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Research article

Should I stay or should I go? The impact of nature reserves on the survival and growth of dairy farms

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ABSTRACT

Special Areas of Conservation (SAC) are part of the EU's nature protection network Natura 2000. SAC often protect nitrogen-sensitive flora and fauna. This is challenging for livestock farmers because they have to meet strict requirements for emission reduction and need to implement costly environmental protection measures. Therefore, SAC could limit farmers' chances to grow or even to survive. This article aims to determine the effects of SAC on dairy farmers by using a Heckman sample selection model. The model explores *i)* the factors that are relevant to the decision to maintain the farm's existing structure, increase dairy production, exit dairy, or exit agriculture altogether, *ii)* an OLS regression to analyse the factors that determine the amount of growth in dairy numbers. The analysis was performed for two periods and is based on annual financial statements and regional data such as information about SAC locations. In the first step, the results confirmed the initial hypothesis, finding that farms in districts with more land under nature conservation had a smaller probability of growth. For one of the two periods analysed, higher probabilities of exiting dairy were observed. The second part of the analysis showed that the amount of growth was not affected by SAC protection. The results indicate that SAC protection is indeed challenging for dairy farmers. Further research on the topic is necessary as the area under protection will increase. Since the protected species also depend on (extensive) farming practices, it might be necessary to provide development prospects to farmers that better align with biodiversity objectives.

1. Introduction

The dairy sector is facing several challenges, including the public's concerns about the environmental impact of livestock farming. For this reason, the common agricultural policy has been redirected. The *Biodiversity Strategy,* for instance, aims to restore biodiversity until 2030 and explicitly addresses agriculture. For example, the usage of pesticides must strongly decrease, and at least 25% of farmers should manage their farms organically. In addition, the area under protection will increase to 30% in 2030 (European Commission, 2022). Farmers are concerned about the increasing requirements for environmental protection. This is shown, for example, by German farmers' protests against the ban on herbicides in SAC (Koch, 2022).

Farmers in nature reserves have faced the challenge of combining agricultural production and nature protection for a long time. The Habitat Directive was introduced in 1992 and protects wildlife, plants, and their habitats. Based on the directive, SAC and special protected areas (SPAs – known as bird sanctuaries) were designated. SAC and SPA form the EU's nature protection network Natura 2000 (Bouwma et al., 2019). SAC include different habitat types, for instance, natural and seminatural grassland. They are important habitats for rare orchids, butterflies, and lizards (Annex I and II - Council Directive 92/43/EEC, 1992). However, they are also important for dairy farmers' feed production. This leads to conflicting interests between nature protectionists and farmers (EEA, 2020).

Many habitats contain plants that are sensitive to nitrogen, and nitrogen dispositions result in biodiversity losses (Maskell et al., 2010). This is important for livestock farmers because deterioration of habitats with SAC status is forbidden (Council Directive 92/43/EEC, 1992). Therefore, a SAC impact assessment has to be carried out when farmers plan to build new livestock housing units. Livestock farmers are particularly challenged because livestock husbandry accounts for 557.8 kt or 95% of Germany's total ammonia emissions (586.6 kt NH_3) (Roesmann et al., 2021). In addition, farmers are expected to implement costly conservation measures (Latacz-Lohmann, 2017; Lakner et al., 2020).

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Although these requirements have important implications for farms, few articles have examined the impact of SAC on agriculture. Koemle et al. (2019) investigated the effects of Natura 2000 protection on land prices. Jacobsen et al. (2019) used investment calculations to determine the costs farmers face for additional emission abatement techniques close to SAC. To the best of our knowledge, this is the first study to examine whether the requirements are so severe that farmers exit agricultural production. We analyse how SAC affect farmers' decisions to maintain their previous structure, expand their dairy production, exit dairy production, or exit farming altogether. This is of interest as 50% of German farms keep cattle, and structural change in the sector is already high, with 25% of cattle farms having left the sector since 2010 (BMEL, 2022).

In doing so, this paper adds to the rich literature on structural change in dairy (Weiss, 1999; Foltz, 2004; Samson et al., 2016; Zimmermann and Heckelei, 2012; Dong et al., 2016; Laepple and Sirr, 2019). Previous studies on structural change have found that herd size is crucial for a farm's survival and growth (Huettel and Jongeneel, 2011; Laepple and Sirr, 2019; Weiss, 1999). Fewer studies have examined the interaction between farms and other stakeholders in the land market, such as other farmers or larger settlements (Foltz, 2004; Sumner and Wolf, 2002; Zimmermann and Heckelei, 2012).

Data on the location of nature reserves and tax accounting data for roughly 6000 dairy farms were used in the analysis. A two-step Heckman model was estimated. In the first step, the determinates of decisions were estimated using a multinomial logit model, and then the driving forces of growth were estimated using an OLS regression. The second step included a correction for sample selection bias. The analysis was performed for two time periods.

The following section provides a literature review and some legal background on the topic. The third section presents the main hypotheses, the empirical method and the data. In section 4, the empirical results for the first and second steps of the analysis are presented. Section 5 gives a critical discussion of the results before the article closes with conclusions.

2. Legal framework - special areas of conservation and their impacts on agriculture

Germany has 4544 SAC, which cover 9.3% of Germany's terrestrial area (German Federal Environmental Agency, 2020). Areas qualify for SAC designation if they contribute significantly to maintaining the habitats of species listed in the Habitats Directive[1] (Council Directive 92/43/EEC, 1992). Almost half of the protected area is agricultural land. The protected agricultural land is mostly grassland (80%) (DVL, 2017). Once an area is designated as worthy of protection, any deterioration is prohibited. In addition, measures must be developed and implemented that improve the conservation status of the areas. The measures are of a legal, administrative, and contractual nature and are intended to avoid species disturbance (Article 6, Council Directive 92/43/EEC, 1992). They often seek to extensity agricultural production because most habitats and species depend on extensive agricultural usage (EEA, 2020). Farmers in SAC not only face challenges because they are expected to extensity production. The following section shows that it is also difficult for them to expand livestock production. Therefore, SAC protection could affect farmers negatively. This is because more intensive dairy farms with larger herds were more likely to continue farming in the past (e.g., Foltz, 2004; Dong et al., 2016).

[1] The protected habitats are: costal and halophytic habitats, coastal sand and continental dunes, freshwater habitats, temperate heath and scrub, natural and seminatural grassland, raised bogs and mires, rock habitats and caves, and forests.

2.1. The environmental impact assessment

New animal livestock housing units are considered to be projects that are not directly related to the area's conservation management. Therefore, an environmental impact assessment is necessary to ensure that they will not result in deterioration (Council Directive 92/43/EEC, 1992). In this context, the ammonia emissions from the planned building are decisive and must be below a certain level (Jacobsen et al., 2019; Latacz-Lohmann, 2017). The threshold levels for additional nitrogen dispositions are the so-called *critical loads*. In principle, the sum of emissions of all barns that were built after SAC registration (pre-pollution) and the emissions from the new installation must remain beneath the threshold value of the SAC. If this applies, a building permit is granted (Latacz-Lohmann, 2017; BMVBS, 2013). Farmers in the immediate vicinity face greater challenges in complying with the regulations because higher levels of nitrogen reach the SAC (Jacobsen et al., 2019; Latacz-Lohmann, 2017).

However, a building permit can be granted in some cases, even if the emissions are above the threshold value. Whether farmers receive such permits depends on the *cut-off criterion* and the *de minimis threshold*. The *cut-off criterion* determines whether the additional emissions are only low, and if the additional nitrogen emitted by the new building is less than 0.3 kg N per hectare per year, the project can be approved. If the *cut-off criterion* is exceeded as well, it must be determined whether the SAC-specific critical load value is exceeded by more than 3% (*de minimis threshold*). If this is not the case, a building permit is also possible (BMVBS, 2013). Both criteria exist because they involve different intensities of examination and because experts disagree on whether there is a causal relationship between very low additional nitrogen inputs and conservation status (Latacz-Lohmann, 2017).

In practice, the pre-pollution of the barns already built after SAC registration is often so high that the critical load would be exceeded by the new barn. In this case, additional nitrogen abatement techniques can be installed to reach the *de minimis threshold*. However, this technical implementation involves additional capital requirements and higher costs, increased running costs due to the use of the technology, and opportunity costs if a smaller barn than that originally planned has to be built (Jacobsen et al., 2019; Latacz-Lohmann, 2017).

2.2. Legal implementation of management plans

Management plans for SAC are also important for farmers. The management plans record the condition of the reserves and define measures to preserve or even improve them. Management plans are not legally binding for farmers but they are for the authorities and are a guideline for the authorities' future actions. However, if they are passed into law, they become legally binding for farmers (Bouwma et al., 2019). Landowners are usually encouraged to participate in the planning processes (Blondet et al., 2017). Existing management plans provide farmers with information about the measures that are planned (EEA, 2020).

Germany's federal states are responsible for implementing these management plans. Lakner et al. (2020) and Koemle et al. (2019) describe differences in the implementation process in Natura 2000 areas. States can implement conservation measures using regulations, voluntary agri-environmental schemes (AES), or both. Saxony and Bavaria are the only states which have not transferred management requirements into legally binding regulations. They use AES, which is a more flexible way of implementing conservation measures, and participation is voluntary for farmers.[2] Therefore, farmers in certain states might be more heavily affected than others.

Management measures for agriculture usually address grassland

[2] Two practical examples in the appendix show that whether measures are implemented by regulations or AES leads to significant differences.

(Koemle et al., 2019). Therefore, dairy farmers might be especially affected. These measures are usually characterised by some of the following: prohibition of pesticides, chemical fertilisers, additional drainage and/or grassland renewals. Additionally, farmers are often required to delay mowing (Koemle et al., 2019). Compensation payments for legal measures are sometimes granted because the measures lead to reduced productivity (Kellermann and Salhofer, 2014). However, farmers are not always compensated for possible disadvantages arising from nature conservation. These must be accepted by the social bond of ownership (National Constitution Article 14, Paragraph 2). In practice, six German states paid no subsidies in the period 2007 to 2013 (Koemle et al., 2019).

However, few articles analyse how the above-described legal requirements affect agriculture, and no article analyses whether the disadvantages of SAC protection are so severe that farmers leave the sector. Koemle et al. (2019) analysed the impact of nature conservation on rental prices for farmland and whether the compensation payments were sufficient. They showed that price elasticities for arable land and grassland were negative in districts with Natura 2000 protection status and concluded that the compensations granted might not be adequate. This might be problematic as research shows that a strong engagement of stakeholders, and long-term funding are drivers of success in Natura 2000 nature conservation (IEEP, 2019). In another study, Jacobsen et al. (2019) calculated the additional costs of emission reduction near nature reserves (2000 m and 400 m distance) for average German, Dutch and Danish farms. The study found that farmers face different costs when reducing emissions below their country's threshold levels. These additional costs can be so high that farmers would prefer to invest in other locations or not to invest at all.

3. Methodology

3.1. Hypothesised effects of SAC and other factors on dairy farmers' investment decisions

This article aimed to analyse the effects of SAC on dairy farmers' past investment decisions and tested four main hypotheses. The first hypothesis is **(H1): Dairy farmers show lower probabilities of growth in districts with more land under protection**. This is because of the environmental impact assessments and potentially high costs for emission abatement (Jacobsen et al., 2019).

However, the increasing regulatory requirements may not only prevent farmers from growing their farms. Abandonment of the whole farm might be caused by the described environmental impact assessment. This assessment is often also necessary for investment in alternative production branches, as is the case with certain tourism activities and some agricultural or fishery practices (German Federal Environmental Agency, 2009). **Therefore, SAC can limit income alternatives in general and lead to farm abandonment (H2).**

However, Thiermann et al. (2019) found that different factors underlie the decision to exit dairy farming and the decision to exit farming altogether. For exits from agriculture, a farmer's age and the income provided by the whole farm were important. In contrast, exits from dairy farming were determined by the characteristics of the branch of dairy production. SAC could especially affect the branch of dairy production because the measures often address grassland (Koemle et al., 2019), and emission abatement is expensive in dairy husbandry (Jacobsen et al., 2019). **Therefore, an additional hypothesis is that SAC protection causes higher exit probabilities from dairy only (H3).**

The emissions added by the new barn are decisive in the environmental impact assessment. Therefore, farmers could build smaller barns to reduce the overall emissions and fulfil the requirements (Jacobsen et al., 2019; Latacz-Lohmann, 2017). **The fourth hypothesis is that farmers build smaller barns in districts with a higher share of protected area (H4).** In this case, we would not find significant effects on growth probabilities.

However, nature protection is not the only factor that could affect farmers' investment decisions. The scale of milk production, as measured by the number of dairy cows or the amount of milk produced, has been shown to have a positive impact on the likelihood of growth (Samson et al., 2016). It is further known that farmers with higher milk production per cow seek to grow (Zimmermann and Heckelei, 2012; Stokes, 2006). While higher milk prices are expected to promote growth, the variance in milk prices affects the probability to expand production negatively (Zimmermann and Heckelei, 2012; Neuenfeld et al., 2018; Petrick and Goetz, 2019).

Natural conditions, such as soil quality, indicate comparative advantages and influence the probability of growth in certain parts of production (Neuenfeld et al., 2018). For example, a high share of grassland or poor soil quality might lead to more investment in dairy (Zimmermann and Heckelei, 2012). However, high levels of specialisation as expressed by the Herfindahl-Index (HHI) can cause sunk costs and lead to a higher probability of maintaining instead of growing (Foltz, 2004).

In addition to these farm characteristics, the financial features of the farm need to be considered. The income from farming activities only ('ordinary results'), the farm's ability to carry additional debt service ('debt service border'), and the 'interest rate' account for farmers' ability to invest. Limited availability of capital (Petrick and Goetz, 2019; Samson et al., 2016) that might be expressed by lower ordinary results, a high utilisation of the debt service border, and higher interest rates are factors that could reduce the probabilities of growth.

Other articles have already considered regional factors other than SAC, such as high population or livestock densities. They might indicate increased competition for workers (Neuenfeld et al., 2018) or concerns about environmental issues (Sumner and Wolf, 2002), both of which might limit farmers' opportunities to grow. It is also assumed that higher livestock densities could indicate high pre-pollution and limit farmers' chances for a building permit. Huettel and Jongeneel (2011) and Bradfield et al. (2020) also describe the availability of land as being important, for example, for fodder production. Therefore, higher land prices are assumed to lead to lower probabilities of growth.

Fewer articles analysed factors that determine the amount of growth in dairy numbers. The former size of the production branch seems to be decisive and increased growth levels. In addition, younger and more highly educated farmers invested in larger barns (Weiss, 1999; Dries and Swinnen, 2004). In terms of regional features, a high population density might lead to lower investment due to increasing concerns about larger animal husbandry units. All of these factors are considered in the analysis.

3.2. Empirical model – two step heckman model

When estimating structural change with regression models, a distinction is made between different possible options. Weiss (1999), Foltz (2004), and Dong et al. (2016) considered decisions to 'maintain' production or to 'exit'. Seo and Mendelsohn (2008) analysed farmers' decision to invest in different livestock types with a multinomial regression. In the first step of this analysis, there are four possible choices considered: *i)* **maintain** dairy production at the same size, *ii)* **increase** dairy production, *iii)* **exit dairy** farming only, and *iv)* **exit agriculture** altogether. The distinction between *iii* and *iv* is made because an exit from animal husbandry alone may be considered desirable, for example to lower overall emissions in the area. However, farm abandonment (exit farming altogether) might not be desirable as it potentially leads to deterioration (EEA, 2020).

The empirical investigation is carried out using a multinomial logit model (MNL). Train (2002) provides a detailed description of discrete choice models. In the multinominal regression, it is assumed that the farmer will choose the option that provides him/her with the highest utility. The utility is assumed to be impacted by the farmer's and farm's characteristics as well as by regional characteristics, such as the amount of area under nature protection. A requirement to be able to use the model is the fulfilment of the independence of irrelevant alternative (IIA) assumption (Train, 2002). The Hausman and the Suest-test can be performed to test the assumption. The latter is used if the Hausman test is undefined (Stata, 2020).

Some articles also used OLS regression to analyse factors that determine herd sizes (Dong et al., 2016), or the amount of growth (Weiss, 1999; Dries and Swinnen, 2004). Following these examples, a linear regression of the amount of growth (in dairy cows) was performed. As in Weiss (1999) and Dries and Swinnen (2004), the dependent variable in the OLS regression is the logarithm of the observed growth in dairy cows. This is because including the logarithm lowers the influence of potential outliers (Bradfield et al., 2020).

Sample selection bias was considered in this step because the linear regression is only performed for the growing subgroup, which is not randomly selected. This can lead to flawed conclusions in the OLS regression (Certo et al., 2016). For this reason, the above-mentioned articles (Weiss, 1999; Dries and Swinnen, 2004; Seo and Mendelsohn, 2008) considered sample selection bias. They used a two-step correction developed by Heckman (1979).

The selection process is considered by including correction terms. They are calculated from the probabilities determined in the first step. In the first step, the MNL determines the probability for an observation to appear in the second equation (OLS). Based on the probability, the correction terms are calculated. Bourguignon et al. (2007) compare different methods for MNL models and recommend the approach by Durbin and Mc Fadden (1984).

In the first step (MNL), it is assumed that the probability for $i = 1, \ldots,$ N farmers to choose one of $m = 4$ options is a latent variable z_i^*. z_i^* depends linearly on the k vectors of predictors denoted as w_i':

$$z_i^* = w_i'\gamma + u_i \tag{1}$$

where γ is a vector of parameters to be estimated and u_i is a random disturbance term. The probability of a farmer growing depends on the probability that 'growth' is the best of all other $j = 1, \ldots, = m\text{-}1$ options. In this case, the observation enters the second equation, which aims to investigate the amount of growth (y_i). y_i is observed for $i = 1, \ldots n < N$ farmers and influenced by the characteristics of the farm and the region (x_i'):

$$y_i = x_i'\beta + \lambda_i\beta_\lambda + v_i \tag{2}$$

The random disturbance v_i has zero conditional mean and is not correlated with u_i. In this parameterisation, sample selection bias was considered by using (m-1) correction terms expressed here as the vector λ_i. The vector λ_i is usually referred to as the inverse mills' ratio. The vector depends on the predicted probabilities estimated in equation (1). As λ_i needs to be estimated from (1), and this extra source of variation needs to be taken into account. Therefore, the inference is based on 50 bootstrap replications. If λ_i are not zero, self-selection affects the decision (Bradfield et al., 2020).

In general, the Heckman model allows common variables in both models. In Weiss (1999) and Dries and Swinnen (2004) the same sets of variables are used in the MNL and the OLS. Newer articles, for example, Bushway et al. (2007) and Certo et al. (2016) advise excluding at least one variable that is assumed to influence the first decision (to invest in dairy) and is assumed to be uninfluential for the second decision (the amount of growth). There is no technical method to apply to decide which variable should be excluded, but the exclusion should be based on substantive grounds. Not excluding a variable can result in multicollinearity (Bushway et al., 2007; Certo et al., 2016).

3.3. Data

Different data sources were used for the analysis. First, there was data on SAC protection at the level of NUTS-3 districts. The data were downloaded from the websites of the individual states' environmental authorities. If no information was available online, it was requested by e-mail.[3]

The main areas of German dairy production were considered in the analysis. Data was not available for all other states. The states considered are Bavaria, Baden-Württemberg, Lower Saxony, Nordrhein-Westfalen, and Schleswig-Holstein. They account for 77% of German dairy production (Statista, 2021). For the federal states of Lower Saxony, Schleswig-Holstein, North Rhine-Westphalia, and Bavaria, the data allowed a quantification of the proportion of the nature reserves in the respective NUTS-3 districts. For Baden-Württemberg, it was presumed that the protected areas were evenly distributed between the districts if SAC were located in more than one district. SAC that are only marine habitats were not considered.

Second, other variables relating to regional characteristics, such as population density and the share of grassland, came from Germany's Federal Office of Statistics. The federal states' statistical offices also provided information about land prices and livestock units in each district. Third, financial statements provided information about the farmers, their farms, and decisions about future investments and originated from LAND-Data and LBV (software providers for tax accounting in agriculture). The number of dairy cows, which forms the primary decision variable in the MNL, also came from inventory records on these financial statements. For the calculation of the Herfindahl Index, additional data from KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft) on standard gross margins were used (Sauer and Hardeweg, 2006).[4]

Since Germany was slow to designate the SAC to the EU, the analysis started in 2000 rather than in 1992 (German Federal Environmental Agency, 2020). Two sub-periods were analysed, each consisting of a base period and a period of evaluation. The first base period is 2001–2003 (Financial year (FY) 2001/2002 - FY 2003/2004), and the second is 2008–2010 (FY, 2008/2009 – FY, 2010/2011). Table 1 gives an overview of the base periods and the periods of evaluation. The two periods are independent of each other. The analysis ended in 2015 because more recent data was not available.

Only conventional, full-time farms with dairy cows in the base period were considered. The variables of interest were obtained by averaging them within the base period. Only for dairy cows, the maximum number

Table 1
Base periods and periods of evaluation.

	Base Period[a]	Evaluation Period[b]
Dataset 2003	2001, 2002, 2003	2006, 2007, 2008
Dataset 2010	2008, 2009, 2010	2013, 2014, 2015

[a] Average expressions of the included variables were calculated for the years in the base period.
[b] The number of cows in the base period and period of evaluation were compared to derive the amount of growth in dairy cows and the decisions for the MNL (Source: Own representation).

[3] The data holds information on the area under SAC protection per NUTS-3 district. Based on this, the share of area protected per NUTS-3 district was calculated. In some cases, only the amount of area protected per district was known. In others, a list of SAC was provided, holding the SAC name, their number, and the habitat types. Measures, their implementation, and the distance to specific farms were unknown. Examples of the data used are provided in the appendix.

[4] Some variables used (dairy cows, milking yields) were taken directly from the tax accounting data. Others for instance, ordinary results per worker, livestock units on farm, HHI values were calculated. Additional information on the variables is presented in the appendix.

of dairy cows in each period was used to model the actual barn size. To derive the decisions for the MNL the number of dairy cows between the period of evaluation and the base period was compared. In this way it was determined whether farmers chose to *i*) maintain dairy production at the same size, *ii*) increase dairy production, *iii*) exit dairy farming only and *iv*) exit agriculture altogether. In the first group, farms 'maintain' if they keep the same number of dairy cows in the base period and the period of evaluation. In the second group, the number of dairy cows increased. If the farm did not keep dairy cows throughout the evaluation period but accounting data were still available, the farms were considered to have 'exited dairy only'. The last group has 'exited agriculture altogether'; these were dairy farmers for which no accounting data was available in the period of analysis. These farmers may have retired or given up farming completely. They could have also arranged for another accounting organisation that is not associated with LBV or LAND-Data. However, the number of software providers is limited in Germany. The amount of growth was determined by a comparison of the maximum number of dairy cows. This amount of growth entered into the model as the logarithm.

4. Results

4.1. Descriptive statistics

Table 2 shows the number of observations according to the possible investment decisions. In total, 6425 dairy farms were considered for the first period analysed and 5531 for the second period. The number of farms that increased their dairy production was larger in the second period.

The mean expression of each variable in the base period is reported in Table 3. In 2003, the average farmer was around 46 years old and cultivated about 76 ha of land, more than half of which was grassland. The soil quality index was relatively low at 34 out of one hundred points. Considering milk production, about 60 dairy cows were kept per farm, and their average milk production per year, per cow was 6605 kg. The Herfindahl Index showed that the average farm was already highly specialised, with the main product generating more than half of the farm's revenue (57%). Each employee generated approximately € 29,555 of ordinary results.

On average, the utilisation of the debt limit in this sample was between 70% and 80%. Following the recommendation of Schuring (2011), the farms were grouped into classes.[5] Considering regional variables, roughly 7% of the area of the districts in which the farms were located was under SAC protection. In 2003, the farms were located in regions with about 162 people per km^2, and the livestock density measured in livestock units (LU) was 120 LU per hectare, which represents intensive livestock production (Eichhorn, 2006). Most of the analysed farms were in Schleswig-Holstein (35.09%) or Bavaria (28.18%). Fewer farms were located in Baden-Württemberg (11.41%), Nord-Rhine-Westphalia (11.86%) or Lower Saxony (13.46%). The mean expressions for the second period were similar, but the number of dairy

Table 2
Number and share of farmers in the decision categories analysed.

	Dataset 2003	Dataset 2010
Maintain	2150 (33.46%)	1111 (20.33%)
Grow	3334 (51.89%)	3566 (65.25%)
Exited dairy farming only	411 (6.40%)	316 (5.78%)
Exited agriculture	530 (8.25%)	472 (8.64%)
Total number of observations	6425 (100%)	5465 (100%)

Source: Own representation/calculation with Stata 15

Table 3
Descriptive statistics of the analysed samples.

	2003		2010		
	Mean	Std. Dev.	Mean	Std. Dev.	**Variable Definitions**
Features of the farm					
Soil quality index	34.41	11.13	33.77	10.93	The soil quality index is a measure of land productivity and reflects soil quality, slope, and climate (100 points represent the best quality)
Agricultural area (100 ha)	0.76	0.39	0.86	0.47	Agricultural area of the farm in 100 ha
Share of grassland farm (%)	52.65	24.26	50.60	23.29	Share of permanent grassland on the farm's total agricultural area
Ordinary results (€1000)	29.55	24.87	43.56	33.78	Ordinary results per worker in € 1000. The so-called ordinary results are the income from farming only.
Employees	1.43	0.90	1.44	0.76	Number of employees (families and foreign workers)
Interest rate (%)	4.35	1.77	4.04	1.75	Interest rate in %
Utilisation of the Debt service border	4.08	2.73	3.76	2.73	The exhaustion of the short-term debt service border describes whether a company is able to pay the debt service in the short term
Herfindahl Index	56.83	12.76	53.69	12.14	The Herfindahl Index measures the amount of specialisation and has values between 0 and 100 (low specialisation - high specialisation)
Livestock Units per hectare on farm	1.45	1.37	1.45	1.05	Livestock units per hectare already kept by the farmer
Milk prices (€/100 kg)	34.19	1.89	32.97	2.16	Milk price paid to the farmer in €/100 kg
Variance milk prices	5.97	13.68	12.61	21.79	Variance of milk price during the base period
Milk yield (100 kg/cow)	66.05	12.89	72.23	13.93	Milk yield per cow in 100 kg/cow * year
Dairy cows (100 cows)	0.60	0.30	0.72	0.42	Number of dairy cows kept in the base period
Demographic factors					
Education	0.32	0.47	0.37	0.48	Farmer has a university degree in agriculture
Age	46.33	9.94	48.98	9.05	Age in years
Regional features					
Share of SAC	7.26	5.53	7.11	5.46	Share of SAC per district
Share of grassland district	38.04	19.77	38.72	19.90	Share of grassland per district
Population density (100 people/km^2)	1.62	1.40	1.57	1.34	Population density in 100 people per km^2
Livestock units district (100 LU/km^2)	1.20	0.37	1.16	0.38	Livestock units (LU) in 100 LU per km^2
Land prices (€1000/ha)	17.19	10.00	21.24	9.93	Land price per hectare in € 1000/ha

Source: *Own calculation with Stata 15*

[5] Farms that exhausted less than 50% of their debt service border were assigned to class 1; if less than 60% was used, the farms were assigned to class 2; if less than 70% was used, they were put in class 3; if less than 80% was used, they were put into class 4; if less than 90% was used, they were put into class 5; if less than 95% was used they were put into class 6; finally if more than 95% was used or the exhaustion of the debt service border was negative due to losses, the farms were assigned to class 7.

cows and agricultural area increased, as did average milk yields. The descriptive statistics for the part of the sample that chose to increase dairy production are shown in appendix Table 1.

Overall, the descriptive statistics reflect German dairy production well. Abdulai and Tietje (2007) analysed German farms that operated on 56 ha and kept 107 livestock units. This led to 1.91 livestock units per hectare. The German dairy farmers in the sample of Skevas et al. (2018) operated on 65 ha and kept 96.4 livestock units, and thus had 2.01 livestock units per hectare. The farmers in this sample had 110 livestock units in 2007, and 125 livestock units in 2010. This led to a slightly lower amount of livestock units per hectare on farm level. In the other two studies, only specialised dairy farms that generated more than 75% of their sales from milk production were included. They were thus more specialised. This might explain the higher livestock units per hectare reported by Abdulai and Tietje (2007) and Skevas et al. (2018).

4.2. Empirical results

The results are presented as follows. First, the results from the MNL are presented, followed by the results of the OLS regression. Possible sample selection bias was considered in the OLS regression.

4.2.1. Results for the first step – factors relevant to farmers' investment decisions

The coefficients of the average marginal effects calculated for the MNL model are shown in Table 4. The null hypothesis that the model has no predictive power for both periods was rejected. McKelvey & Zavoina's Pseudo-R^2 were calculated for the decision categories.[6]

The decision to 'maintain' was considered as the base, and the coefficients were restricted to zero. The average marginal effects in Table 4 were calculated for the other decision categories. In both periods, the largest share of farmers decided to grow their dairy operations. The predicted probability of growth was 54%, followed by the predicted probability of maintaining (32%) and probabilities of exit (8%). Furthermore, 6% were predicted to discontinue dairy. In 2010 the probabilities were 65% for growing, 20% for maintaining, 6% for exiting dairy and 9% for exiting agriculture.

Based on the estimation, the four main hypotheses can be answered as follows: Dairy farms located within districts with more land under nature conservation showed smaller probabilities of growth (both periods). Therefore, **H1** can be accepted. Regarding the exit probabilities, the results vary over the periods. No effect was found in the 2010 dataset, but in the 2003 dataset, higher probabilities for exiting dairy production were observed. This is in line with **H3,** and we assume that SAC mostly affect the branch of dairy production. **H2** assumed higher exits from agriculture and is thus rejected. However, it may also be possible that higher exit probabilities only appear in the longer term.

Overall, the effects found are small. The marginal effect of the share of SAC is half as big as the one for age but comparable to the effects of other regional features, for example, land prices. In general, the size of the effects was larger in the second period.

Considering the other included variables, growth in the branch of dairy production seemed to be more likely for efficient dairy producers. Higher milking yields and higher milk prices increased the probabilities of growth. The number of cows kept was not influential in 2003. In 2010, larger dairy operations were more likely to continue growing. High soil quality reduced the probability of growing, whereas a higher share of grassland per district increased the probability of growth. Overall, these results are in line with the literature, and we can confirm the findings of Samson et al. (2016) regarding the amounts of dairy production and of Zimmermann and Heckelei (2012) for milking yields and prices.

Other regional variables, such as land prices, also led to higher investment in dairy. This is not in line with the assumptions. The results could indicate that farmers in areas with high land prices are more challenged to invest in cropping and, therefore, invest in livestock. As expected, high exhaustion of the debt service border limited the probability of growth. These farmers were assumed to be less likely to be granted credits. A higher Herfindahl index had the same effect. This confirms the assumptions of Foltz (2004) or Petrick and Goetz (2019). Regarding personal characteristics, the probabilities of growing were higher for younger farmers. Furthermore, lower probabilities for growth were found for farms in districts with a high population density and an already high livestock density in 2010. These regional effects are described, in example, by Neuenfeld et al. (2018).

Concerning exit intentions, farmers with smaller herds seemed more likely to leave dairy farming. Furthermore, older farmers tended to end dairy production, and those strongly depended on fodder production from grassland (share of grassland on farm). In contrast, a higher share of grassland per district and high land prices reduced the probabilities of exiting dairy, indicating that investment alternatives might be limited. A higher soil quality that could indicate better chances of investing in arable farming also led to increasing exits. The described results were found in both periods. In addition, a high population density led to higher probabilities of exits from dairy in 2003. In 2010, we found that higher variance in milk prices also increased exits from dairy and that more efficient dairy farmers (based on milking yields) were more likely to continue. The results are also described by Dong et al. (2016) for age and herd size. A higher technical efficiency (milk yield) also reduced exit probabilities in their study. Weiss (1999) also found higher exit probabilities of smaller herd sizes and farmers over fifty years old. However, Weiss (1999) and Dong et al. (2016) did not analyse exits from dairy and agriculture separately.

In comparison, fewer effects were found in both periods for exits from agriculture. This might be explained by the data. For the exit decisions it is only assumed that farmers disappearing from the dataset exited farming. Overall, we find that age was of importance and that the competition within the area (livestock units) was influential in both periods.

Thiermann et al. (2019) found that the decision to stop farming is independent of certain characteristics of production branches. Whether a farmer is close to retirement age seemed to be decisive for an exit from agriculture. Farmers' and farms' characteristics seemed to determine whether they disinvested in dairy. This could explain why few variables are significant for an exit from farming.

4.2.2. Results for the second part of the estimation – factors relevant for the amount of growth

For the second part of the estimation, regular R^2 were calculated. The OLS regression models were able to explain roughly 16% of the variation in 2003 and 26% of the variation in 2010. The archived model fit is comparable to Seo and Mendelsohn's (2008) values. The presented parsimonious models in Table 5 were determined using the likelihood ratio test.

As recommended by Bushway et al. (2007) and Certo et al. (2016), a variable of significant influence in the first step was excluded from the OLS regression to avoid correlation. In the estimation, the exhaustion of the debt service border was left out of the OLS regression. It is assumed that the extent to which a farmer reaches their debt limit is decisive for being granted further credit. Farmers already exhausting the debt limit to a large extent are unlikely to be granted any further credit, especially

[6] Langer (2016) and Veall and Zimmermann (1996) show that McFadden's pseudo-R^2 is not a suitable measure for the explanatory power of MNL models. This is because McFadden's pseudo-R^2 is downward biased in multinomial regression models. They recommend the calculation of McKelvey & Zavoina's pseudo-R2 per decision category. Veall and Zimmermann (1996) show that both pseudo-R2s are comparable. Comparing our results to Weiss (1999) the models seem to provide an equal fit. Weiss (1999) calculated Pseudo-R^2 values that ranged between 0.052 and 0.094, the estimated pseudo-R^2 of the models presented in the article varied between 0.09 and 0.15.

Table 4
Marginal effects on farmers' investment decisions in dairy (dataset 2003 and 2010).

	Dataset 2003 (LL = −6098.69)						Dataset 2010 (LL = −5349.04)					
	Growth		Exit Dairy		Exit Agriculture		Growth		Exit Dairy		Exit Agriculture	
	dy/dx	**P > z**	**dy/dx**	**P > z**	**dy/dx**	**P > z**	**dy/dx**	**P > z**	**dy/dx**	**P > z**	**dy/dx**	**P > z**
Soil quality index	−0.001*	0.061	0.0005*	0.074	−0.000003	0.993	−0.002***	0.002	0.001**	0.030	0.001***	0.003
Agricultural area (100 ha)	−0.042	0.102	0.031***	0.003	0.014	0.300	−0.010	0.621	−0.011	0.321	0.011	0.348
Share of grassland farm (%)	−0.001**	0.029	0.0003*	0.095	−0.0003*	0.079	−0.0003	0.456	0.0003*	0.061	−0.0002	0.243
Ordinary results (€1000)	0.001***	0.000	0.0001	0.358	−0.0003*	0.066	0.0001	0.609	−0.0002	0.125	−0.0002	0.242
Employees	0.019**	0.032	0.003	0.331	−0.004	0.404	−0.033***	0.001	0.006	0.146	0.005	0.375
Interest rate (%)	0.004	0.268	0.002	0.222	0.003	0.153	0.000005	0.999	0.0002	0.922	0.006***	0.007
Debt service border	−0.022***	0.000	0.002	0.109	0.001	0.285	−0.006**	0.010	−0.001	0.584	−0.001	0.402
Herfindahl Index	−0.001**	0.021	0.001**	0.045	0.001**	0.012	−0.002**	0.010	−0.001***	0.007	0.001	0.147
Livestock units per ha on farm	0.012*	0.072	−0.003	0.427	0.003*	0.080	0.009	0.185	−0.003	0.538	−0.0002	0.963
Milk prices (€/100 kg)	0.008**	0.047	−0.006***	0.001	0.004*	0.091	0.005*	0.095	−0.003	0.135	−0.001	0.672
Variance milk prices	−0.00005	0.942	−0.0002	0.558	−0.001	0.284	−0.0003	0.497	0.0003**	0.042	−0.0001	0.816
Milk yield (100 kg per cow)	0.005***	0.000	0.0001	0.582	0.001*	0.071	0.005***	0.000	−0.001***	0.004	0.0003	0.239
Log-Dairy cows (100 cows)	0.013	0.523	−0.074***	0.000	−0.014	0.178	0.123***	0.000	−0.035***	0.000	0.003	0.754
Education	0.024*	0.091	0.004	0.564	−0.010	0.220	−0.005	0.707	0.008	0.251	0.003	0.670
Age	−0.006***	0.000	0.001***	0.000	0.004***	0.000	−0.008***	0.000	0.002***	0.000	0.004***	0.000
Share of SAC	−0.003**	0.011	0.001*	0.066	0.001	0.314	−0.002*	0.067	−0.001	0.332	0.001	0.381
Population density (100 people/km^2)	−0.004	0.444	0.005**	0.015	0.002	0.580	−0.011**	0.028	0.001	0.684	0.011***	0.000
Livestock units district (100 LU/km^2)	−0.014	0.505	0.001	0.958	0.043***	0.000	−0.090***	0.000	0.013	0.236	0.048***	0.000
Land prices (€1000/ha)	0.002***	0.007	−0.002***	0.000	−0.001	0.202	0.005***	0.000	−0.001**	0.015	−0.001**	0.007
Share of grassland district	0.002***	0.000	−0.001***	0.002	−0.0002	0.382	0.002***	0.000	−0.001***	0.000	0.0002	0.505
McKelvey & Zavoinas R^2	0.09		0.15		0.11		0.15		0.11		0.13	

Level of significance: *p < 0.1, **p < 0.05, ***p < 0.01.
Source: Own representation/calculation with Stata 15. The IIA assumption was fulfilled in both data set. The fulfillment of the IIA hypotheses also means that the decision category 'Exit Agriculture' can be left out of the analysis without significantly affecting the other coefficients. Correlation coefficients were calculated for the variables considered. The Pseudo-R^2 values were provided by Stata. The McKelvey & Zavoina's R^2 values for the MNL were calculated as proposed by Langer (2016).

Table 5
Heckman sample selection model – the amount of growth.

	2003				2010			
	Log-Growth - full model		Log-Growth - parsimonious model		Log-Growth – full model		Log-Growth - parsimonious model	
	coef.	p > z	coef.	p > z	coef.	p > z	coef.	p > z
Soil quality index	−0.002	0.453			−0.005*	0.066	−0.004**	0.044
Agricultural area (100 ha)	0.004	0.975			0.029	0.694		
Share of grassland farm (%)	0.0004	0.806			0.001	0.440		
Ordinary results (€1000)	−0.001	0.632			−0.001	0.372		
Employees	−0.025	0.339			−0.011	0.734		
Interest rate (%)	0.014	0.304			0.017	0.255	0.027**	0.038
Dept service border								
Herfindahl Index	−0.007***	0.006	−0.008***	0.000	−0.009***	0.005	−0.009***	0.000
Livestock units per hectare on farm	−0.038	0.392	−0.045	0.315	−0.004	0.882		
Milk prices (€/100 kg)	0.008	0.700			−0.009	0.390		
Variance milk prices	−0.002	0.669			0.001	0.510		
Milk yield (100 kg per cow)	0.002	0.560			0.010***	0.006	0.011***	0.001
Log-Dairy cows (100 cows)	1.309***	0.000	1.291***	0.000	1.222***	0.000	1.274***	0.000
Education	−0.014	0.786			−0.095**	0.014	−0.100**	0.023
Age	−0.013*	0.057	−0.018***	0.000	−0.026***	0.000	−0.024***	0.000
Share of SAC	−0.006	0.228	−0.006	0.162	−0.0003	0.955		
Population density (100 people/km^2)	−0.045**	0.014	−0.047***	0.008	0.002	0.397		
Livestock units district (100 LU/km^2)	0.060	0.604			−0.088	0.442		
Land prices (€1000/ha)	0.0002	0.948			0.007*	0.074	0.004	0.101
Share of grassland district	0.0031	0.105	0.003***	0.008	0.007	0.219	0.004***	0.005
m1_0	1.635***	0.002	1.859***	0.000	1.411**	0.014	1.253***	0.008
m1_2	−1.357	0.137	−1.041**	0.020	−0.819	0.301	−1.302***	0.009
m1_3	−0.341	0.735	−0.968**	0.043	−1.275	0.127	−0.587	0.186
_cons	−2.373	0.115	−1.629***	0.000	−1.717*	0.068	−2.577***	0.000
R^2	0.165		0.164		0.257		0.256	

Level of significance: *p < 0.1, **p < 0.05, ***p < 0.01.
Source: Own representation/calculation with Stata 15. VIF values were calculated to check for multicollinearity. The maximum value was 2.51 for the first period and 2.92 for the second period. This indicates that there are no concerns that could arise from multicollinearity in our results. M1_0, m1_2 and m1_3 are the correction terms calculated from the MNL estimation.

for large investments. Therefore, the amount of growth is assumed to be independent of the debt limit.[7] The effects estimated for the correction terms were significantly positive, indicating that sample selection should be considered.

The share of SAC per district was not a significant factor in explaining the growth in dairy numbers. Therefore, **H4** is rejected. As indicated by earlier studies, former herd size seemed to be highly important, as were the age of the farmer and the investment alternatives in the area (share of grassland per district). In 2010, higher milk yields also resulted in greater growth. The positive influence of interest rates in 2010 might indicate growth processes in the past (Foltz, 2004). Furthermore, farmers with high levels of specialisation (HHI) seemed to grow to a smaller extent in both periods.

The results are consistent with the literature. Dong et al. (2016) found positive effects of greater efficiency, a higher education, a larger agricultural area, and a negative influence of age. The influence of a larger amount of land and higher level of education could not be confirmed in this article. Weiss (1999) also found smaller growth for older farmers and that herd size was influential.

5. Discussion

The article aimed to determine whether SAC protection affects farmers' decisions to invest in dairy, exit dairy production only, or even exit agriculture altogether. Significantly lower probabilities for the decision to grow were found for farms located within districts that had larger shares of land under nature conservation. Furthermore, a significantly positive effect was found for farmers' decisions to exit dairy in the 2003 dataset. For the amount of growth, the share of SAC was uninfluential. We can empirically confirm the assumed effects in Jacobsen et al. (2019). The non-significant effect in the OLS regression can be explained by the higher requirements for emission abatement technology in SAC; Investments close to SAC might become unprofitable or be banned altogether.

Furthermore, the estimation for 2003 showed that farmers in districts with a greater area under conservation were more likely to leave dairy farming. However, the effect was not found in 2010. When comparing both periods, it should be noted that the quotation system ended in 2015. From 2015 on, Huettel and Jongeneel (2011) and Zimmermann and Heckelei (2012) assumed increasing exits and growth decisions. This was confirmed by the present analysis. The change in the market system could explain why the size of the coefficients was greater in the second period. In the first period, structural change was slowed down by the regulated market. The market system might also explain why no significant effect of SAC shares on exit decisions was found for the 2010 data set. Other factors, such as increasing variance in prices, could have been more important. Another possible explanation is that higher compensation payments may have been granted during that period. Since data was only available up to the year 2015, follow-up analyses are needed to examine how SAC areas affected farmers after the abolishment of the milk quota.

In addition, an increase in exits from dairy production or even agriculture altogether might only be fully observable after a delay. Weiss (1999), Stokes (2006), and Dong et al. (2016) show that current herd size is an important factor behind farmers' intention to exit dairy. Another relevant factor are higher milking yields, which indicate greater efficiency (El-Osta and Morehart, 1999). Lower exit probabilities for efficient farms were found in this analysis and other studies (Dong et al., 2016; Foltz, 2004; Laepple and Sirr, 2019; Stokes, 2006). Farmers working on extensive grassland show lower productivity and smaller increases in productivity over time (Kellermann and Salhofer, 2014). Therefore, measures that demand extensification could increase exits in the long run.

The results indicate that already smaller and less intensive farms might find it especially challenging to continue. However, these farms are usually more deeply engaged in nature conservation; for instance, they are more likely to participate in voluntary AES (Lakner et al., 2020). This raises the question of whether they can be supported. Simply allowing farms in SAC to continue to invest is not in line with the goals set in the *Biodiversity Strategy* (European Commission, 2022). That additional investments in livestock might not be an option in SAC in the future can be shown for the Netherlands. Currently, the Dutch state is offering a buy-out of barns close to SAC (Dutch Government, 2020). This seems to mark a shift in policy. Beforehand, some farmers close to SAC were still allowed to invest in additional housing capacity in areas with high pre-pollution and without installing additional environmental abatement technology. This applied to farms in areas with so-called '*room for development*' and was applied to allow them to produce cost-efficiently (Details on the Dutch impact assessment can be found in Jacobsen et al. (2019)). Our results indicate that the stricter German environmental impact assessment was able to reduce additional investments in livestock.

Promoting techniques to lower emissions and enable farmers to fulfill the requirements also seems particularly challenging for dairy farms (Jacobsen et al., 2019). Most of the German stables (87%) are 'open-stable systems' and using air scrubbers is not possible (BFE, 2022). However, newer techniques, for instance, slurry acidification, can highly reduce emissions from dairy barns and might be an option for the future (Zhang et al., 2015).

A more suitable development perspective might be to promote organic farming. The conservation measures introduce extensive agricultural practices (EEA, 2020). These might be easier to fulfil for organic farms. In addition, the average organic farm keeps 66 heads of cattle and is smaller than the average conventional farm with 104 heads of cattle (Destatis, 2020). Therefore, former conventional farmers might have a large enough herd to compete after switching.

Another, alternative development perspective for farmers in SAC might be provided by the new CAP (common agricultural policy) eco-schemes post-2020. These might allow smaller, less intensive farmers to continue. The eco-schemes provide funds for AES from the CAP's first pillar budget. A special feature of eco-schemes is that they may offer more than simple compensation for loss of income or costs incurred (European Commission, 2019). Additionally, the eco-schemes could provide (hitherto lacking) financial incentives for environmental improvements in SAC. The AES currently used to compensate farmers only for the costs of nature protection. Allowing farmers to benefit from nature conservation could also help increase their acceptance of it (Koemle et al., 2019). That the AES are important for nature conservation is highlighted in the IEEP (2019) report on the drivers of success in Natura 2000 areas. However, the authors also point out that investments need to be expanded, and long-term contracts should be offered.

6. Conclusion

Overall, the results of the study should be further validated. This is because the main hypotheses of this article could be partly confirmed by comparing two periods. SAC led to reduced probabilities of growth in both periods. However, increases in exits from dairy were only found in one period. Additionally, the study has several other limitations that also require future research. For instance, data availability did not allow us to consider the actual distance of a farm to a SAC. The distance from reserves is essential in environmental impact assessments, as Jacobsen et al. (2019) show. In addition, adverse effects could not be attributed to the measures or the environmental impact assessment because data on the measures and their implementation were not available. The measures and the compensation granted could also be decisive. Improved

[7] Other variables, for example, milk prices and variances in milk prices and thus factors unknown for the future, were left out from the start in other estimations. This was intended to ensure that the debt border is indeed uninfluential.

data availability through surveys or more detailed information provided by the authorities could contribute significantly to the improvement of the models. Research on the topic should be continued because farmers are concerned about their development perspectives in nature protection areas, and the results of the article indicate that their worries might be justified.

Author statement

Insa Thiermann: conceptualization, methodology, software, validation, formal analysis and data curation, writing (original draft and revision), **Thomas Bittmann:** methodology, writing (original draft and revision).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.116993.

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