow	0	0
2	2003	45,650	Suckler cow	0	0
2	2004	41,250	Dairy	0	0
2	2005	41,250	Dairy	0	1
2	2006	46,560	Suckler cow	0	0
2	2007	46,300	Suckler cow	0	0
2	…	…	…	…	…
2	2016	44,890	Suckler cow	0	0
2	2017	45,370	Suckler cow	0	0
2	2018	45,510	Suckler cow	.	.

As a result of this definition of outcome variables, the last year of observation is not used in the following analysis and marked as missing value (".")

from different farms—which still can be part of the analysis—are temporarily pastured in the Alps, but also non-commercial livestock farms and specific cases such as cattle dealers and slaughterhouses. Regarding the legal form, only natural persons or ordinary partnerships are included (hereby excluding companies with shared capital or public companies). These two legal forms represent 98.4% of all Swiss farms. All other farms were not considered in this analysis. Finally, the analysis relies on 441,281 observations from 29,754 farms.

One major advantage of the data set is its panel structure. The panel structure allows for the analysis of individual farm behaviour over a long period. Hence, one can use the panel data to define outcome variables of interest (i.e. farm exits and changes of the main production type).

A farm exit is a binary variable indicating the last period a farm received direct payments. Direct payments in Switzerland are provided for farmers younger than 66 years. Farmers that pass this age threshold without handing over the farm to a younger farmer are considered a farm exit. An economic rationale dairy farm operator, however, who does not receive direct payments anymore for age reasons should either sell or lease the farm. So, our variable definition is justified by the low attractiveness to take over the farm and supported by the data. Given the small share of farmers older than 65 years (0.02% of observations), we do not expect that these can drive the results.

A change of the farm type is a binary variable taking up one if a dairy farm changes its main production type into the specialised suckler cow farm type in the next period. Due to the time dimension of the outcome definition, the last observation year 2018 cannot be used in the following analysis for both farm exits and farm type changes. For illustration, Table 2 displays possible observations for two farms with identifier 1 and 2. Farm 1 is observed for two years and not registered as receiving

Table 3 Summary statistics of outcome variables. *Source*: Authors' calculations based on AGIS 2000–2017

Variable	Mean	Standard deviation	Number of farms	Number of observations
Farm exit	0.018	0.133	29,754	441,281
Farm type change: from specialised dairy to specialised suckler cow	0.003	0.057	29,733	440,995

direct payments from 2002 onwards. Thus, the farm abandons in 2001 (Farm exit = 1). Farm 2 does not exit between 2000 and 2017, but changes its farm type from dairy farming to suckler cow husbandry in 2001 (Farm type change = 1). Once changed, the variable becomes 0 again. In 2004, Farm 2 changes again its farm type to dairy. This development is not considered as a farm type change in the direction dairy to suckler cow. Only in 2006, the farm becomes again a suckler cow farm, which gives a positive assignment in 2005. Hence, one farm can theoretically experience several changes from dairy to suckler cow husbandry. Our sample shows that from 1440 farms with at least one farm type change only 21 farms change twice.

Table 3 provides the descriptive statistics of the outcome variables. We utilised about 441,000 data points from nearly 30,000 farms, of which about 2% experienced an exit between 2000 and 2017. About 0.3% of all observations changed their main production type from dairy farm to suckler cow production.

The explanatory variables are shown in Table 4. As expected for European family farms, mainly family members carry out the work on Swiss dairy farms.[3] Only about 13% have non-family employees. The average herd size in the pooled sample is 16.3 dairy cows, which is relatively small for dairy farms in the European context. A considerable share of the farms is organic (12%), and three out of four farms regularly keep their cows outdoors.

The Herfindahl–Hirschman index (Piet 2016) based on 29 farm enterprises (sum of squared enterprises' shares in farm's total standard output[4]) describes the degree of specialisation of a farm. The average value of 0.412 indicates that Swiss dairy farms are relatively diverse. Direct payments' total is 47,783 CHF per farm. This corresponds to 42% of a farm's standard output. The regionally differentiated mean of the annual salary in the second and third sector is included to depict the off-farm job opportunities of the farmer. It amounts on average to 63,761 CHF. The milk price decreased during the period of analysis almost constantly by more than 20%; we used averages of a milk price index from the previous three years to reflect the medium-term impact. Dummies were used for farms that are located in two regions in which specific quality cheeses can be produced. Milk for Gruyère and Raclette du Valais cheese (see Fig. 1a) realizes above average prices for cheese milk; this applies to 20% of the observations.

Additionally, we controlled for regional characteristics. We differentiate between the valley, hill and mountain regions (administrative and agricultural zones) that may

[3] To keep the modelling flexible we use dummies instead of a continuous variable for the number of family workers.

[4] To calculate the Herfindahl–Hirschman index, we differentiate 18 animal farm enterprises and 11 crop enterprises based on the categories for which standard outputs are documented.

Table 4 Summary statistics of explanatory variables*. *Source*: Authors' calculations based on AGIS 2000–2017, milk price data from the Federal Statistical Office (FSO) and unemployment data from the State Secretariat for Economic Affairs (SECO)

Variable	Mean	Standard deviation
Number of workers (family): 0	0.001	0.024
1	0.084	0.278
2	0.362	0.481
3	0.297	0.457
4	0.177	0.382
5	0.045	0.206
> 5	0.035	0.183
Apprentices (binary)	0.029	0.168
Employees (binary)	0.126	0.332
Age of the farmer (years)	45.033	13.521
Number of dairy cows	16.338	12.206
Stocking rate (LU/UAA)	1.414	0.935
Organic farm (binary)	0.122	0.328
Animal welfare housing system (BTS, binary)	0.354	0.478
Regularly keeping animals outdoors (RAUS, binary)	0.755	0.430
Herfindahl–Hirschman index (0: diversified, 1: specialised)	0.412	0.115
Direct payments in 1000 CHF	47.783	27.786
Ratio of direct payments/SO	0.422	0.226
Milk price index (2015: 100)	115.881	10.172
Gruyère (PDO region)	0.155	0.362
Raclette du Valais (PDO region)	0.042	0.200
Rest of CH	0.803	0.398
Comparison salary in 2nd and 3rd sector in 1000 CHF	63.761	5.553
Unemployment rate (Canton level)	0.024	0.009
Valley region	0.217	0.412
Hill region	0.353	0.478
Mountain region	0.430	0.495
Farm type (groups)		
Specialised dairy farms	0.666	0.472
Specialised cattle farms	0.169	0.374
Suckler cow farms and combined cattle farms (group)	0.077	0.267
Horse/sheep/goat farms	0.012	0.108
Arable crops, special crops, granivore farms (group)	0.076	0.265
Number of observations	441,281	

*Not displayed are the 26 Cantons (regional administrative units) and the five policy periods

differ in terms of regional policies, but also topographical or climatic particularities. A small share of 22% is located in the valley region, while 35% are in the hill region and the remaining majority of the farms are located in the mountain region.

Finally, to document the trajectory of an exiting farm that was once classified as specialised dairy farm we differentiate five farm types or groups of related farm types consisting of one (specialised dairy farms, specialised cattle farms) or several farm types (the other three groups). This classification scheme documents the last recorded farm type (group) of an exiting (former) dairy farm. The 18 farm types differentiated

in Switzerland are grouped into five categories of farm type (groups) according to their proximity to dairy and grassland production.

Changes in the political setting and corresponding progressive liberalisation of the Swiss milk market are modelled by differentiating five policy periods. These periods consist of two base years before liberalisation (2000–2001), the implementation of a new agricultural policy in 2002 with reduced market support and the beginning of the cheese market liberalisation (2002–2006), followed by complete liberalisation of the cheese market with the EU in 2007 (2007–2008). The last two periods are defined by the end of the Swiss milk quota in 2009 (2009–2013) and the redesign of direct payment systems with transformation of animal-related contributions into area-based payments per January 2014 (see Fig. 6 in the "Appendix", Bundesrat 2017; El Benni and Finger 2013; Finger et al. 2013; Oeschger 2013).

Due to the binary nature of the outcome variables, multivariate logistic regression is used to analyse how different factors contribute to farm exits and changes. In general, the conditional probability of the outcome variable y taking up 1 is denoted by:

$$P\left(y_i = 1 \middle| x_i, \beta\right) = \Lambda\left(x_i'\beta\right) = \frac{\exp(x_i'\beta)}{1 + \exp(x_i'\beta)}$$

where i is the farm index, x a set of explanatory variables, β a vector of $1, \ldots J$ coefficients and Λ the logistic distribution function. Hence, β corresponds to the coefficients of a linear regression on the logarithm of the odds:

$$\log\left(\frac{P\left(y_i = 1 \middle| x_i, \beta\right)}{1 - P\left(y_i = 1 \middle| x_i, \beta\right)}\right) = x_i'\beta + \varepsilon_i$$

with error term ε. We estimate β with the standard maximum likelihood procedure as implemented in the Stata command 'logit' (Stata version 16.1). The standard errors of these coefficients are clustered on the farm level.

As we are interested in the estimated marginal effect:

$$\frac{\delta E\left(y_i \middle| x_i\right)}{\delta x_{ij}} = \frac{\delta P\left(y_i = 1 \middle| x_i, \widehat{\beta}\right)}{\delta x_{ij}} = \lambda\left(x_i'\widehat{\beta}\right)\widehat{\beta}_j$$

of variable $1, \ldots J$, the sign of $\widehat{\beta}_j$ can only inform about the direction of the effect. To interpret the size, we indicate average marginal effects:

$$\widehat{\mathrm{AME}}_j = \frac{1}{N}\sum_{i=1}^{N}\frac{\delta P\left(y_i = 1 \middle| x_i, \widehat{\beta}\right)}{\delta x_{ij}}$$

for selected variables.[5] The AME of a variable averages the effects across all observations and hereby provides a meaningful summary of the effect of a variable (Long and

[5] The distribution of the outcome variables is imbalanced increasing the potential for a parameter bias (King and Zeng 2001). We observe 7980 out of 441,281 observations with an exit and 1461 out of 440,995 with a farm type change. Allison (2012) explains that an imbalanced distribution is only problematic in case of small samples (about less than 1000 observations). King and Zeng (2001) give a formal prove that the parameter bias vanishes with increasing sample size by $1/N$. Hence, given the large sample size in our application, biased parameters due to an imbalanced outcome variable are less of a concern.

Freese 2014). Furthermore, AMEs allow to compare the estimated effects across groups and models (Mood 2010).

This estimator does not exploit the panel structure of the data we use. The conditional or fixed effects-logit estimator (Chamberlain 1984) provides the possibility to account for farm fixed-effects that are constant over time. A drawback of this estimator is that it only uses farms that change their outcome variable at least once. This limitation would extremely reduce our sample size from about 30,000 to only 1400 farms and yield estimates for a subsample of farms. Hence, there is a trade-off between sample size and model assumptions to consider.

Furthermore, one might think that a farm's exit strategy is a gradual process, i.e. farms change to a more extensive farm type and exit some years later. We descriptively check this possibility, but find less evidence that it is a common practice.[6] Hence, we do not implement a more complex modelling framework.

Results

Before turning to the multivariate analysis, we present summary statistics for the explanatory variables. Similar to Table 4, the following Tables 5 and 6 illustrate how the (unconditional) means differ between the group of farms with and without exit or change, respectively. Exit (change) observations represent the last observation of an abandoning (changing) farm, whereas all other farms as well as previous years' observations of an abandoning (changing) farm are summarised in the column 'Farm exit (Farm type change) = 0'.

Unsurprisingly, Table 5 shows that older farmers are more likely to exit farming. Exiting farms employ fewer family workers and non-family workers. This could be linked to the smaller average herd size (12 dairy cows) of exiting farms, requiring less work input. The Herfindahl–Hirschman index as a measure of specialisation indicates a higher degree for exiting farms. Larger farms (size measured in either employees or dairy cows) seem to be less concerned by an exit.

The share of farmers fulfilling additional standards, such as organic, animal welfare through a housing system, and regularly keeping animals outdoors (free-range) is significantly lower for exiting farms. Likewise, total direct payments are considerably lower for farms that leave the sector. This can be partly explained by smaller farms (farmed area and herd size) and lower production system payments (such as organic or animal welfare payments) of exiting farms.

Exit rates in both designated regions where farms have the opportunity to produce milk for quality PDO cheeses are considerably higher. The comparison salary is slightly higher for the exiting group. Concerning the agricultural regions, we cannot find any systematic, large difference between those farms without and with exit. The only significant difference can be found for the valley region.

Regarding the periods differentiated with regard to agricultural policy impacts, we observe lower exit rates during the first years, a steady middle period, and higher exit rates after milk quota abolition. The majority of farms exit directly from dairy farming

[6] E.g. we find for the 480 farms abandoning in 2017 that only 26 (5.4%) have experienced a farm type change over the years 2000 to 2016. For preceding years, the numbers are accordingly smaller.

Table 5 Summary statistics of staying and leaving farms. *Source*: Authors' calculations based on AGIS 2000–2017, milk price data from the FSO and unemployment data from the SECO

Variable	Farm exit = 0		Farm exit = 1		Mean difference
	Mean	Std. dev.	Mean	Std. dev.	(mean 1 − mean 0)
Number of workers (family): 0	0.001	0.024	0.001	0.025	0.000
1	0.082	0.275	0.198	0.399	0.116***
2	0.360	0.480	0.459	0.498	0.099***
3	0.298	0.457	0.208	0.406	−0.091***
4	0.179	0.383	0.097	0.296	−0.081***
5	0.045	0.207	0.019	0.136	−0.026***
> 5	0.035	0.184	0.018	0.134	−0.017***
Apprentices (binary)	0.029	0.169	0.012	0.111	−0.017***
Employees (binary)	0.126	0.332	0.105	0.306	−0.022***
Age of the farmer (years)	44.903	13.429	52.076	16.319	7.173***
Number of dairy cows	16.420	12.191	11.892	12.202	−4.528***
Stocking rate (LU/UAA)	1.414	0.934	1.387	0.983	−0.027**
Organic farm (binary)	0.123	0.329	0.070	0.255	−0.053***
Animal welfare housing system (BTS, binary)	0.357	0.479	0.184	0.388	−0.173***
Regularly keeping animals outdoors (RAUS, binary)	0.759	0.428	0.571	0.495	−0.188***
Herfindahl–Hirschman index	0.411	0.115	0.443	0.133	0.032***
Direct payments in 1000 CHF	48.052	27.727	33.183	27.048	−14.869***
Ratio of direct payments/SO	0.422	0.226	0.422	0.230	0.001
Milk price index (2015 = 100)	115.909	10.170	114.395	10.165	−1.513***
Gruyère (PDO region)	0.154	0.361	0.207	0.405	0.053***
Raclette du Valais (PDO rgn.)	0.041	0.198	0.069	0.253	0.028***
Rest of CH	0.805	0.397	0.724	0.447	−0.080***
Comparison salary in 2nd and 3rd sector in 1000 CHF	63.749	5.551	64.394	5.587	0.645***
Unemployment rate	0.024	0.009	0.024	0.009	0.001***
Valley region	0.217	0.412	0.227	0.419	0.011**
Hill region	0.353	0.478	0.350	0.477	−0.003
Mountain region	0.431	0.495	0.423	0.494	−0.007
Agricultural policy periods					
2000–2001	0.123	0.328	0.117	0.321	−0.006*
2002–2006	0.299	0.458	0.225	0.418	−0.074***
2007–2008	0.114	0.318	0.115	0.318	0.000
2009–2013	0.267	0.443	0.324	0.468	0.057***
2014–2018	0.196	0.397	0.220	0.414	0.023***
Farm type (groups)					
Specialised dairy farms	0.665	0.472	0.723	0.448	0.058***
Specialised cattle farms	0.169	0.375	0.144	0.351	−0.025***
Suckler cow farms and comb. cattle farms (group)	0.078	0.267	0.073	0.260	−0.004
Horse/sheep/goat farms	0.012	0.107	0.018	0.131	0.006***
Arable crop, granivore farms (group)	0.076	0.266	0.043	0.202	−0.034***
Number of observations	433,301		7980		

t-statistic of mean difference calculated as $(\text{Mean}_1 - \text{Mean}_0)/\sqrt{\frac{(\text{Std.dev.}_1^2)}{N_1} + \frac{(\text{Std.dev.}_0^2)}{N_0}}$

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 6 Summary statistics of farms who change to specialised suckler cow farm type and those who do not. *Source*: Authors' calculations based on AGIS 2000–2017, milk price data from the FSO and unemployment data from the SECO

Variable	Farm type change = 0		Farm type change = 1		Mean difference
	Mean	Std. dev.	Mean	Std. dev.	(mean 1 − mean 0)
Number of workers (family): 0	0.001	0.024	0.001	0.026	0.000
1	0.084	0.278	0.100	0.300	0.016**
2	0.362	0.481	0.378	0.485	0.016
3	0.297	0.457	0.295	0.456	−0.002
4	0.177	0.382	0.164	0.370	−0.014
5	0.045	0.206	0.036	0.187	−0.008*
> 5	0.035	0.183	0.027	0.161	−0.008*
Apprentices (binary)	0.029	0.168	0.015	0.122	−0.014***
Employees (binary)	0.126	0.332	0.127	0.333	0.001
Age of the farmer (years)	45.038	13.525	43.323	12.685	−1.714***
Number of dairy cows	16.340	12.210	14.266	9.347	−2.074***
Stocking rate (LU/UAA)	1.415	0.936	1.216	0.511	−0.198***
Organic farm (binary)	0.122	0.327	0.194	0.396	0.072***
Animal welfare housing system (BTS, binary)	0.353	0.478	0.463	0.499	0.110***
Regularly keeping animals outdoors (RAUS, binary)	0.755	0.430	0.814	0.389	0.059***
Herfindahl–Hirschman index	0.412	0.115	0.404	0.114	−0.008***
Direct payments in 1000 CHF	47.770	27.771	46.889	29.320	−0.881
Ratio of direct payments/SO	0.422	0.226	0.437	0.182	0.016***
Milk price index (2015 = 100)	115.882	10.170	115.603	10.717	−0.280
Gruyère (PDO region)	0.156	0.362	0.157	0.364	0.002
Raclette du Valais (PDO reg.)	0.042	0.200	0.027	0.163	−0.014***
Rest of CH	0.803	0.398	0.815	0.388	0.012
Comparison salary in 2nd and 3rd sector in 1000 CHF	63.757	5.553	63.991	5.334	0.234*
Unemployment rate	0.024	0.009	0.024	0.009	0.001***
Valley region	0.217	0.412	0.203	0.403	−0.013
Hill region	0.353	0.478	0.386	0.487	0.033***
Mountain region	0.431	0.495	0.411	0.492	−0.020
Agricultural policy periods					
2000–2001	0.123	0.328	0.120	0.326	−0.002
2002–2006	0.298	0.457	0.300	0.458	0.002
2007–2008	0.114	0.318	0.114	0.317	−0.001
2009–2013	0.269	0.443	0.199	0.400	−0.069***
2014–2018	0.197	0.397	0.267	0.443	0.070***
Number of observations	439,534		1461		

t-statistic of mean difference calculated as $(\text{Mean}_1 - \text{Mean}_0)/\sqrt{\frac{\left(\text{Std.dev.}_1^2\right)}{N_1} + \frac{\left(\text{Std.dev.}_0^2\right)}{N_0}}$

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

and do not change their farming type prior to exiting. Additionally, higher exit rates result for farms that were once a dairy farm and changed farm type to 'horse/sheep/goat farms' before exiting. On the other hand, dairy farms that evolve to the specialised cattle farm type or to the class 'arable crop, granivore farms' exhibit lower exit rates. For suckler cow farms, we observed no differences between exiting and persisting farms.

Summing up, considerable absolute differences between the groups occur for the variables age, number of dairy cows and the sum of direct payments. Furthermore, large relative differences appear for the label dummies (organic and animal welfare schemes RAUS and BTS).

Within the farms that do not exit, changes in farm type may occur. Here, our specific interest lies in changes to the specialised suckler cow farm. The descriptive statistics of the farms that change their farm type to suckler cow and those which do not are illustrated in Table 6. The average age of farmers who change is slightly lower. Production type changing farms are on average smaller (number of dairy cows) and exhibit higher shares of organic, free-range, and animal welfare housing production systems. Farm type change occurs more often for less specialised farms who are slightly more dependent on direct payments. Especially farms in the hill region are switching to suckler cow production.

In the following section, we will analyse the structural change using a multivariate regression approach.[7] Table 7 presents the results of two logistic regression models: (1) exit from farming and (2) the change to the suckler cow farm type. Notice that average marginal effects (AMEs) are illustrated. For variables whose squared terms or other interactions are included in the logistic models, the overall AME is given. For selected continuous variables (farmer's age, dairy herd size, Herfindahl–Hirschman index, direct payments total), graphical illustrations of average marginal effects are provided. Conclusions on the strength of the relationship of individual variables with the outcome variable on the basis of the present results must be considered in connection with the scaling of the respective variable and the observed value ranges. For example, the average marginal effect of being located in the mountain region is associated with an approximately 1 percentage point increase in the probability of exiting. The supposedly small effect of a continuous variable, such as the number of cows, which also has a relatively high standard deviation in relation to the mean value, can have a stronger relationship with the exit probability in case of large cow herds.

First, the results of the model '(1) Exit' are presented. The probability of farm exit increases with age, employees, the degree of specialisation, the dependence on direct payments, for farms located in one of the two PDO regions, off-farm opportunity costs of labour, and the difficulty of production (in hill and mountain regions). A higher number of family workers, herd size, quality, animal welfare programs (organic, BTS, RAUS), direct payments, as well as elevated cantonal unemployment rates work against farm exit (e.g. additional 1000 CHF of direct payments lower the exit probability by 0.05 percentage points).

Second, the model '(2) Farm type change to suckler cow' demonstrates that farm type change increases for farms with label production (organic, RAUS, BTS), higher comparison wages and milk prices, as well as with increasing difficulty of production conditions (hill or mountain area). Decreasing effects go along with a larger number of family workers, age, direct payments, a higher ratio of direct payments to a farm's total standard output, the stocking rate and operating in the Raclette du Valais PDO region.

[7] For a better overview, Table 8 in the "Appendix" provides a comprehensive summary of our preliminary hypotheses and the results of the logit models.

Table 7 Average marginal effects of logistic regressions. *Source*: Authors' calculations based on AGIS 2000–2017, milk price data from the FSO and unemployment data from the SECO

Variables	Exit	Farm type change to suckler cow
Number of family workers: 0 (1 is base category)	−0.0102 (0.0065)	0.0003 (0.0041)
2	−0.0055*** (0.0007)	−0.0003 (0.0004)
3	−0.0106*** (0.0008)	−0.0005 (0.0004)
4	−0.0120*** (0.0009)	−0.0008** (0.0004)
5	−0.0143*** (0.0012)	−0.0011** (0.0005)
> 5	−0.0137*** (0.0013)	−0.0010* (0.0006)
Employees (binary)	0.0054*** (0.0008)	0.0003 (0.0003)
Apprentices (binary)	−0.0003 (0.0018)	−0.0015*** (0.0004)
Age of the farmer (years)°	0.0019*** (0.0000)	−0.0001*** (0.0000)
Number of dairy cows°	−0.0003*** (0.0000)	−0.0000 (0.0000)
Stocking rate°	−0.0002 (0.0004)	−0.0034*** (0.0003)
Organic farm (binary)°°	−0.0025*** (0.0008)	0.0013*** (0.0003)
Animal welfare housing system (BTS, binary)°°	−0.0030*** (0.0007)	0.0019*** (0.0003)
Regularly keeping animals outdoor (RAUS, binary)°°	−0.0014*** (0.0005)	0.0011*** (0.0003)
Herfindahl–Hirschman index	0.0172*** (0.0021)	0.0001 (0.0009)
Direct payments in 1000 CHF°	−0.0005*** (0.0000)	−0.0000*** (0.0000)
Ratio of direct payments/standard output (SO)	0.0068*** (0.0015)	−0.0043*** (0.0008)
Milk price index (2015 = 100)	0.0000 (0.0001)	0.0001*** (0.0000)
Gruyère (PDO region)	0.0034*** (0.0011)	0.0006 (0.0005)
Raclette (PDO region)	0.0055*** (0.0013)	−0.0023*** (0.0007)
Comparison salary in 2nd and 3rd sector in 1000 CHF	0.0009*** (0.0003)	0.0007*** (0.0002)
Unemployment rate	−0.3039*** (0.0569)	−0.0260 (0.0250)
Region (Valley region is base category)		
Hill region	0.0039** (0.0016)	0.0035*** (0.0008)
Mountain region	0.0096*** (0.0036)	0.0097** (0.0039)
Agricultural policy periods (base period 2000–2001)		
2002–2006	−0.0026 (0.0016)	−0.0018 (0.0013)
2007–2008	−0.0039* (0.0020)	−0.0031* (0.0016)

Table 7 (continued)

Variables	Exit	Farm type change to suckler cow
2009–2013	−0.0014 (0.0026)	−0.0042** (0.0018)
2014–2018	−0.0062*** (0.0029)	−0.0040** (0.0020)
Number of observations	441,281	440,995
Number of farms	29,754	29,733
Wald test statistic	9814.78 ($df = 65$)	1037.97 ($df = 60$)
Canton dummies	YES	YES
Production type dummies	YES	NO
Not included Cantons°°°		GE, SH

Standard errors in parentheses are clustered on the farm level

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Degrees of freedom = df

°These variables are included also in squared terms in the regression analysis. In this table, the overall marginal effect of a variable is presented

°°These variables additionally are considered as interaction variables with the variable direct payments; here, the overall marginal effect is presented

°°°As there are no farms in the cantons Geneva (GE) and Schaffhausen (SH) which switched to specialised suckler cow farm type, farms from these cantons are not taken into account in this model

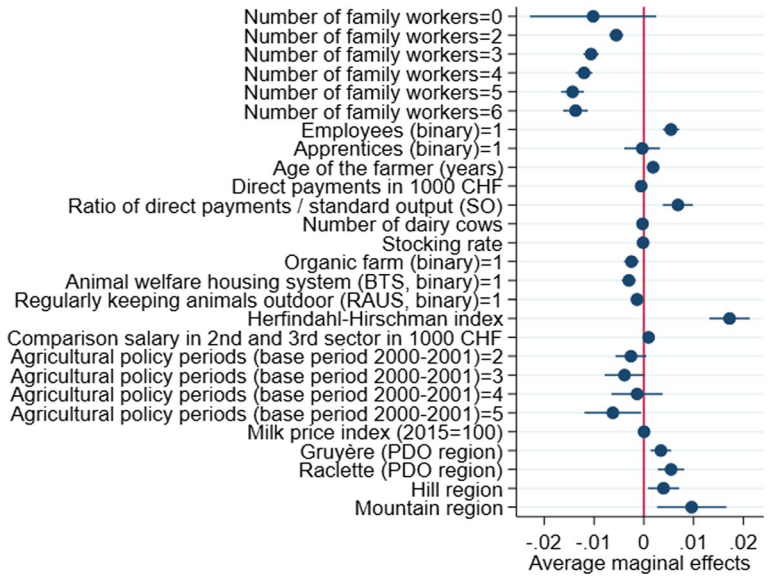

Fig. 2 Plots of average marginal effects of the logistic regression for the probability of a farm exit. *Notes*: Point estimates with lines illustrating the 95% confidence interval

To illustrate the patterns within the regression results of the models but also to compare the two logit models, we provide plots of the average marginal effects of the two estimated models. Figure 2 shows plots of the AMEs of the farm exit model, and Fig. 3 shows those of the farm type change model.

Comparing the exit and change model shows oppositional coefficient signs for age, quality labels (organic, BTS, RAUS), the ratio of direct payments to the standard output,

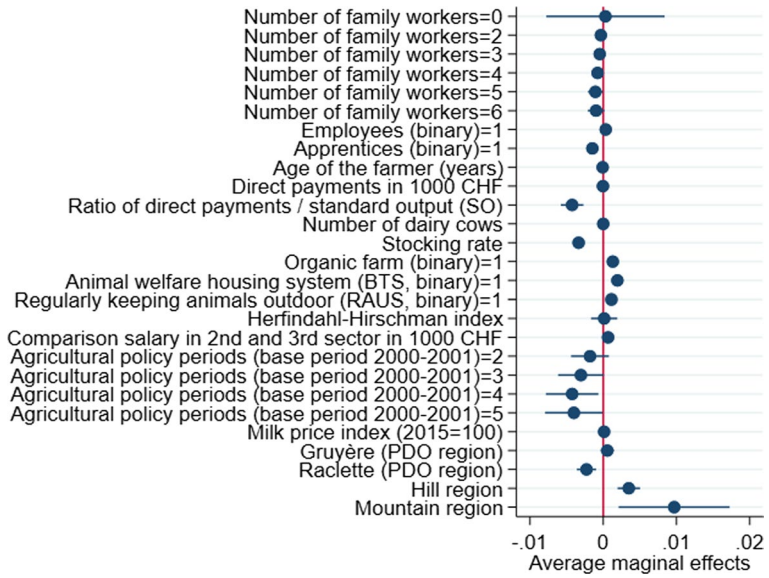

Fig. 3 Plots of average marginal effects of the logistic regression for the probability of a farm type change to suckler cow farming. *Notes*: Point estimates with lines illustrating the 95% confidence interval

and in the PDO region Raclette du Valais. Few variables are in either the exit model or the change model of economic and statistical relevance, such as the number of dairy cows, specialisation (Herfindahl–Hirschman index), the milk price index, or the unemployment rate.

The agricultural policy periods, differentiated with regard to the dairy sector, exhibit significant negative effects during two periods (2007–2008 and 2014–2018) in the exit model and during the last three periods (since 2007) in the change model. In other words, the exit (change) probability rather decreases in relation to the base period (years 2000–2001). We do not interpret the agricultural policy periods as a direct measure for agricultural policies. For example, our analysis does not allow disentangling the effect of the milk quote abolition. We rather consider these dummies as a categorization of political events, which is quite close to a pure trend variable.

To better understand the specific relevance of certain variables, AMEs are plotted for the variables age, herd size (number of dairy cows), specialisation (Herfindahl–Hirschman index), and total direct payments. Figure 4 displays the corresponding AMEs for the farm exit model.[8]

The first graph top left in Fig. 4 depicts the curve illustrating the AME on the farm exit probability dependent on the farm operator's age. The intersection of the curve with the horizontal axis is at around 30 years; beyond that, the AME on the exit probability is positive. Above 55 years, the AME on the exit probability increases sharply.

The statistically significantly negative effect of herd size is larger for smaller herd sizes and further diminishes with increasing herd size. Interestingly, the positive AME of specialisation on the exit probability is higher for more specialised farms than for diverse

[8] Figure 7 in the annex complementary provides exit probability plots for the displayed variables.

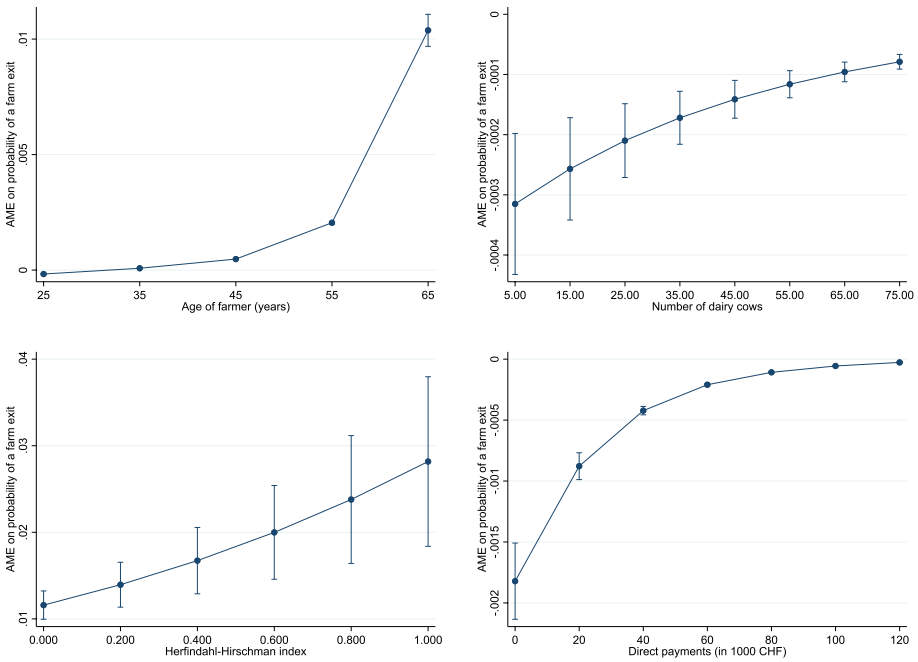

Fig. 4 Average marginal effect (AME) of logistic regression for the probability of a farm exit. *Notes*: Point estimates (solid line) with 95% confidence interval (dashed lines). Direct payments are measured on an annual basis in 1000 Swiss francs

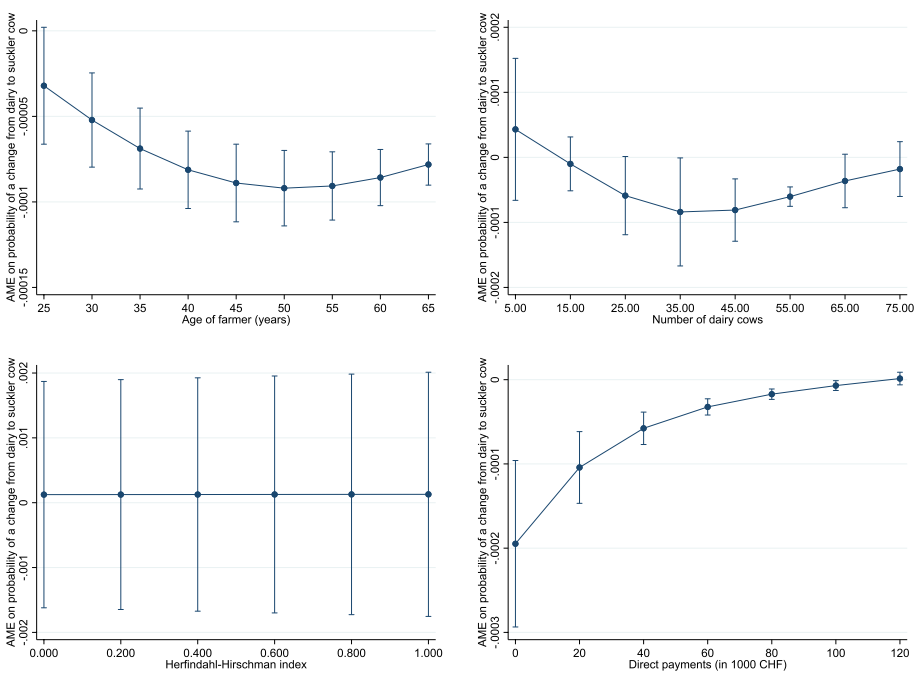

Fig. 5 Average marginal effect of logistic regression for the probability of a change from dairy to suckler cow. *Notes*: Point estimates (solid line) with 95% confidence interval (dashed lines). Direct payments are measured on an annual basis in 1000 Swiss francs

farms. The effect of direct payments is negative over the variable's entire range, but approaches zero for very high values. Hence, one may conclude that higher transfers alone cannot prevent farms from abandonment.

Figure 5 illustrates the AMEs for the change model to the specialised suckler cow farm type.[9] The curve of the farm operators' age lies mostly within a low negative range. Regarding herd size, the effect is positive but statistically zero for very small farms; it turns significantly negative for farms with more than 45 dairy cows, but approaches zero again for very large farms. The AME of a farm's specialisation is neither economically nor statistically significantly different from zero all over the range. Furthermore, like for a farm's exit, the generally negative effect of direct payments diminishes with higher levels of direct payments and eventually approaches zero.

Discussion

The results of the two logistic models confirm essential hypotheses for structural change in Swiss dairy farms. The side-by-side analysis of farm exit and farm type change reveals similar and differing relations with single factors. First, we discuss results that confirm our hypotheses and former results of similar studies. Second, we discuss results from our analysis that deserve further attention.

The general relevance of the difficulty of production conditions and of general economic conditions as well as the stabilising association with direct payments is supported by our analysis. According to the model results, farm operators' age is positively related to farm exit and negatively to the probability of a farm type change. Looking in detail at differentiated age classes, the probability of exits increases sharply for older farmers. This can be interpreted as a generally stable farm situation in the dairy sector, which is defined by farm exits of older farmers (e.g. in case no successor is available when exceeding the age threshold of 65 years to get direct payments).

Regarding the farm type change model, we observed a negative (change probability decreasing) relationship with age. The strategic orientation to change farm type is rather taken by younger farmers after farm acquisition. Anecdotal evidence that mostly small farms change to suckler cow production is supported by the number of family workers; however, herd size seems not to be related to the change probability.

When differentiating herd size, we observe that the generally decreasing relation of the dairy herd size with the exit probability is particularly important for small farms. Furthermore, lower amounts of direct payments have a stronger association with a farm exit and farm type change than high payments. These two findings express the marginal perspective that an additional dairy cow or increasing direct payments are worth more for small farms.

The adherence or fulfilment of additional standards such as organic or animal welfare schemes reduces the probability of a farm exit. As expected, these programs allow farms to tap into added value (Salvioni et al. 2013). Apart from economic motivation, however, adherence to organic or animal welfare schemes could also be an expression of openness for innovation or motivation for sustainable family farming (also in terms

[9] Figure 8 provides in addition farm type change-probability plots for the displayed variables.

of family farming tradition), i.e. unobserved characteristics. Such unobserved characteristics could positively impact the possibility to stay in farm business which would bias our estimates. Hence, as discussed also at the end of this section, we are cautious about interpreting the results as causal effects, but prefer the interpretation as conditional correlations.

Other variables for which the results differ from former analyses or our hypotheses deserve further discussion: Theoretically ambiguous, a higher degree of specialisation is empirically related to significantly more exits. Specialised dairy farms in grassland areas where only limited alternative farming activities exist, in combination with barriers to growth (e.g. limited area for farm enlargement, dead end), could contribute to this result. Specialised farms could be less resilient due to their focus on a single or few outputs and increased income risk (El Benni et al. 2012).

In both regions in which internationally known quality cheeses can be produced, we observe increased exit probabilities. Milk production for these cheeses often takes place in mountain areas; however, we control for difficulty of production. Since the production involves specific requirements (such as milk delivery twice a day in case of Gruyere) and the quantity of production is controlled for, not all farms in a PDO region may benefit; farmers located in a PDO region but not belonging to a PDO production scheme could experience a more pronounced price difference. Higher exit rates in a PDO region could reflect stronger competition for land which is reflected in above average growth rates of different farm size measures. The UAA (growth rate in region Gruyère: 1.6%, Raclette: 2.3%, rest of Switzerland 1.4%), the dairy herd size (growth rate in region Gruyère: 1.7%, Raclette: 1.1%, rest of Switzerland 0.8%) as well as the farms' standard output (growth rate in region Gruyère: 1.8%, Raclette: 1.6%, rest of Switzerland 1.2%) increase more strongly in the Gruyère and Raclette regions compared to the rest of Switzerland. In summary, we can state that structural change is more apparent in the PDO cheese regions under consideration. For policy makers, the promotion of such qualitative differentiation could therefore offer a starting point for stimulating structural change in the dairy sector. Given the high relevance of quality schemes in regional and agricultural policies, a deeper understanding of the underlying effects deserves further attention.

The average milk price declined by nearly 20% during the period of analysis, especially after the milk quota abolition. However, milk prices do not seem to be related to a dairy farm's exit, but higher milk prices increase the probability of a farm type change. This unexpected effect could trace back to the level of aggregation of the milk price index, and there may be different findings for disaggregated data at farm level. Unfortunately, such data sources are not widely available. One may also suggest that the downward movement of the milk price may confound the coefficient in the sense that it depicts a linear trend rather than the variation of the milk price itself. However, the results from a model including a linear time trend turn out to be robust with our presented findings.

The higher probability of a farm type change for organic and free-range farms (RAUS) may be explained by growth barriers that accompany the implementation of free-range practices. Since free-range grazing is limited to areas close to the barn, such farms could imply a higher probability of diversification since herd size growth relies on additional free-range area. To empirically test this hypothesis, we estimate an additional model with interactions of herd size and RAUS or organic farming,

respectively. Although the marginal plots do not systematically differ between additional quality schemes, the AMEs are negative and larger pronounced for RAUS and organic dairy farms with a large herd size. Hence, those who can tap additional value by quality schemes and grow in size experience smaller probabilities to change to suckler cow husbandry, which supports our hypothesis. Apart from economic motives, the implementation of organic and animal welfare schemes and their association with a farm type change could be linked to a farmers' disposition with regard to moral and environmental concerns (Ferguson and Hansson 2013; Kielland et al. 2010).

Specialisation does not exhibit an association with farm type change. This implies that both specialised and diversified farms exhibit similar change probabilities (i.e. there are farms that gradually shift by diversifying and other farms that directly shift from specialised dairy to specialised suckler cow production). This finding illustrates that the effects of higher profitability and higher risk may cancel each other out.

According to the logit models' results, structural change in the dairy sector was not stimulated during the periods of different agricultural policy reforms. Although we observed significant differences between staying and leaving (changing) farms when comparing groups of farms, the multivariate model results indicate only negative coefficients. The last period in particular reflecting the last agricultural policy reform exhibits decreasing exit and change probabilities indicating a deceleration of structural change in the Swiss dairy farm sector. Lips et al. (2016) explain the specific steadiness of Swiss dairy farms by nonpecuniary job preferences, such as passion and farm managers' preference for self-employment.

However, agricultural policy can also drive structural change in the sector and hereby directly and indirectly influences other policy areas. The simultaneous analysis of different development options of dairy farms at the same time, using the example of Swiss dairy farming, illustrates different starting points. With regard to environmental policy, the change from dairy to suckler cow farming typically is accompanied by a lower land use intensity (lower stocking density), which can contribute to the objective to reduce nitrogen surplus. On the other hand, the lower intensity of suckler cow farms goes along with lower value-added in the agricultural sector and decreased food provision compared to more intensive farming activities. This example illustrates potential conflicts of objectives. Depending on the primary policy objective, this analysis of Swiss dairy production offers various starting points for agricultural policy. To safeguard agricultural income and milk supply, policy could focus on stabilizing viable dairy farms, e.g. by supporting their growth. This could imply exit incentives for older dairy farmers. To reduce the sector's nutrient surplus, the change to suckler cow farm types could be stimulated, e.g. by corresponding farm advice especially during the process of intergenerational farm handover. The detailed understanding which factors of dairy farms correlate with farm exit or with farm type change to suckler cow husbandry allows governments to better control structural change in the dairy sector. Therefore, knowledge of the detailed development of the sector is important in order to be able to comprehensively assess the possibilities and the consequences of agricultural policy measures with regard to the different policy goals.

Changing to a less intensive farm type could be the first step of a longer process of farm exit. However, we could not find any descriptive evidence for this expectation given our comprehensive data set of almost 20 years.

Overall, the results show a diverse picture of factors that influence the development of Swiss dairy farms. Age is of high relevance for farm exit. Generally, the influence of other economically important factors, such as herd size (AME of −0.0003 per cow in the exit model) or direct payments (AME of −0.0005 per 1000 CHF), may seem of limited significance. However, such an isolated consideration of individual factors might neglect the overall effect of significant variables. The low absolute relevance of individual factors can rather be understood as expression of the complexity of change processes.

Finally, we would like to add some thoughts on further robustness checks or extensions of the analysis. The quality of the administrative data used in this article is generally high. More details would have been useful with regard to the concrete labour input (which is only documented in three rough categories), farm household's off-farm labour and income, the existence of a potential farm successor, and to farm-related activities. A high number of family workers only roughly models the existence of a potential farm successor which is an important factor to prevent farm exit (Dong et al. 2016). Farm-related activities can offer diversification and business development opportunities and could therefore enrich such analyses. Suckler cow products in Switzerland are often marketed via direct marketing; therefore, existing farm shops could increase the probability to change from dairy to suckler cows. However, data on farm-related activities such as direct marketing, tourism, services (work as private contractor, care farming) are not yet collected systematically in the given data.

Our analysis raises some questions about the relevance of farm specialisation and PDO cheese production regions for dairy farms' structural development. Both factors result in increased farm exit probabilities. Which farms in the PDO regions exit—those with PDO production or those without? Are barriers to growth the reason that specialised dairy farms exit? Which other reasons could contribute to the increased exit probabilities of specialised farms? Such questions should be answered by in-depth analyses.

Additionally, the outcome variables under consideration all relate to the extensive margin of farm type changes (i.e. change versus no change), and neglect the intensive margin (i.e. the number of dairy or suckler cows). Hence, it may be worthwhile to examine changes with respect to herd size. With a continuous outcome measure, the estimation of a linear fixed effects model may be suitable and would allow considering the panel structure of the data. Such a model implies the elimination of time-constant farm-specific effects.

In this context, a causal interpretation of our empirical analysis is based on the assumption that we can fully observe all relevant variables that are related to the outcome and our factors of interest. Although we have detailed data on farm characteristics that we include in the logistic regression, we are cautious about any causal interpretation and prefer the wording "conditional correlation".

Conclusion

This contribution sheds light on the changing nature of Swiss agriculture's most important farm type, dairy farms, and its structural development. Using administrative data from the agricultural policy information system, logit models were estimated for

different occurrences of structural change, farm exit, and the change to the labour-extensive farm type suckler cows. Both farm types rely on grassland and cattle. Our findings contribute to the literature by analysing farm exit and farm type change side-by-side. The results indicate considerable differences between these different strategic decisions (Hansson and Ferguson 2011).

Our analysis reveals that older farmers rather exit farming, whereas the decision to change farm type is taken by younger farmers. In order to influence the development of the agricultural sector, the phase before the age limit is reached or the phase after the younger generation has taken over the farm offers itself to the policy.

Farm size, quality schemes such as organic or animal welfare schemes, and direct payments correlate with farm viability. More difficult climatic and geographic production conditions and better off-farm working opportunities and off-farm income contribute to farm exit and farm type change.

Swiss agriculture is small-structured, and the objective of Swiss agricultural policy is to increase its competitiveness. Therefore, the results are relevant when orientating policy measures concerning structural change in Swiss dairy production. Incentives to exit could be focused on older farmers conventionally producing milk, whereas incentives and advice to change farm type rather should be oriented to younger farmers adhering to quality schemes in case off-farm working opportunities are available. Given the high importance of dairy production in Swiss agriculture, particularly in mountain regions, and the discussion on more sustainable farming practices (e.g. reduction in farm manure to ensure water quality), such differentiation of policy measures is relevant (Pedersen et al. 2020) and could be a blueprint for neighbouring European countries' mountain dairy farms. Implications are also relevant for neighbouring policy areas such as spatial planning, environmental, as well as food policies.

Furthermore, we determined that both farm exit and farm type change can occur either directly or as perennial process during which the farm activity abated. Farm type changes could even constitute an ongoing farm exit over a longer period. The analysis of structural change mostly emphasises farm exit and thus neglects farm type changes. Therefore, structural change analysis of agriculture should be more focussed on intra-sectoral changes by considering farms' strategic decisions not to exit but to diversify or specialise. Predicting farm exits and farm type changes could be also a relevant, further development of this paper. Using advanced methods such as Markov models and accounting for the imbalance of the outcome variables might contribute to the scientific work and serve as a tool for policy makers. These issues deserve further attention.

Appendix

See Table 8 and Figs. 6, 7, 8.

Table 8 Hypotheses on the direction of action of explanatory variables and the final results of the farm exit and farm type change models. *Source*: Authors' calculations based on AGIS 2000–2017

Variable	Hypotheses		Model results	
	Exit	Change	Exit	Change
Number of family workers	−	−	−	−
Age	+	−/+	+	−
Herd size (number of dairy cows)	−	−	−	0
Intensity of production (stocking rate)	−/+	−	0	−
Organic production	−	−	−	+
Animal welfare housing system	−	−	−	+
Animal welfare: outdoor keeping	−		−	+
Specialisation (Herfindahl–Hirschman index)	−/+	−/+	+	0
Direct payments total	−	−	−	−
Dependency from direct payments (share of DP in farm's standard output)	+	+	+	−
Milk price	−	−	0	+
PDO cheese region with above average milk prices	−	−	+	−
Comparison salary	+	+	+	+
Unemployment rate	−	−	−	ns
Difficulty of farm production	+	+	+	+

+: increasing the probability; −: decreasing the probability; 0: economically not significant; ns: statistically not significant

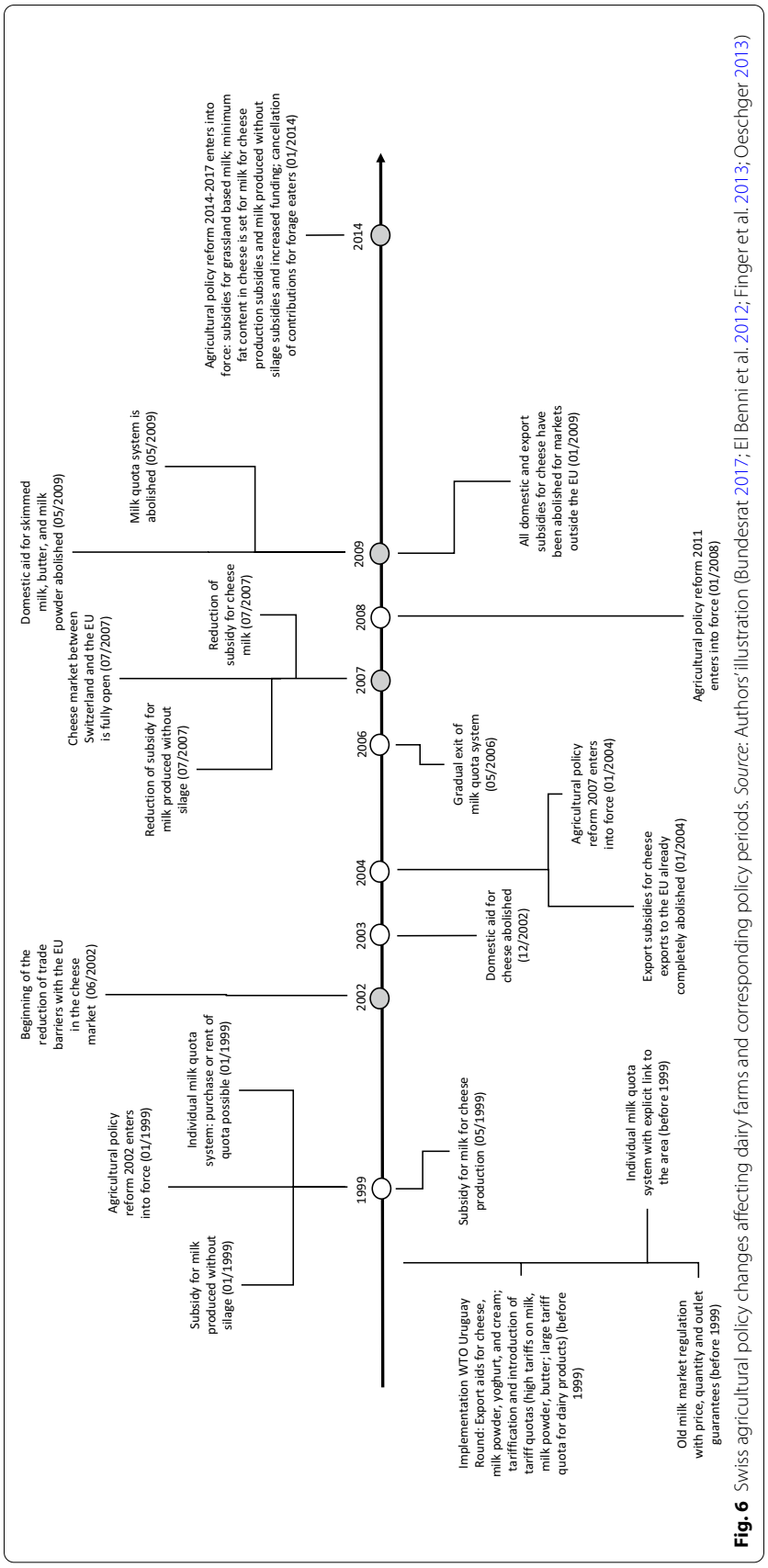

Fig. 6 Swiss agricultural policy changes affecting dairy farms and corresponding policy periods. *Source:* Authors' illustration (Bundesrat 2017; El Benni et al. 2012; Finger et al. 2013; Oeschger 2013)

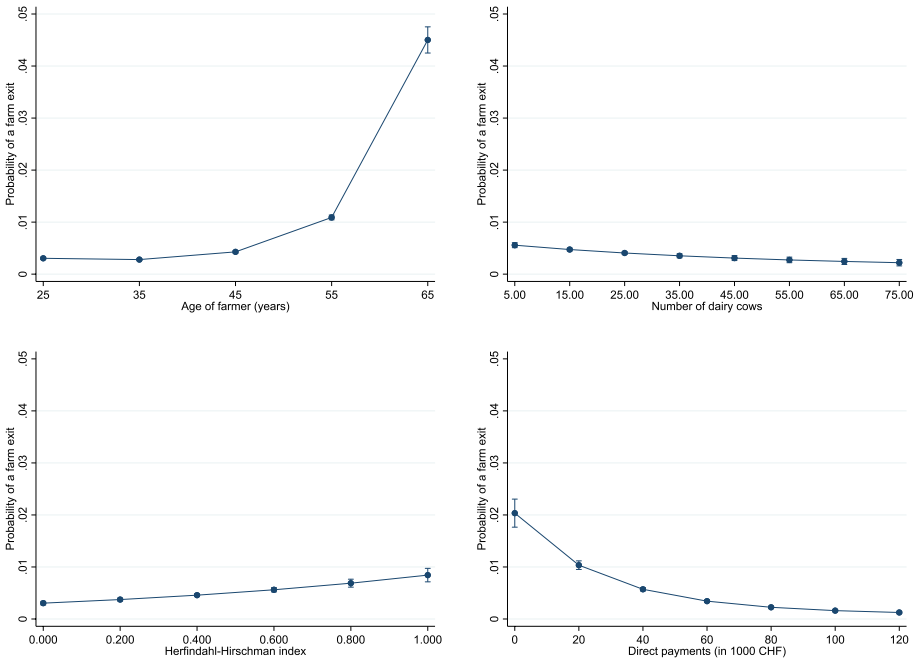

Fig. 7 Predicted probabilities for a dairy farm exit. *Notes*: Predictions with 95% confidence interval

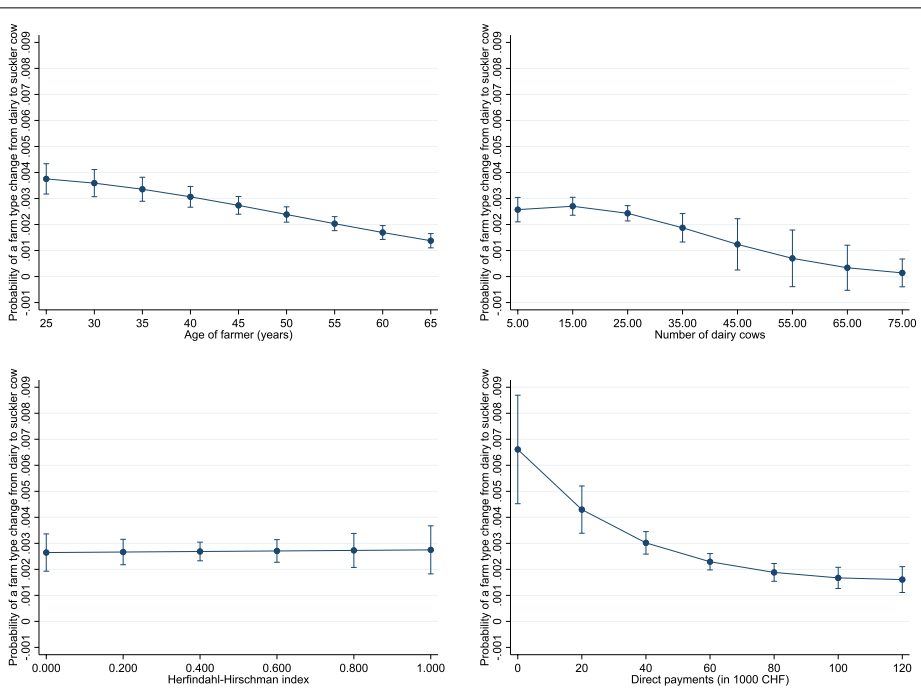

Fig. 8 Predicted probabilities for a farm type change from dairy to suckler cow. *Notes*: Predictions with 95% confidence interval

Abbreviations
AGIS: Agricultural information system; AME: Average marginal effect; BTS: Animal welfare through housing system (direct payment programme); CHF: Swiss francs; DP: Direct payments; EU: European Union; FADN: Farm accountancy data network; FOAG: Federal Office for Agriculture; FSO: Federal Statistical Office; LU: Livestock units; OECD: Organisation for Economic Cooperation and Development; PDO: Protected designation of origin; RAUS: Regularly keeping animals outdoors (direct payment programme); rgn: Region; SECO: State Secretariat for Economic Affairs; SO: Standard output; Std. dev.: Standard deviation; UAA: Utilisable agricultural area.

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Authors' contributions
AZ planned the analysis and processed the data. FZ designed and performed the data analysis and interpretation. AZ and FZ drafted the article. Both authors critically revised the text and read as well as approved the final manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The underlying data are available from the Swiss Federal Office for Agriculture. However, restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission of the Federal Office for Agriculture. The estimation of the logit models was performed using the software STATA. The corresponding do-files document the methods of estimation and are available from the authors upon request.

Declarations

Competing interests
The authors declare no competing interests.

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