STRUCTURAL CHANGE OF EUROPEAN DAIRY FARMS – A CROSSREGIONAL ANALYSIS

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Abstract

Previous analyses of dairy farm structural change focused on the variation over time in one or a small number of regions. Here we present an EU-15-wide analysis of the change of the number of farms in different size classes. The purpose is (1) to identify the differences in regional development patterns and (2) to measure the explanatory relevance and effect of key factors suggested in the literature. Apart from the unprecedented scope, [illegible]ov chain analysis also contributes by combining observed transitions in micro[illegible] on farm numbers. Results show widely significant impacts of most explanatory [illegible]eveal the complexity of the underlying processes.

Structural change of European dairy farms – a

1 Introduction

With the EU milk quota abolition approaching in 2015 and the recent milk price volatility, structural changes in the European dairy sector are once again a major topic of discussion among policy makers, media, and science. Our analysis aims at (1) identifying the patterns of structural change for dairy farms in the whole EU15 at regional level, and (2) detecting the key exogenous factors explaining the differences in regional structural developments. For this purpose, structural change is defined as the change of the number of farms in different size classes.

Our model adds to the existing literature on farm structural change in the following ways: (1) We combine micro data on transitions between size classes from the Farm Accountancy Data Network (FADN) with macro data on the total number of farms in different size classes. (2) The structural development of dairy farms is shown for 94 regions of the EU15 going far beyond previous approaches with respect to the cross sectional scope. So far, the dairy farm structure development has mostly been analysed as a function of time in certain regions (e.g. Stokes, 2006 and Zepeda, 1995a). Only recently, attempts are made to compare regional development patterns to each other. Examples are Jongeneel et al. (2005) presenting a combined analysis of structural changes in the dairy sector in four European countries and Huettel and Jongeneel (2009) comparing structural developments in Germany and the Netherlands. (3) We analyse the relationship between certain regional (and time-dependent) characteristics and the different structural development patterns across the 94 regions. To our knowledge, a similar panel data Markov chain approach has only been used by Rahelizatovo and

Gillespie (1999) who employ dummy variables to represent characteristics of two regions in Louisiana, USA. The regional differences however are not the focus of their discussion.

Methodologically, we use a Markov chain generalised cross-entropy framework similar to Karantininis (2002) and Stokes (2006). The estimated transition probabilities are transformed into log-odds ratios and linearly regressed against region-specific and time-dependent variables (Stavins and Stanton, 1980; Rahelizatovo and Gillespie, 1999; Stokes, 2006).

The paper is structured as follows: Chapter 2 introduces the data and the size classes used for the analysis and gives an overview of the structural developments in the dairy farm sector from 1995 to 2005. Chapter 3 explains the methodological approach and chapter 4 describes the results on the transition probabilities. In chapter 5 hypotheses on factors supposed to affect structural change are formulated. Chapter 6 gives the results regarding the explanatory variables' impact on the transition probabilities and Chapter 7 summarises and concludes.

2 Structural developments of dairy farms across Europe

This chapter gives an overview of the structural development of dairy farms in the observation period. Before doing so, the data used throughout the analysis and the applied farm typology are introduced.

2.1 Data and farm types

Farm Accountancy Data Network (FADN) data is used throughout the study to determine farm numbers in total and in the different size classes. FADN comprises data on sample farms in each FADN region and for each combination of size and specialisation classes present in the region. The sample farms are surveyed annually and stay in the sample for a varying number of years. To each sample farms an aggregation weight is attached representing the number of similar farms (according to size and specialisation) in the region known from an about tri-annual census. For the Markov chain analysis the data on the transitions of sample farms between classes (micro data) as well as the number of farms represented by the sample farms (macro data) are used. The selection of the FADN farms adheres to certain threshold levels. The threshold levels vary across countries and give the minimum size of a farm to be considered as a 'professional' farm. As a result, FADN does not represent all farms in a region, but only farms that exceed this threshold level. Our analysis considers only farms that are classified as 'specialist milk'. We distinguish five size classes: SIZE1 represents farms with less than 20 cows, SIZE2 consists of farms with 20 to 39 cows, SIZE3 contains farms of a size between 40 to 79 cows, in SIZE4 all farms with 80 to 119 cows are represented and SIZE5 contains all farms with 120 and more cows. An artificial ENTRY/EXIT class is added to the five size classes. For our analysis, we observe EU15 farms at a regional level in the time period 1995 to 2005.

2.2 Main structural developments

Generally, the number of dairy farms in the EU15 has declined drastically in the observation period. Figure 1 shows the average annual change of dairy farm numbers from 1995 to 2005 in the EU15 FADN regions.

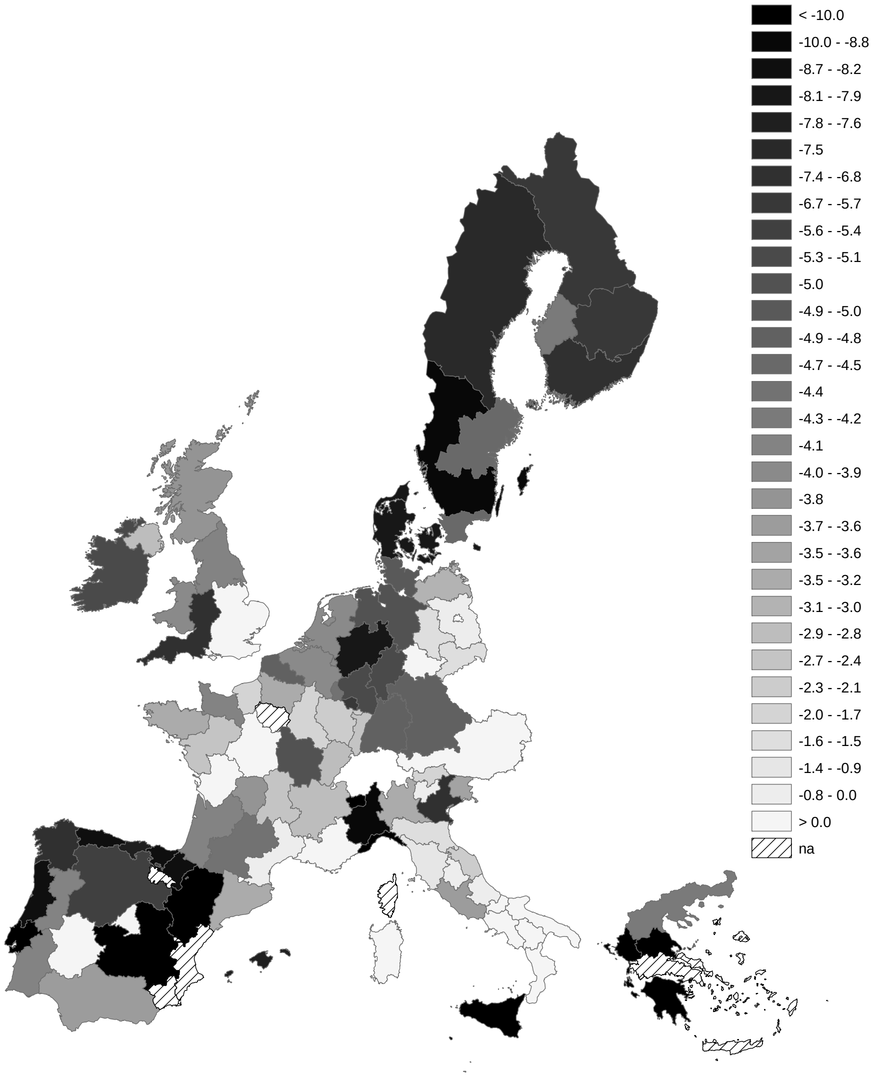

Figure 1. Average annual change rate of dairy farms 1995-2005[1]

Source: Own figure based on FADN data.

The average annual rate of change for the EU15 regions is -3.9 per cent. The decline was strongest in Scandinavia, West Germany, and large parts of Spain. Looking at the development of the number of

[1] For the hatched regions data on dairy farming was not available or not sufficient. They are not considered in the analysis.

farms in the different size classes we find an average annual farm number decrease of 10.5 per cent in SIZE1. The standard deviation of the average annual change rate across the regions is 9.5. The number of farms in SIZE2 decreased by approximately 3.9 per cent with large differences across the regions (the standard deviation is 7.1). In average across the European regions, dairy farm numbers increased in size classes three to five. The larger the size class, the higher the rates of farm number increase. The average annual rates are 1.6 per cent (standard deviation: 9.3) in SIZE3, 4.4 per cent in SIZE4 (standard deviation: 8.3), and 9.2 per cent in SIZE5 (standard deviation: 12.0).

3 Markov chain approach

Transition probabilities are estimated in order to identify the different regional development paths. Each transition probability represents the likelihood of a farm to move from one size class to another. The transition probabilities are derived in a Markov chain estimation framework. Technically, Markov chains have long been used for the analysis of structural change (cf. Zimmermann et al., 2009). A theoretical background for the use of the Markov chains when analysing structural change in the dairy farm sector is developed by Stokes (2006). We are particularly interested in the determinants leading to regionally different structural development patterns. Therefore, the transition probabilities are represented as a function of exogenous variables. In order to estimate these non-stationary transition probabilities various estimation approaches were tested. Particularly, an instrumental variables generalised cross-entropy approach according to Golan and Vogel (2000) and Karantininis (2002) and a simultaneous generalised cross-entropy estimation framework with the transition probabilities being represented as multinomial logit functions of coefficients and explanatory variables have been explored. However, due to general convergence difficulties due to the regional dimension of the problem, eventually a two-step procedure was applied. In the first step, time-varying transition probabilities are derived which are then regressed against a set of exogenous variables. Similar approaches were applied by Stavins and Stanton (1980) and Stokes (2006).

3.1 Transition probabilities (step 1)

3.1.1 Calculation of the transition probabilities

The time-varying transition probabilities for each region are derived by combining observed transitions between size classes from the FADN sample farms (micro data) with the data on the total number of farms per farm type (macro data). This is achieved by applying a generalised cross-entropy approach similar to the one used by Karantininis (2002) and Stokes (2006). The objective function (1) minimises the distance between transition probabilities p_{ijt} and the prior transition probabilities q_{ijt} both indicating the probability to move from size class i to size class j in time t. Prior probabilities are generally calculated as the number of observed transitions over the number of farms in the sample averaged across years. The same prior exit rate per size class is assumed and calculated based on the average annual exit rate of all farms. The prior probabilities on farm entry are assumed to be zero. Simultaneously, the distance between the error weights w_{mjt} and the prior information on the error weights u_{mjt} is minimised. The prior information on the error weights is a symmetric uniform distribution around zero.

$$\min\left[\sum_i\sum_j\sum_t p_{ijt}\ln\left(p_{ijt}/q_{ijt}\right)+\sum_m\sum_j\sum_t w_{mjt}\ln\left(w_{mjt}/u_{mjt}\right)\right] \quad (1)$$

s.t.

$$y_{jt}=\sum_i y_{it-1}p_{ijt}+\sum_m v_m w_{mjt} \quad \forall j,t \quad (2)$$

The objective function is minimised subject to the Markov constraints (2). These constraints relate the share y of farms in each farm size class j at time t to the share of farms in all classes i at time $t-1$ multiplied by their respective transition probabilities p_{ijt}. The shares are derived from the macro data. The error term is constructed as the product of the support point values v_m and the probabilities w_{mjt} summed over the *m* support points. The support points are set according to the three sigma rule (see Pukelsheim, 1994 and Tonini and Jongeneel, 2009). Non-negativity ($p_{ijt}, w_{mjt} \geq 0$) and summing-up-to-unity ($\sum_j p_{ijt}=1,\ \sum_m w_{mjt}=1$) also apply to transition and error probabilities.

3.1.2 Mobility indices

Mobility indices according to Shorrocks (1978), Jongeneel and Tonini (2008) and Huettel and Jongeneel (2009) are used to simplify the information contained in the transition probability matrices. Thus, structural developments can be more easily compared across regions and time. The overall mobility index

$$M^{ov}=\left[J-tr(\hat{P})\right]\Big/(J-1) \quad (3)$$

is equal to zero if farms do not change their size class at all. Perfect overall mobility with a value of one occurs if the average probability of remaining in the same category is not larger than the one of moving to any category ($1/J$). Partial mobility indices according to Jongeneel and Tonini (2008) and Huettel and Jongeneel (2009) are obtained by decomposition of the overall mobility index as follows:

$$M^{ov}=M^{exit}+M^{entry}+M^{s+}+M^{s-}. \quad (4)$$

M^{exit} is defined as the part of overall mobility associated with going out of business, M^{entry} with new or re-entry to the market, M^{s+} with changes to a larger size class, and M^{s-} with changes to a smaller size class. The partial mobility indices are calculated according to formula:

$$M^{part}=\sum_i\sum_k \hat{p}_{ik}\Big/(J-1) \quad (5)$$

with $\hat{p}_{ik}$ being the respective probabilities in the exit or entry class, for size increases or declines. For exit $k = J$, for entry $i = J$, for size increase $k > j, k \neq J$ and for size decline $k < i, k \neq J$.

3.2 Regression analysis of the transition probabilities (step 2)

The transition probabilities obtained in the Markov chain estimation step shall now be explained by a set of explanatory variables. More precisely, the transition probabilities are represented as multinomial logit function of the exogenous variables Z and the coefficients to be estimated β (MacRae, 1977; Zepeda, 1995b):

$$p_{ijt} = \frac{\exp\left(Z_{it}\beta_{ij}\right)}{1+\sum_{k=1}^{s-1}\exp\left(Z_{it}\beta_{ik}\right)}, \ i=1,\ldots,s \quad j=1,\ldots,s-1 \tag{6}$$

$$p_{ist} = \frac{1}{1+\sum_{k=1}^{s-1}\exp\left(Z_{it}\beta_{ik}\right)}, \ \text{i=1,}\ldots\text{,s} \tag{7}$$

The equations are linearised by transforming the transition probabilities into log-odds ratios (Stavins and Stanton, 1980; Greene, 2003).

$$\ln\left(\frac{p_{ijt}}{p_{ikt}}\right) = \mathbf{z}_{it}\boldsymbol{\beta}_{ij} \tag{8}$$

for $i = 1, 2, ..., s$ and $j = 1, 2, ..., s-1$ and $k = s$.

Since the estimated coefficients indicate marginal effects on the log-odds ratios and are difficult to interpret, the direct influence of the exogenous variables on the transition probabilities is evaluated in form of probability elasticities (Zepeda, 1995b; Greene, 2003). The probability elasticities measure the effect of a one per cent change in the *i*th explanatory variable on each transition probability:

$$E_{ijt}^{p} = \frac{\partial p_{ijt}}{\partial Z_{it}}\frac{Z_{it}}{p_{ijt}} = \left(\beta_{ij}p_{ijt} - p_{ijt}\sum_{k=1}^{s-1}p_{ikt}\beta_{ik}\right)\frac{Z_{it}}{p_{ijt}} \tag{9}$$
$$\text{for } i=1,...,s \ j=1,\ldots,s-1$$

$$E_{ist}^{p} = \frac{\partial p_{ist}}{\partial Z_{it}}\frac{Z_{it}}{p_{ist}} = -\left(p_{ist}\sum_{k=1}^{s-1}p_{ikt}\beta_{ik}\right)\frac{Z_{it}}{p_{ist}}, \quad i=1,...,s \tag{10}$$

4 Results on the transition probabilities (from step 1)

4.1 Transition probability matrix

The estimated transition probabilities can be collected in a transition probability matrix $P \ (J \times J)$:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1J} \\ p_{21} & p_{22} & \cdots & p_{2J} \\ \vdots & \vdots & \cdots & \vdots \\ p_{I1} & p_{I2} & \cdots & p_{IJ} \end{bmatrix}.$$

Table1 shows the probabilities as averages over time and over region. In addition, their standard deviations separated by time and regional dimension are presented.

Table 1. Average transition probabilities and standard deviations

	SIZE1	SIZE2	SIZE3	SIZE4	SIZE5	EXIT
SIZE1	0.863	0.079	0.001	0.000	0.000	0.056
Std. dev. Region	0.094	0.084	0.009	0.001	0.001	0.056
Std. dev. Time	0.012	0.004	0.001	0.000	0.001	0.011
SIZE2	0.039	0.839	0.069	0.000	0.000	0.052
Std. dev. Region	0.038	0.065	0.043	0.001	0.001	0.048
Std. dev. Time	0.004	0.011	0.005	0.000	0.000	0.012
SIZE3	0.003	0.069	0.841	0.034	0.002	0.051
Std. dev. Region	0.012	0.079	0.106	0.036	0.013	0.060
Std. dev. Time	0.000	0.004	0.010	0.006	0.001	0.009
SIZE4	0.000	0.002	0.096	0.811	0.047	0.043
Std. dev. Region	0.000	0.011	0.115	0.144	0.070	0.037
Std. dev. Time	0.000	0.000	0.005	0.012	0.004	0.008
SIZE5	0.011	0.003	0.004	0.083	0.861	0.038
Std. dev. Region	0.102	0.026	0.023	0.192	0.222	0.038
Std. dev. Time	0.001	0.001	0.002	0.004	0.015	0.008
ENTRY	0.001	0.001	0.001	0.001	0.001	0.996
Std. dev. Region	0.004	0.003	0.002	0.001	0.002	0.008
Std. dev. Time	0.001	0.001	0.001	0.001	0.001	0.005

Source: Own calculations.

The probabilities show much more variability across regions than across time. Although this was generally expected, the effect might be amplified by the time-invariant a priori information entering the Markov chain approach. The matrix reveals a typical pattern. The highest values on the diagonal represent the probabilities to remain in the same farm type as in the year before. Probabilities adjacent to the diagonal are next in size indicating that transitions to neighbouring size classes are relatively more frequent. Furthermore, all size classes show relevant probabilities to exit. However, they are consistently decreasing with the size class. The entry probabilities for all size classes are very low. Note, that there are three possibilities of farm entry: entry from outside the agricultural sector, re-entry, and entry to dairy farming from other specialisation classes.

4.2 Mobility indices

The overall mobility associated with the average transition probability matrix (TPM) is 0.158. The mobility for changes to larger size classes, 0.047, is smaller than the mobility value for changes to lower size classes, 0.062. This may be partially explained by the fact that entry probabilities are low and the increase in size of larger farms requires that, relative to initial endowment, more resources have to be given up by smaller farms. The exit mobility is 0.048 and the entry mobility is 0.001.

4.2.1 Mobility indices across region

Figure 2 shows the mobility to change to larger size classes for each region (averaged over time).

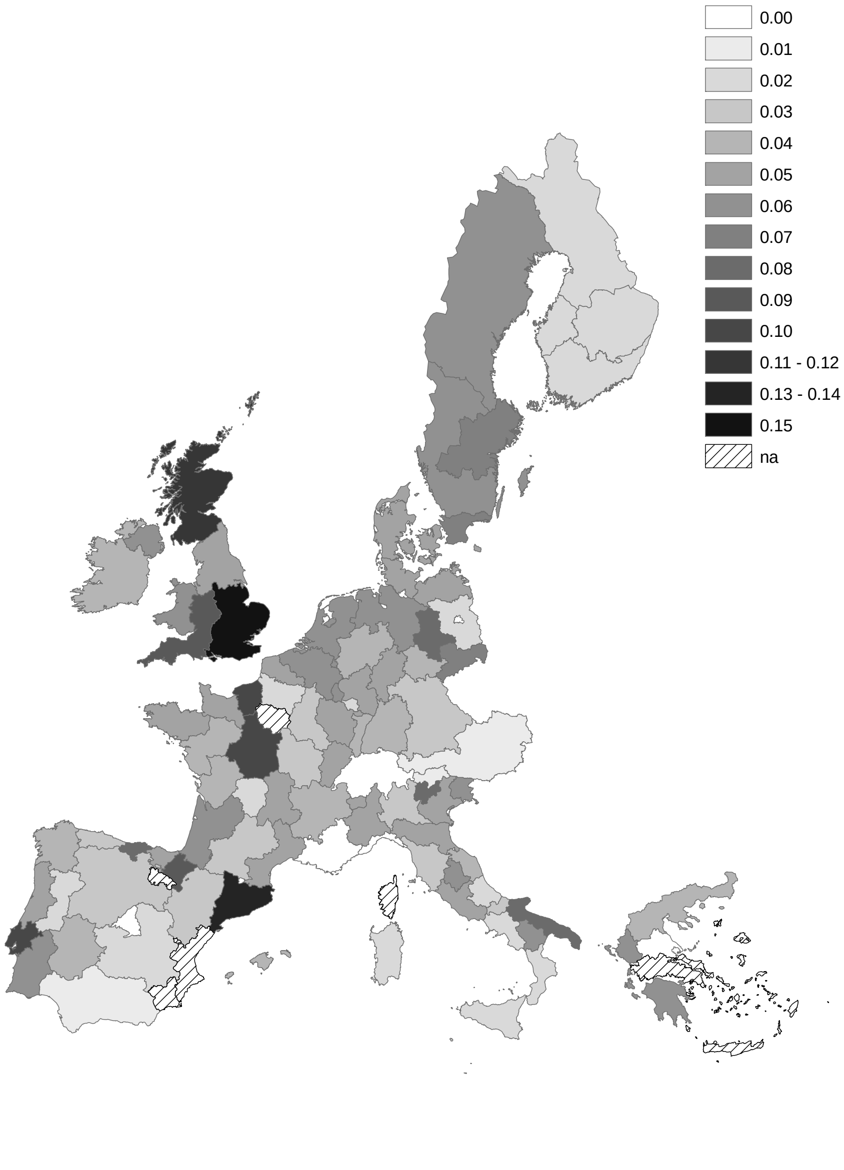

Figure 2. Mobility for size increase

Source: Own figure.

The median mobility value for size increases across the regions is 0.05. The 10 per cent quantile lies at 0.02, and the 90 per cent quantile at 0.08. Generally, the mobility for size increases is higher in the Northern European regions. In order to save space the map on the mobility for size decline is not shown here. The median mobility of size decline is 0.5, the 10 per cent quantile lies at 0.01 and the 90 per cent quantile at 0.12. Thus, the mobility values for size decline are much wider spread than the mobility values for size increases (the standard deviation for size decline is 0.06, the standard deviation of size increase is 0.03). Regions where the mobility values for size reductions are high can especially be found in France, in the southern part of Germany, and in the northern part of Spain. The exit mobility corresponds largely to the exit rates depicted in Figure 1. Its median is 0.04 with a standard deviation of 0.04 (the 10 and 90 per cent quantiles are 0.01 and 0.08, respectively). The mobility for market entries is zero or very close to zero in all FADN regions.

4.2.2 Mobility indices over time

Figure 3 shows the development of the mobility measures over time. For this purpose, the mobility values are averaged across the regions and examined only across the years.

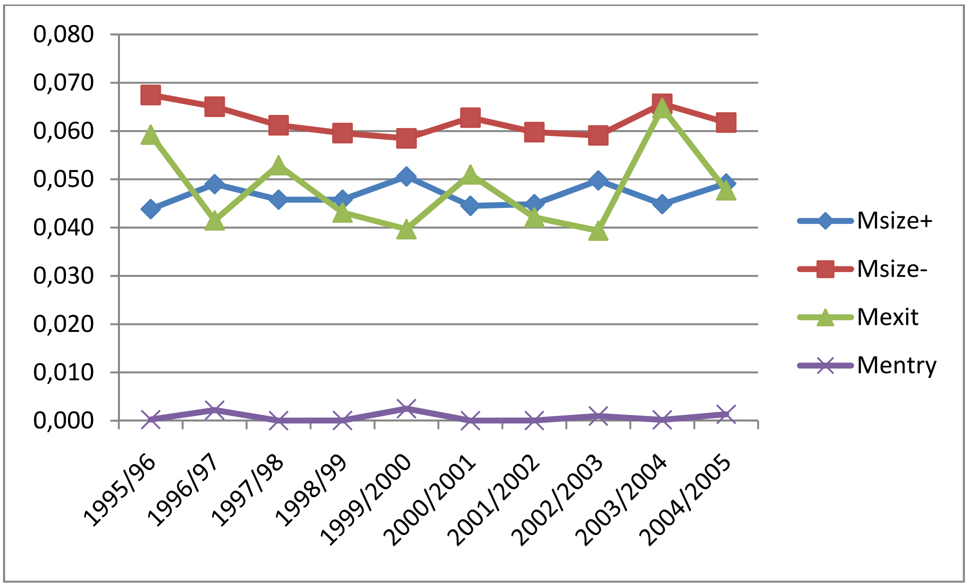

Figure 3. Development of the mobility measures over time

Source: Own figure.

The mobility for size decline tends to decrease slightly over time. The mobility for farm size growth remains rather stable. The exit mobility is rather volatile with stronger upward fluctuations in the beginning and the end of the observation period. The entry mobility is almost zero with few fluctuations especially in the beginning of the observation period. As mentioned before, the development over time must be assessed carefully since the prior information in the Markov chain approach is time-invariant. Although the estimates are free to vary over time, this might explain why there is relatively little variance over time. On the other hand, especially the development of the exit mobility index shows that estimates do respond to time-dependent changes in the data. Another point to be aware of is that the mobility values are averaged across the regions. Contrary regional developments could thus mistakenly lead to the assumption that there is not much change in the mobility measures over time.

5 Determinants and hypotheses

Deviating from existing studies, this paper combines time-variant factors considered to impact structural change (several literature reviews exist, for example Goddard et al., 1993; Boehlje 1992) with region-specific determinants explaining the regional development of dairy farm sizes (literature review by Mosnier and Wieck, 2009). The determinants are divided into the sections technology, farm structure, market conditions, natural resources, and spatial and demographical factors. For each factor theoretical considerations regarding its effect on dairy farm structural change are given. An overview on the determinants and the expected signs concerning the impact on respective transition probabilities is given in Table 2. The table distinguishes between probabilities on changes to larger size classes (growth), probabilities on changes to smaller size classes (decline), entry and exit.

Table 2. Hypotheses

		Growth	Decline	Entry	Exit
Technology	Trend	+	-	-	+
	Milk yield	+	-	0	-
Farm structure	Farm size	+/-	-	-	-
	Farm size heterogeneity (dairy farms)	+	+	+	+
	Farm size heterogeneity (all farms)	+	+	+	+
	Stocking density	+	-	+	-
Economic factors	Milk price over time	-	-	+	-
	Milk price across regions	-	-	+	-
	Milk price volatility	+/-	-	-	+
	Land rent	+	+	0	+
Natural resources	Share of grassland	-	+	-	+
	Slope	-	+	-	+
	Temperature	+/-	+/-	0	+/-
Spatial and demographical factors	Population density	+	-	0	-
	Population growth	-	+	-	+
	Unemployment	+/-	-	+	-
	Age	-	+	0	+

Source: Own table.

5.1 Technology

Technical change is generally assumed to play a major role in farm structural change and is closely related to the concept of economies of scale (e.g. Cochrane, 1958; Boehlje, 1992; Harrington and Reinsel, 1995). The trend is included in order to account for time-dependent technological developments, most importantly the increase of the optimally dairy farm size. The milk yield is considered to reflect regional technology differences. In other Markov chain studies on dairy farm structural change, it is often used to represent technical change over time (Zepeda, 1995b).

Trend

We hypothesize that the probabilities for changes to larger size classes and the exit probabilities are positively affected by progressing time, whereas there will be a negative effect on movements to smaller size classes and on entry.

Milk yield

Milk yield is expected to be positively correlated with farm growth and negatively correlated with farm size decline and the exit probabilities.

5.2 Farm structure

The initial farm structure will likely determine farm structural change (Boehlje, 1992). The factors used to represent the initial farm structure are firm size, firm size heterogeneity, and stocking density as a measure of intensity. Firm size acknowledges the role of economies of scale (e.g. Hallam, 1991) and path dependency (Balmann, 1995) in farm structural change. Sectoral heterogeneity is assumed to play a major role in facilitating adjustment processes (Harrington and Reinsel, 1995).

Farm size

The expected impact of initial farm size is ambiguous. On the one hand, larger initial average farm size might be a result of strong past growth processes in a region and this might continue. On the other hand one could argue that in regions with already larger farms, pressures for further growth decrease. Consequently, no definite hypothesis on the sign of the impact is stated for farm size. We hypothesize that initial farm size is negatively related to farm size decline. It is rather unlikely that farms which have grown to a certain size again decrease in size. In some cases (for example England), however, also decreasing farm sizes due to multiple succession schemes are reported (Burton and Walford, 2005). Due to the more consolidated farm structure exits and entries are expected to go down with initial farm size.

Farm size heterogeneity

Farm size heterogeneity is expected to enhance resource reallocation between farms and thereby generally increase the upward and downward transition probabilities. We consider the farm size heterogeneity of dairy farms as well as the farm size heterogeneity of all farms in a region.

Stocking density

The stocking density is a measure of intensity. The higher the intensity of farming, the more likely is farm growth and the less likely is farm decline. Translating this hypothesis to entries and exits, a positive influence on entries and a negative influence on exits is hypothesized.

5.3 Market conditions

In the long run, there exists a strong interdependency between input and output prices and the concepts of technical change and economies of scale. In the medium and short run, prices may be assumed to be more exogenous and to significantly impact structural change (e.g. Goddard et al., 1993). Our analysis includes the milk price and the land rent.

Milk price

We consider three aspects of the milk price: (1) the milk price development over time, (2) regional price differences, and (3) regional differences in the milk price volatility. In the literature, the milk price is the most frequently used variable to explain structural changes in the dairy sector (e.g. Stavins and Stanton, 1980; Chavas and Magand, 1988; Rahelizatovo and Gillespie, 1999; Stokes, 2006). Over time, it is assumed that high milk prices lead to less pressure on the farms which results in generally low probabilities for changes into other size classes and for exits and high probability values for staying in the same farm type. The sector entry could also be positively affected.

Considerable milk price differences exist between regions. Generally, a strong north-south divide can be observed with milk prices tending to be higher in Southern European countries. Differences exist also across regions within the countries. A general rule is that the more mountainous the areas, the higher are also the milk prices (for example in Germany and France) (Mosnier and Wieck, 2009). Again, we argue that the farm structure tends to remain rather stable if prices are high.

Apart from the general price level also price volatility is expected to impact on farm structure development. The higher the milk price volatility, the more risky is dairy farming, and the more farms probably exit the sector. Regarding the transition between size classes one could argue that a higher price volatility and thus uncertainty causes farms to refrain from investments and generally leading to fewer changes to other size classes. On the other hand, large farms can probably better deal with higher volatility (for example due to higher liquidity) and therefore a positive relationship between milk price volatility and the probability to change to larger size classes could exist.

Land rent

Since dairy farming is not very demanding regarding soil quality, dairy farms are generally located where land is cheaper. However, the competitiveness of intensive dairy production is larger in areas with good soils accompanied by high land rents. Furthermore, areas with an emphasis in dairy production are often characterized by profitable "multifunctional" activities (for example the south of Germany) and corresponding high prices for agricultural land. In a cross regional comparison, we therefore expect that the higher the land price, the more probable is a dynamic growth of dairy farms.

5.4 Natural resources

Natural resources are usually not part of structural change analyses (with the exception of Zepeda 1995a, who includes the factor drought in her analysis). They play, however, a significant part in the spatial dynamics of dairy production (Mosnier and Wieck, 2009). As factors representing natural resources, the share of grassland, the regions' average slope and climate conditions are considered.

Share of grassland

The share of grassland is a proxy for soil quality. The higher the share of grassland, the worse is the soil quality. As livestock production is often located in less fertile areas (Mosnier and Wieck, 2009), one could get the idea that the higher the share of grassland in a region, the less likely are farm exits and the more likely are farm size increases. Experience, however, shows that the dynamics move into another direction. Especially in regions with a very high grassland share, farms in general and also dairy farms are more likely to disappear and/or decline (for example if farming is continued as tourist attraction or as part-time business). Especially intensification (which is likely to go hand in hand with farm size growth) usually takes place in more fertile areas due to availability of concentrated feeding stuff. Thus, a negative correlation between the share of grassland and farm growth and entry, and a positive correlation between the share of grassland and farm decline and exit is predicted.

Slope

Although slopes limit mechanisation possibilities and the intensification of crop and forage production, many dairy production systems are based in mountainous areas (Mosnier and Wieck, 2009). We assume that the regions' slope is negatively correlated with the probability for changes into larger size classes, positively correlated with changes to smaller size classes (change to part-time farming, tourist attraction), and also positively impact on exit probabilities.

Climate

Climate stresses impact the animal performance and constrains fodder production (Mosnier and Wieck, 2009). Dairy cow systems are generally more often located in relatively low temperature areas as for example in Northern Europe. A priori, however, it is unclear to us whether warmer climates increase or decrease structural adjustments between farms compared to colder climates.

5.5 Social and demographical factors

Social and demographical factors impact farm structural change in various ways (see for example Goddard et al., 1993). We consider population measures in order to reflect market distance, the opportunity for off-farm employment and the farmers' age.

Market distance

Generally, farms located close to main transportation axes in plane areas are advantaged compared to farms in remote or mountainous areas (Mosnier and Wieck, 2009; Limao and Venables, 2001). In dairy farming the market distance is especially important regarding the milk collection scheme. According to Mosnier and Wieck (2009) dairy farms tend to be located in populated areas in order to benefit from public infrastructure. Thus, a positive relationship of the population density with farm growth, and a negative impact on decline and exit is assumed. However, with increasing population growth, the increased non-agricultural competition on land might lead to a different picture: the larger the population growth rates, the less farm growth and the more farm decline and exits are observed (Foltz, 2004).

Off-farm employment

The opportunity for off-farm employment has proven to be a significant factor for farm sector exits in several studies (Weiss, 1999; Kimhi and Nachlieli, 2001). Apart from its effect on sector exits we expect that it also affects the transition probabilities of changes between size classes as transition to part time farming is similarly dependent on employment opportunities. As proxy for the opportunity for off-farm employment we use the unemployment rate per region. The higher the unemployment rate, the less likely are sector exits and farm size decline. Changes to larger size classes and entry are likely furthered by higher unemployment because farming becomes a relatively more important source of income and entry. However, farms willing to grow might not benefit as much from the resources of downsizing farms leaving the hypothesis on the variable's effect on size increases ambiguous.

Age

Since farms most often close down if the farmer retires (and a successor does not exist), the farmers' age is one of the most important factors driving structural change (e.g. Weiss, 1999; De Haen and Von Braun, 1977; Pietola et al., 2003; Happe at al., 2004). For our analysis, we use the regional share of farmers being older than 55 years in the beginning of the observation period as explanatory variable. We assume that the higher the share of farmers being older than 55 years wasthe more likely are declines and exits of smaller farm sizes increasing the growth opportunities of remaining farms.

6 Regression results (from step 2)

A panel data regression is used in order to identify the relationship between transition probabilities and the explanatory variables discussed in Chapter 5. Combining the time and the regional dimension leads to a panel of 10 (years)*94 (regions) observations.

First, a fixed effects (least squares dummy variable) model is estimated with dummy variables for each region and a time index as trend. Due to the large number of regions, the fixed effects model is split into two parts, one for North[2] and one for South Europe[3]. The fixed effects model exhibits rather high R^2 values and an F-test confirms the high significance of the regional effects for all transition probabilities of the two models. Only in South Europe the regional effects for the entry probabilities into the smallest size class are not significant.

After confirmation of the significance of the regional effects, a pooled regression model is used to establish the relationship between the transition probabilities and the explanatory variables. Table 3 presents a descriptive analysis of the explanatory variables. The coefficient estimates and their significance for the regression of the log-odds ratios are given in Table 4. The probability elasticities (equations (9) and (10)) are evaluated at the variable means and given in Table 5. The majority of the estimates are highly significant. The R^2 values are below the fixed effects models but overall still solid for a panel estimation with cross-sectional focus. The entry probabilities are explained worst with an average R^2 of 0.058. The average R^2 of the other transition probabilities (without entry) is 0.194 with the minimum value being 0.081 and a maximum value of 0.382. In the following, we will restrict interpretations mainly to the probability elasticities as they better reflect the overall impact of the determinants on transition probabilities.

Table 3. Explanatory variables

	Variable	Mean	Standard deviation	Source
Technology	Milk yield (kg/cow)	5603.96	1046.72	FADN
Farm structure	Initial size (Cows)	40.00	34.94	FADN
	Gini coefficient of dairy farms (index)	0.31	0.12	FADN
	Gini coefficient of the other farms (index)	0.44	0.11	FADN
	Stocking density (Livestock units/forage ha)	2.54	2.60	FADN

[2] The North European model comprises the United Kingdom, France, Germany, Belgium, Luxembourg, Netherlands, Denmark and Ireland.

[3] The South European model consists of Italy, Greece, Spain and Portugal.

Economic factors	Milk price over time (deviation from regional average) (€/kg)	-0.01	0.02	FADN
	Average milk price (€/kg)	0.33	0.05	FADN
	Milk price coefficient of variation (€/kg)	0.05	0.02	FADN
	Land rent (€/ha)	456.44	713.89	FADN
Natural resources	Share of grassland (per cent)	37.47	20.76	CAPRI database[4]
	Slope (per cent)	7.71	7.32	CAPRI database[5]
	Temperature sum (1000 °C)	3.71	1.22	CAPRI database[6]
Spatial and demographical factors	Population density (population/km^2)	161.28	178.33	EUROSTAT
	Population growth (per cent)	0.30	0.49	EUROSTAT
	Unemployment rate (per cent)	8.65	4.48	EUROSTAT
	Share of farmers > 55 years (per cent)	23.66	13.80	FADN

Source: Own table.

[4] Britz and Witzke (2008). Original data from the Farm Structure Survey (EUROSTAT: http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/legislation).

[5] Britz and Witzke (2008). Original data from European Comission, JRC-IES Digital Elevation Model (CCM DEM, 250 meters), received 2004.

[6] Britz and Witzke (2008). Original data from Orlandi, S. and Van der Goot, E.: Technical description of interpolation and processing of meteorological data in CGMS, Available under http://agrifish.jrc.it/marsstat/Crop Yield Forecasting/cgms.htm, European Commission, DG JRC, Agrifish Unit, 2003.

Table 4. Estimated coefficients

		Constant	Trend	Milk yield	Initial size	Gini dairy farms	Gini all farms	Stocking density	Milk price over time	Regional milk price	Milk price volatility	Land rent	Share of grassland	Slope	Temperature sum	Population density	Population growth	Unemployment	Age
Own size	p11	11.943 ***	-0.041	-0.001 ***	0.030 ***	-2.173 *	-0.593	0.142 ***	4.518	-10.886 ***	3.743	0.000	-0.025 ***	0.115 ***	-0.286 *	0.002 **	-1.281 ***	0.198 ***	-0.055 ***
	p22	10.954 ***	-0.018	-0.001 ***	0.026 ***	-0.514	-3.010 **	0.200 ***	3.268	-7.798 **	2.539	0.000 ***	-0.030 ***	0.104 ***	-0.205 *	0.001 *	-0.054	0.108 ***	-0.029 ***
	p33	10.614 ***	0.025	-0.001 ***	0.027 ***	3.078 ***	-4.964 ***	0.158 ***	0.609	-8.609 ***	0.946	0.000 **	-0.035 ***	0.085 ***	-0.231 *	0.002 ***	-0.188	0.115 ***	-0.021 **
	p44	5.164 **	0.022	0.000	-0.015 **	-15.184 ***	12.286 ***	0.675 ***	1.522	-0.007	-27.158 ***	-0.001 ***	0.011	0.140 ***	-1.151 ***	0.002 **	-0.180	0.373 ***	0.036 ***
	p55	0.800	0.035	-0.001 ***	-0.009	-17.385 ***	16.932 ***	0.304 ***	0.167	45.776 ***	-76.935 ***	-0.001 ***	0.016	-0.023	-0.744 ***	-0.001	-0.359	0.048	-0.001
Entry	pe1	-17.283 ***	-0.086 ***	0.000	-0.001	0.007	-0.913	-0.044 *	2.711	3.229 **	-3.029	0.000	-0.012 ***	0.054 ***	0.208 ***	-0.001 **	0.115	0.039 **	0.001
	pe2	-15.243 ***	-0.060 **	0.000	-0.003	-1.403 *	0.602	0.081 **	8.581 **	-0.576	-3.239	0.000	-0.004	0.043 ***	0.073	0.000	-0.339 *	0.031	0.010 *
	pe3	-17.070 ***	0.051 **	0.000 **	-0.006 *	2.293 **	-0.371	-0.104 ***	4.076	-4.455 **	9.633 **	0.000	-0.002	0.040 **	0.206 **	0.001	0.018	0.040 *	-0.014 **
	pe4	-21.078 ***	0.131 ***	0.000 *	0.006	-2.896 **	0.913	-0.009	4.980	8.533 ***	-9.135 *	0.000	-0.002	0.048 **	-0.071	0.001 *	0.724 **	0.042	0.013
	pe5	-19.361 ***	0.219 ***	0.000	-0.006	-1.283	3.669 **	-0.013	7.154	-0.741	4.926	0.000 **	-0.001	0.008	0.052	0.001 **	0.376	0.084 **	-0.011
Growth	p12	0.170	-0.080 *	0.000	-0.038 ***	10.670 ***	0.500	-0.032	6.537	-5.323	-7.254	-0.002 ***	0.010	0.028	-0.282 *	0.003 ***	1.008 **	0.136 ***	-0.053 ***
	p13	-2.833	-0.013	-0.001 ***	0.026 ***	0.901	0.920	0.095 *	3.861	-9.737 **	17.088 **	0.000	-0.022 **	0.061 **	-0.430 **	0.000	-0.251	0.172 ***	-0.040 ***
	p14	-10.944 ***	0.002	0.000	0.037 ***	-3.253 **	-0.262	0.253 ***	6.380	-0.799	-5.915	0.000	-0.013	0.136 ***	-0.292 *	0.004 ***	-0.821 **	0.205 ***	-0.059 ***
	p15	-6.226 **	0.034	-0.001 ***	0.030 ***	-4.394 ***	3.236 *	0.203 ***	-1.818	-7.171 *	8.411	0.000	-0.026 ***	0.080 ***	-0.308 *	0.002 **	-1.131 ***	0.156 ***	-0.069 ***
	p23	6.998 ***	0.029	0.000 **	0.007	7.432 ***	-7.558 ***	0.205 ***	2.851	1.339	-18.105 **	0.000 **	-0.023 **	0.021	0.072	0.001 *	-0.789 **	-0.148 ***	-0.071 ***
	p24	-14.464 ***	0.058	0.000	0.034 ***	-2.599 *	-5.383 ***	0.160 ***	4.595	8.676 **	-15.517 **	0.000 **	-0.027 ***	0.187 ***	-0.121	0.002 ***	0.716 **	0.193 ***	-0.001
	p25	-7.438 ***	0.043	0.000 *	0.017 ***	-1.180	-1.458	0.241 ***	0.971	-12.594 ***	18.201 ***	0.000 *	-0.027 ***	0.124 ***	-0.161	0.001 *	-0.369	0.125 ***	-0.031 ***
	p34	-9.918 ***	0.104 **	0.001 ***	0.045 ***	18.920 ***	-7.253 ***	-0.297 ***	4.516	-10.444 **	-10.107	0.000	-0.029 ***	0.083 **	0.784 ***	0.002 **	-0.460	-0.175 ***	-0.069 ***
	p35	-10.548 ***	0.059	0.000	0.054 ***	-5.206 ***	-1.664	0.412 ***	0.548	-0.657	12.372 *	0.000 **	-0.050 ***	0.219 ***	0.085	0.001	-1.613 ***	-0.161 ***	-0.024 **
	p45	-10.028 ***	0.023	0.002 ***	-0.027 ***	6.265 ***	11.045 ***	0.584 ***	0.004	-36.737 ***	28.195 ***	0.001 ***	0.020 *	0.266 ***	-1.405 ***	0.006 ***	-0.729 *	0.294 ***	0.003
Decline	p21	1.997	-0.013	-0.001 ***	-0.006	5.951 ***	-2.284	0.003	3.682	7.068 *	20.103 ***	-0.001 ***	0.007	0.002	-0.134	0.001	-0.002	-0.036	-0.092 ***
	p31	-6.833 ***	0.030	-0.001 **	0.014 **	8.062 ***	-3.150 *	-0.034	-0.871	3.930	-11.495 *	-0.001 ***	-0.025 **	0.061 **	0.093	0.003 ***	0.157	-0.355 ***	0.034 **
	p32	0.335	0.008	0.000	0.042 ***	4.116 **	-12.498 ***	0.445 ***	1.307	4.267	-13.459 *	0.000	-0.007	0.126 ***	0.312 *	0.000	-0.316	-0.193 ***	-0.031 **
	p41	-14.128 ***	0.017	0.000	-0.017 ***	-14.633 ***	11.574 ***	0.665 ***	1.678	5.882 *	-37.262 ***	-0.001 ***	0.005	0.174 ***	-0.881 ***	0.002 **	-0.039	0.310 ***	0.048 ***
	p42	-13.297 ***	0.008	0.000	-0.019 ***	-11.433 ***	10.436 ***	0.556 ***	1.676	1.218	-37.259 ***	-0.001 ***	-0.002	0.382 ***	-1.480 ***	0.001 *	0.044	0.389 ***	0.070 ***
	p43	-20.364 ***	0.017	0.001 ***	0.030 ***	7.465 ***	-4.270 **	0.273 ***	1.075	18.262 ***	-64.172 ***	0.001 ***	0.108 ***	-0.034	0.435 **	0.004 ***	-0.807 **	0.160 ***	0.010
	p51	-1.085	0.037	-0.001 ***	-0.024 ***	-11.993 ***	11.541 ***	0.117 *	1.175	20.341 ***	-53.571 ***	-0.001 ***	-0.030 ***	-0.022	-0.149	-0.003 ***	-1.015 **	-0.076	0.005
	p52	-3.531	0.015	-0.002 ***	-0.005	-16.322 ***	13.067 ***	0.117 *	0.750	35.026 ***	-65.702 ***	-0.002 ***	-0.018 *	0.038	-0.896 ***	-0.005 ***	-0.645 *	-0.072	0.057 ***
	p53	-2.431	0.023	-0.002 ***	0.016 **	-22.114 ***	16.910 ***	0.294 ***	-0.011	24.655 ***	-45.773 ***	-0.002 ***	0.021 **	0.032	-0.912 ***	0.000	-0.303	-0.126 **	0.025 *
	p54	-0.649	0.021	0.000	-0.004	-16.906 ***	13.559 ***	0.340 ***	0.282	8.914 *	-18.066 **	-0.001 ***	0.004	-0.137 ***	-0.557 **	0.003 ***	-3.258 ***	-0.266 ***	0.034 **

Source: Own calculation. Significance levels: ***: 1 per cent, **: 5 per cent, *: 10 per cent.

Table 5. Probability elasticities

		Constant	Trend	Milk yield	Initial size	Gini dairy farms	Gini all farms	Stocking density	Milk price over time	Regional milk price	Milk price volatility	Land rent	Share of grassland	Slope	Temperature sum	Population density	Population growth	Unemployment	Age
Own size	p11	1.636	0.003	-0.576	0.288	-0.340	-0.053	0.064	0.033	-0.342	0.053	0.059	-0.165	0.103	-0.063	-0.005	-0.097	0.130	-0.092
	p22	1.207	-0.021	-0.265	0.149	-0.267	0.056	0.056	0.059	-0.531	0.043	-0.001	-0.133	0.124	-0.125	0.004	0.014	0.236	0.084
	p33	2.046	-0.001	-0.842	-0.023	-0.154	0.139	0.000	-0.047	-0.436	0.074	-0.029	-0.149	0.008	-0.326	0.028	0.003	0.329	0.021
	p44	3.436	0.006	-1.338	-0.174	-1.230	0.905	0.161	0.058	-0.014	-0.043	-0.138	-0.384	0.107	-0.722	-0.041	0.023	0.326	0.125
	p55	0.197	0.012	-0.493	-0.032	-0.241	0.413	0.026	-0.004	1.632	-0.411	-0.044	0.078	0.034	-0.196	-0.059	0.055	0.261	-0.084
	pee	0.068	-0.002	-0.002	0.000	0.001	-0.001	0.000	-0.007	-0.001	0.000	0.000	0.001	-0.002	-0.002	-0.001	0.000	-0.002	0.000
Exit	p1e	-10.307	0.187	3.237	-0.926	0.328	0.206	-0.297	-1.439	3.205	-0.139	-0.018	0.764	-0.786	0.996	-0.313	0.288	-1.578	1.219
	p2e	-9.748	0.063	3.266	-0.886	-0.109	1.370	-0.451	-1.006	2.010	-0.087	0.221	0.987	-0.676	0.637	-0.153	0.030	-0.695	0.771
	p3e	-8.569	-0.114	2.381	-1.099	-1.099	2.307	-0.400	-0.245	2.369	0.025	0.141	1.147	-0.650	0.530	-0.236	0.059	-0.668	0.506
	p4e	-1.729	-0.091	0.107	0.436	3.433	-4.458	-1.554	-0.438	-0.011	1.348	0.209	-0.804	-0.970	3.550	-0.392	0.077	-2.896	-0.728
	p5e	-0.602	-0.146	3.952	0.336	5.098	-6.979	-0.746	-0.058	-13.284	3.530	0.576	-0.516	0.209	2.564	0.138	0.163	-0.151	-0.059
Entry	pe1	-17.215	-0.388	0.186	-0.047	0.003	-0.400	-0.110	0.877	1.051	-0.155	0.018	-0.446	0.414	0.769	-0.131	0.034	0.333	0.028
	pe2	-15.175	-0.271	-0.367	-0.139	-0.430	0.262	0.205	2.790	-0.189	-0.166	-0.007	-0.132	0.327	0.269	-0.041	-0.102	0.270	0.242
	pe3	-17.002	0.230	1.270	-0.247	0.705	-0.164	-0.263	1.321	-1.453	0.493	0.050	-0.076	0.307	0.763	0.095	0.005	0.344	-0.324
	pe4	-21.010	0.590	1.532	0.258	-0.889	0.397	-0.024	1.616	2.779	-0.468	0.006	-0.058	0.372	-0.267	0.191	0.217	0.357	0.315
	pe5	-19.293	0.985	0.644	-0.243	-0.393	1.600	-0.034	2.324	-0.243	0.252	0.166	-0.028	0.060	0.193	0.241	0.113	0.726	-0.266
Growth	p12	-10.137	-0.172	3.934	-2.457	3.604	0.424	-0.378	0.691	1.471	-0.510	-0.740	1.148	-0.570	-0.049	0.166	0.591	-0.404	-0.042
	p13	-13.140	0.126	-2.847	0.097	0.605	0.607	-0.057	-0.181	0.032	0.737	0.049	-0.060	-0.314	-0.598	-0.364	0.213	-0.092	0.269
	p14	-21.251	0.194	2.022	0.535	-0.671	0.091	0.345	0.640	2.945	-0.442	0.086	0.287	0.261	-0.088	0.253	0.041	0.197	-0.171
	p15	-16.533	0.340	-0.405	0.289	-1.022	1.619	0.218	-2.031	0.869	0.292	0.082	-0.194	-0.170	-0.147	-0.036	-0.052	-0.230	-0.425
	p23	-2.749	0.192	0.910	-0.602	2.173	-1.929	0.070	-0.077	2.446	-1.014	0.012	0.122	-0.515	0.906	0.074	-0.207	-1.972	-0.917
	p24	-24.211	0.324	3.445	0.476	-0.907	-0.980	-0.044	0.492	4.837	-0.882	0.026	-0.016	0.770	0.187	0.213	0.246	0.972	0.743
	p25	-17.185	0.257	1.615	-0.198	-0.472	0.734	0.162	-0.689	-2.094	0.845	0.064	-0.007	0.282	0.038	0.065	-0.081	0.386	0.029
	p34	-18.487	0.351	10.186	0.698	4.711	-0.860	-1.155	1.226	-1.034	-0.492	0.248	0.071	-0.011	3.440	0.076	-0.079	-2.182	-1.116
	p35	-19.117	0.152	2.492	1.062	-2.698	1.580	0.646	-0.067	2.155	0.659	-0.085	-0.732	1.037	0.846	-0.089	-0.426	-2.063	-0.052
	p45	-11.757	0.014	8.745	-0.633	5.357	0.363	-0.072	-0.436	-11.982	2.792	0.583	-0.060	1.080	-1.662	0.561	-0.142	-0.351	-0.649
Decline	p21	-7.750	0.004	-0.236	-1.110	1.718	0.373	-0.442	0.194	4.313	0.943	-0.436	1.266	-0.664	0.141	-0.045	0.030	-1.005	-1.416
	p31	-15.402	0.022	-0.669	-0.521	1.377	0.931	-0.485	-0.529	3.650	-0.563	-0.160	0.198	-0.181	0.874	0.213	0.106	-3.737	1.308
	p32	-8.234	-0.079	3.588	0.566	0.165	-3.149	0.730	0.181	3.759	-0.664	0.149	0.882	0.320	1.688	-0.302	-0.036	-2.335	-0.223
	p41	-15.856	-0.014	0.117	-0.232	-1.060	0.594	0.133	0.109	1.906	-0.561	-0.120	-0.631	0.368	0.280	-0.137	0.065	-0.218	0.403
	p42	-15.025	-0.054	1.017	-0.320	-0.078	0.098	-0.143	0.108	0.385	-0.561	-0.041	-0.884	1.971	-1.940	-0.173	0.090	0.464	0.920
	p43	-22.092	-0.017	6.757	1.636	5.726	-6.322	-0.860	-0.087	5.939	-1.939	0.599	3.246	-1.229	5.165	0.255	-0.166	-1.509	-0.499
	p51	-1.687	0.020	-4.148	-0.618	1.415	-1.941	-0.448	0.324	-6.656	0.786	-0.091	-1.636	0.041	2.010	-0.411	-0.142	-0.810	0.064
	p52	-4.134	-0.078	-4.804	0.151	0.086	-1.275	-0.449	0.186	-1.871	0.164	-0.116	-1.189	0.503	-0.759	-0.615	-0.031	-0.775	1.286
	p53	-3.034	-0.041	-4.939	0.964	-1.693	0.403	0.001	-0.062	-5.250	1.185	-0.284	0.278	0.457	-0.822	0.073	0.072	-1.240	0.524
	p54	-1.251	-0.054	4.040	0.193	-0.094	-1.060	0.117	0.034	-10.379	2.605	0.161	-0.376	-0.846	0.495	0.695	-0.817	-2.449	0.751

Source: Own calculation.

6.1 Technology

Trend

Confirming our observation that there is little systematic change in the structural process over the 10 years from 1995 to 2005, the trend is largely not significant. The only significant estimates apply to entry probabilities and two other exceptions. The probability elasticities show that with progressing time, there is less entry to the two small size classes and more entry to classes three to five. Assuming that the entries come from other farm types, this is generally in line with our expectations of a negative relationship between the trend and the entry probabilities and a positive relationship between the trend and farm size growth. The exit elasticities confirm this observation: the trend is positively correlated with the two small size classes and negatively correlated to size classes three to five.

Though the estimates are not significant, apart from one all elasticities for farm size growth are positive and the elasticities for farm size decline are generally negatively affected by the trend. The results fit in with our hypothesis and a Markov chain study by Tonini and Jongeneel (2009) showing that the trend negatively impacts Polish small dairy farms, and positively impacts larger size classes.

Milk yield

The milk yield is derived from the FADN sample data and calculated as average over the years 1995 to 2005. In average across the FADN regions, it is about 5600 kg/cow with a standard deviation of about 1050 kg/cow. The milk yield is significant for many transition probabilities. We expected that there would not be a relationship to dairy sector entries, the estimated coefficients however are significant for entry to SIZE3 and SIZE4. Generally, the elasticities for sector entry are positively correlated with the milk yield. Contrary to our expectation, the milk yield is also positively correlated with the exit probabilities. According to the elasticities, the milk yield is negatively correlated with all own-size probabilities. In line with our expectation, the elasticities for changes to larger size classes are mostly positively affected by the milk yield. Where the estimates for farm size decline are significant, the elasticites show a negative correlation with the milk yield. Other Markov chain analyses confirm the observation that higher milk productivity per cow positively affects farm size growth (Stokes, 2006; Rahelizatovo and Gillespie, 1999; Chavas and Magand, 1988). Zepeda (1995b) by contrast found that the milk production per cow had no measurable impact on farm size.

6.2 Farm structure

Farm size

The variable is composed of the average farm size in a region at the beginning of the observation period in 1995. The average initial farm size across the FADN regions was 40 cows. The standard deviation is about 35 cows. The initial farm size is highly significant for the own-size log-odds ratios and the ratios for farm growth and decline. A positive correlation is found for the probabilities for staying in the two small size classes and a negative correlation is given for staying in the larger size classes three to five. Confirming our hypothesis, entry is generally negatively affected by the initial farm size. As expected, the effect on farm growth is mixed. A negative effect of the initial farm size on farm decline is confirmed by half of the elasticities. However, especially the probabilities for changes from the largest size class to smaller classes are positively affected by the initial size. Further growth of farms in regions with predominantly large dairy farms requires also more large farms to downsize and provide the necessary resources.

Dairy farm size heterogeneity

Regional farm size heterogeneity is based on the FADN data and represented by the Gini coefficient of the number of cows per farm in 1995. The Gini coefficient is bounded between zero and one. The higher the Gini coefficient, the more heterogeneously is farm size distributed in a region. The average

Gini coefficient for dairy farms has a value of 0.31. The standard deviation is 0.12. We expected that a higher dairy farm size heterogeneity would generally lead to more structural change within this sector. This is confirmed by the elasticities in so far as all own-size probabilities and the larger entry probabilities are negatively correlated with the dairy farm size heterogeneity. The effect on exit, growth and decline is generally ambiguous regarding the signs, but positive probabilities are clearly larger on average.

General farm size heterogeneity

The regional farm size heterogeneity of all farms apart from dairy farms is based on FADN data. Because farm size may be land-independent, the Gini coefficients are calculated based on the economic farm size in European Size Units (ESU). The average Gini coefficient has a value of 0.44. The standard deviation across the regions is 0.11. The Gini coefficients for the size distribution across all farms in a region are a bit less significant than the dairy Gini coefficients. Significances occur for the own-size log-odds ratios and the log-odds ratios for farm growth and especially decline. Interestingly, the sign of the effects are often opposite to the ones found for the dairy farm size heterogeneity which contradicts our hypothesis. Apparently, the size heterogeneity of other farms predominantly stabilises the farm structure in the dairy sector. The effect could be caused by the existing opportunities for concentration of other activities, but this cannot be inferred from our analysis.

Stocking density

The initial stocking density is calculated from the FADN data. For stability reasons, it is based on the average of the years 1995, 1996 and 1997. The initial stocking density across the FADN regions was 2.54 Livestock Units per forage hectare with a standard deviation of 2.60. The stocking density is highly significant for most log-odds ratios. According to the elasticities, it has a small but positive effect on all own-size probabilities. Confirming our hypothesis, the effect on sector exits is negative and the one on entries is mainly positive. Beyond that, the initial stocking density shows a mixed effect on the transition probabilities for farm growth and decline.

6.3 Market conditions

Milk price over time

The milk price is derived from the FADN sample data. The fluctuation of the milk price over time is represented by the yearly deviation of the milk price from its regional average. The average value of the variable across time and region is -0.01 €/kg, the standard deviation is 0.02. The effect of the milk price over time is insignificant for all log-odds ratios apart from entry to the second smallest size class which is (as expected) positively affected. The effect of a positive milk price impact on entries to small size classes is also confirmed by Stokes (2006) for dairy farms in Pennsylvania. Though the estimates are not significant, the exit probabilities are, as expected, negatively affected by the milk price which is also in line with the findings of Stokes (2006).

Milk price across regions

For this variable, the above mentioned yearly milk price is averaged over the time period 1995 to 2005 and takes into account only regional differences. The average value is 0.33 €/kg, the standard deviation of the average milk price across the regions is 0.05 €/kg. It is significant for two thirds of the log-odds ratios. The regional milk price negatively affects the own-size probabilities for size classes one to four. It has a positive effect on the probability for staying in the largest size class. The effect of an increased probability for large farms to remain in the same size class is confirmed by Rahelizatovo and Gillespie (1999). However, they found the same effect for the small size classes which is contrary to our results. Contrary to our expectation, the exit from size classes one to three are positively and only the exit from the two largest size classes is negatively affected by the regional milk price. Stokes (2006) found a negative correlation between the milk price and all exit probabilities. The effect on sector entries is mixed. Farm size growth is mostly positively affected, especially the probabilities for changes from the two small size classes to larger size classes. Stokes (2006) found a positive effect only on the probability of expanding the size from a small- to a medium-sized farm. We expected a stabilization of farm structure with higher prices. This is widely confirmed for changes from and to the largest size class but the opposite is shown regarding other size classes.

Milk price volatility

The milk price volatility is defined by the coefficient of variation of the milk price across time per region. The average value is 0.05 €/kg and the standard deviation is 0.02 €/kg. The milk price volatility is especially significant for the log-odds ratios for farm size decline, but also other estimates are significant with an emphasis on probabilities associated with the larger size classes. The elasticities reveal positive signs for the own-size probabilities from size class one to three and negative signs for the two large size classes. Counterintuitively, the exit from the two small size classes is negatively and the exit from the other (larger) size classes positively affected by the milk price volatility. Stokes (2006) states a positive relationship between the milk price volatility and exits from all size classes. The effect on the entry and growth probabilities is ambiguous, whereby the mixed effect on the latter was expected in the hypotheses. Regarding farm decline, the expected negative sign is confirmed for the probabilities to decrease from size classes three and four. For changes from the largest to smaller size classes a positive sign is shown. Stokes (2006) found similar results for sector entry, farm growth and decline.

Land rent

The average land rent per region (from 1995 to 2005) is derived from the FADN information. Its average value across the regions is about 456 €/ha with a high standard deviation of about 714 €/ha.

The land rent is highly significant for most of the own-size log-odds ratios and the log-odds ratios on size decline. Apart from the probability on staying in the smallest size class, the own-size probabilities are negatively affected by the land rent. The elasticities for sector exits show that, as expected and consistent with Stokes (2006), the exit probabilities are the higher, the higher the land rent is (exception: exit from the smallest size class). The entry probabilities are also mostly positively affected as are the probabilities to expand in size. Consequently, the hypothesis of increasing dairy farm growth with increasing land rents is supported by the results. Interestingly, resources for the growth are apparently mainly mobilised by exiting farms while a stepwise decline of existing farms is negatively affected by the land rent.

6.4 Natural resources

Share of grassland

The share of grassland is taken from the CAPRI database (Britz and Witzke, 2008) and originally based on Farm Structure Survey data. Its average value across the regions is 37 per cent with a standard deviation of 21 per cent. The grassland share is especially significant for the log-odds ratios for farm size growth. The own-size probabilities are mostly negatively correlated with the share of grassland. Regarding exits, the expected positive sign is found for the exit probabilities from the three smaller size classes. Exits from the both largest size classes are negatively affected. All entry probabilities are negatively affected by the grassland share. A mixed pattern is revealed for the relationship between the grassland share and farm size growth, though all changes to the largest size class show the expected negative sign. Wieck and Heckelei (2007) find that a higher grassland share is associated with higher marginal costs. The effect on farm size decline is also ambiguous.

Slope

The average slope of the FADN regions is taken from the CAPRI database (Britz and Witzke, 2008). It originates from the JRC-IES Digital Elevation Model. The average slope across all FADN regions is 7.71 per cent, its standard deviation is 7.32 per cent. The slope in a region is highly significant for many of the log-odds ratios. It positively affects the own-size probabilities. Contrary to our expectation, it has a negative effect on the exit probabilities except the one from the largest size class. Entries are positively affected by the slope. The effect on farm growth and decline remains is mixed. Obviously, mountainous regions are not uniformly characterised by declining and departing dairy farms, but instead support to some extent also the growth of farms with lower intensity taking over resources from farms declining in size.

Temperature sum

The temperature sum is used to represent climate conditions. It is taken from the CAPRI database (Britz and Witzke, 2008). The temperature sum is defined as the sum over the average daily temperature for all days in a year with an average temperature above 8°C. The mean temperature sum across the FADN regions is about 3700°C with a standard deviation of about 1200°C. The coefficients of the temperature sum are highly significant for two thirds of the log-odds ratios. The own-size probabilities are negatively affected by the temperature sum. Exit probabilities are the higher, the higher the temperature sum is. Larger farm sizes tend to grow more and decline less with increasing temperatures and the opposite effect occurs for smaller dairy farms. Consequently, the structural adjustment processes are more intensive in warmer compared to colder climates.

6.5 Social and demographical factors

Population density

The population density stems from regional EUROSTAT data. The average value across the FADN regions is about 160 people/km^2 with a standard deviation of about 180 people/km^2. The population density is highly significant for most log-odds ratios of the transition probabilities. In line with our expectation, it is found that the higher the population density in a region, the lower is the probability to exit the sector (with exception of the exit from the largest size class). The elasticities also show that the higher the population density, the higher is the probability of sector entries into size classes three to five, and the lower are the entry probabilities to the both small size classes. As expected, farm growth is mainly positively affected by the population density. Farm size decline is partly positively and partly negatively affected by the population density.

Population growth

The population growth rate is calculated from regional EUROSTAT data. The average across the FADN regions is 0.3 per cent with a standard deviation of about 0.5. Many of the estimates of population growth are significant but overall less than the population density itself. Confirming our expectation, the probabilities to leave the sector is higher the higher the population growth rate. Concerning farm size growth and decline it is evident that population growth negatively impacts the structural adjustment of larger farms but transition probabilities of smaller farms are generally increased in both directions. Foltz (2004) also found a negative impact of the population change on the probability of staying in business and the probability of growing in size. The latter is only confirmed for smaller dairy farms in our case.

Off-farm employment

The unemployment rate comes from regional EUROSTAT data. The average unemployment rate across the FADN regions is 8.65 per cent with a standard deviation of 4.48 per cent. The unemployment rate is highly significant for most log-odds ratios. As expected, the unemployment rate is negatively correlated with the exit probabilities. The elasticities also show that the higher the unemployment rate, the more likely are farms to remain in the same farm type (and the more likely are the less relevant sector entries). The effect of the unemployment rate on farm growth and decline clearly shows that a high unemployment rate negatively affects the farms' structural adjustment. The lack of alternative income opportunities and the corresponding incentive to stay in dairy production does not allow a sufficient mobilization of resources for farms willing to grow..

Age

The share of farmers being older than 55 years in the beginning of the observation period is derived from the FADN data. It is calculated as the average of the years 1995 to 1997. Its average across the regions is about 24 per cent, the standard deviation being about 14 per cent. The variable is highly significant for many of the log-odds ratios. The elasticities confirm our hypothesis that the larger the share of farmers being older than 55 years, the higher is the probability for sector exits from the three smaller size classes. For the two largest size classes the effect is the other way around. As expected changes to smaller size classes are mostly positively affected. Interestingly, changes to larger size classes are mostly negatively affected indicating that the direct effect of an aged farmer population is not outweighed by increased opportunities for farms willing to grow. Although our hypotheses are largely confirmed there are two limitations concerning the use of the age variable in our analysis: (1) Apart from the age, also information on a potential successor should be considered since the existence of a successor would likely alter the farmers' behaviour significantly. This data was however not available. And (2) the data comes from the FADN sample farms and its regional representativity cannot be confirmed.

7 Conclusions

Dairy farm structural change and its patterns are identified at a regional level for the EU15 from 1995 to 2005. For this purpose non-stationary transition probabilities are calculated region-wise in a generalised cross-entropy Markov chain framework. Afterwards, a panel data regression on the transition probabilities is conducted in order to identify time- and region-dependent drivers of structural change. The dependent variable consists of the regional non-stationary transition probabilities, explanatory variables are picked from the literature on structural change and spatial dynamics of dairy farms.

The contributions to the existing literature on dairy farm structural change are: (1) the combination of micro and macro data in the calculation of the non-stationary transition probabilities, (2) the comparison of dairy farm structural change across a large number of regions, and (3) the cross-sectional focus in explaining the transition probabilities.

The analysis of the transition probabilities shows that there is considerable cross-regional variance dominating variation over time, although this effect might be somewhat amplified by the use of time-invariant prior information in the Markov chain approach. Mobility indices which are based on the transition probabilities indicate that the probability to change to larger size classes is higher in northern than in southern European countries. Over time, the mobility for farm decline decreases and the mobility on farm growth remain stable. The exit mobility is very volatile and entry to dairy farming is almost zero.

The effect of time-dependent variables as the trend and the milk price on the transition probabilities is rather limited compared to variables with regional variation. The trend has a negative effect on entries into small size classes and a positive effect on entries to large size classes. The milk price positively affects entries.

In general, region-specific variables very significantly affect the transition probabilities. Summarising and simplifying the results, it is found that the milk yield as technology proxy positively affects farm growth and negatively affects farm decline. The initial farm structure as a combination of farm size and dairy farm size heterogeneity has a strong impact and generally confirms our hypotheses of positively affecting structural adjustments. However, the size heterogeneity of all farms apart from dairy farms rather stabilizes the current dairy farm structure. The initial stocking density as a further structural variable has a negative effect on the exit probabilities. The effects of market conditions given as regional milk price, milk price volatility and land rent are rather mixed. The regional milk price stabilizes larger farms but the mobility of smaller size dairy farms is positively affected. A higher land rent is connected to higher exit probabilities and supports the growth of dairy farms. Regarding the effects of variables reflecting natural resources (grassland share, slope and temperature), the share of grassland positively affects exits from the three smaller size classes. The slope exhibits a significant impact but contrary to our expectations exits are generally discouraged and a mixed pattern with respect to dairy farm size growth and decline occurs. The increase in temperature is accompanied by more intensive structural adjustment processes including more prominent sector exits. Regarding population measures we expected an antithetic effect of population density and population growth. This hypothesis is confirmed by the calculated elasticities: dairy farming is positively affected by the population density as a measure for market proximity, but negatively affected by population growth likely reflecting the increasing competition for resources by non-agricultural activities. An increasing unemployment rate clearly slows down size related structural adjustments of dairy farms. Interestingly, a larger share of farmers close to retirement increases exits of small farms and the probabilities for size reductions, but this does not mobilize sufficient resources for farm growth to overcompensate the direct age effect.

Overall, the analysis confirms the relevance of the broadly propagated key factors of structural change: technical progress, economies of scale, path dependency, opportunity costs outside the agricultural sector.

While adding valuable information to the calculation of the transition probabilities by using micro data as prior information, a shortcoming of the analysis is the time-independency of the prior information. Time-invariant prior information was chosen due to the lack of robustness in the yearly observed transitions across the regional dimension of the data set. Nonetheless, the calculated transition probabilities were induced to vary over time following the (macro) data constraints. A potential solution to this shortcoming could be the employment of moving averages and this will be investigated in the future.

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