

DAIRY FARM SIZE DISTRIBUTION IN EAST AND WEST: EVOLUTION  
AND SENSITIVITY TO STRUCTURAL AND POLICY VARIABLES:  
CASE-STUDIES OF THE NETHERLANDS, GERMANY POLAND AND  
HUNGARY

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# DAIRY FARM SIZE DISTRIBUTION IN EAST AND WEST: EVOLUTION AND SENSITIVITY TO STRUCTURAL AND POLICY VARIABLES: CASE-STUDIES OF THE NETHERLANDS, GERMANY, POLAND AND HUNGARY

## Abstract

This paper analyses the dynamics in the farm size distribution for The Netherlands, Germany, Poland and Hungary. A (non-)stationary Markov model approach is used. The transition probabilities are explained by a set of exogenous (policy) variables. The models are estimated using an information theoretical approach, including non-sample (prior) information. The models can be used to simulate the impact of alternative dairy policies on the dairy sector structure. For all countries there is an autonomous decline in farm numbers over time (implying increase in average farm size). This trend continues irrespective of the EU dairy policy type. For both Hungary and Poland the role of the subsistence sector is expected to substantially decrease over time.

Keywords: Farm size structure, dairy, milk quota, policy, maximum entropy

## 1. Introduction

Farm numbers have been declining drastically over the past decades, whereas farm size has increased. Farm size and structure have long been issues considered by agricultural policy both in Europe (Keane and Lucey, 1997) and the US (Sumner, 1985). This is related for a large part to the (social) goal of agricultural policy, aimed at supporting farmers incomes, in particular helping the 'weak' ones (small scale farmers, farmers with difficult production circumstances, e.g. mountaneous areas). The aim of this paper is to analyse the farm size distribution of the Dutch, West and East German, Polish and Hungarian dairy sectors, with a particular focus on tracing out how technological change (structural variable) and past adjustments in common agricultural policy (CAP) affected this distribution. This research should provide a framework to analyse the implications of new changes in the EU dairy policy (for example a substantial change in the dairy quota system or even its abolition) on the dairy farm size distribution. Predictions for the farm size distributions in 2010 are made.

In the next section (Section 2) a brief overview of the literature explaining farm size and farm size distribution is given. In Section 3 the general Markov model structure is discussed. In Section 4 the estimation procedures used are discussed. In the subsequent sections the country case studies are discussed (farm sector characteristics as well as obtained estimation results). Sections 5, 6, 7 and 8 discuss respectively the cases studies of theThe Netherlands, West and East Germany, Poland and Hungary. Section 9 presents some (endogenous) simulation results. Future farm size structure is predicted (2010) assuming that the policy variables remain unchanged (status quo). Finally, Section 10 closes with some concluding and qualifying remarks

## 2. Literature

An examination of the literature yields a number of variables likely to affect transition probabilities including relative prices, technological change, economies of size, farm debt, sunk costs, policy variables, demographic variables, indicators related to off-farm employment, etc. (see Goddard *et al.*, 1993; Zepeda, 1995b, Foltz, 2003 and Eastwood, *et al.*, 2004 for an overview)<sup>1</sup>. Several theoretical approaches try to explain entry, exit, and farm size dynamics, among which the family farm theory (which relies to a large extent on neoclassical production and household economics), institutional economics (relying on concepts like governance structures, principal-agent theory, and transaction costs), and sunk costs theory.

The classical family farm theory more or less started from classical microeconomic producer theory, which was later on complemented by the household theory. The optimal farm size is often related to the minimum locus on the long-run average cost curve. More recently the family farm theory of farm size was enriched by contributions made from the field of institutional economics. Institutional economics emphasized the relevance of transaction costs, especially those associated with the supervision of hired labour, which are thought to be sufficiently important in relation to scale economies to make the family farm<sup>2</sup> the optimal production unit over a large range of different circumstances (variations in tenancy structure, skewed land ownership) (Eastwood *et al.*, 2004, Section 3).

Eastwood *et al.* (2004, Section 2) explored the impact of ‘economic development’ on farm size. As compared to the family farm theory, which is strongly based on the static neo-classical theory of producer and household behaviour, the economic development-literature is focusing more on the dynamics in the farm size evolution. Eastwood *et al.* show that assuming that economic development increases the reservation utilities of families, makes capital cheaper and facilitates technical progress, it is likely to raise the farm size. The impact of technical progress is somewhat ambiguous and can, depending on its nature (neutral, land-augmenting, labour-augmenting) and the prevailing elasticity of substitution, either reduce or increase farm size (Braun, 2004, 24).

The sunk costs theory focuses in particular on the entry and exit issues (active/inactive), although it could also be applied to entry and exit into specific farm size classes. From the sunk cost theory it is hypothesized that farm exits will be decreasing in output price levels, increasing in price variances, decreasing in current capital, decreasing in the level of technology and increasing to the value of the returns to non-farm capital (Foltz, 2003).

Scanning a number of empirical studies shows that one of the most important drivers of farm growth and decline is financial efficiency (Schunk, 2001). The drop in total farm numbers is accelerated by increasing and high input prices and slowed down by increasing and high output prices. However, in general strong commodity markets are not able to stop the decline in the number of small farms. Less favourable economic conditions have a particularly strong negative effect on the number of small farms. Unfortunately most studies neglect the debt structure of farms in their analysis. From the scale economies argument<sup>3</sup> mentioned before one would expect small farms to be less profitable than larger farms and/or having a higher average production cost than larger farms. Often this relationship is confirmed in reality, in particular when land and labour are highly priced, and also in situations of imperfect credit markets. There seems to be an optimal farm size: increasing the farm scale beyond this optimum does not generate scale economies (Carthagne *et al.*, 2005). In some cases opposite evidence was found (eg. crop and milk yields that are higher for small farms than for large farms). In addition to these economic variables also farmers’ attitude and family characteristics are found to influence farm strategy, farm size and legal farm type choice (Jongeneel and Slangen, 2004).

The specific aim of this paper is to analyse (dairy) farm size distribution with respect to a limited number of key (policy) variables. This should be done in such a way that the simulations made at sector level<sup>4</sup> can be translated into their consequences for the farm size distribution. Given the complexity of factors influencing the farm size evolution, in the approach followed here a simplified model is followed. The following explanatory variables (ignoring a constant) are selected:

1. a technology shifter (eventually based on estimated autonomous milk yield development);
2. level of aggregate milk production (which might be effectively constrained by a milk quota regime);
3. a dummy or dummy-trend variable indicating the switch in policy regime (price support with free supply or supply management) or break in the data (cf. East-Germany);
4. actual farm gate price of milk (based on actual fat and protein content).

Although dairy cows play a non-negligible role in EU beef production, no explicit variable (like for example the beef price) is taken into account in this case, assuming that milk is the main output and meat is a by-product for the dairy sectors.

### 3 The Markov model

A tool often used to describe changes in firm size distributions over time is the Markov process. This approach has the advantage that it relies on aggregated data of finite size categories --the so-called Markov states -- at given discrete time intervals<sup>5</sup>. Therewith it avoids the requirement longitudinal

time-ordered micro data describing movement of individuals between different states, data, which are only sparsely available. The main result of this analysis is the transition probability matrix, which describes the probability of a variable in a certain Markov state (for example a firm size class) to enter another Markov state. See Zepeda (1995a,b) and Karantininis (2001) for a list of both general and agriculture related Markov studies<sup>6</sup>.

Based on Gibrat's Law, which states that firm growth is independent of firm size, firm size was initially often modelled as a purely stochastic Markov process, where the transition probability matrix (TPM) is assumed to be constant over time. However, this approach neglects the impact of the 'environment' on an industry's firm structure as well as the behavioural response of the entrepreneurs to these factors. From the brief literature review presented in the previous section it appeared that these latter factors are important in explaining transition probabilities. Non-stationary Markov chain analysis explicitly allows variables characterising the industry's environment, among which policy variables aimed at influencing the sector, to explain the non-stationary transition probabilities. Therefore the non-stationary Markov chain approach well fits with what is known from economic theory.

Most studies using a non-stationary transition probability matrix make very strong parametric distributional assumptions and other restrictions. Traditional estimation techniques like OLS fail, or require strong restrictions, because the estimated parameters must satisfy probability assumptions (non-negative probabilities, adding up). MacRae (1977) suggested a Logit transformation, which automatically satisfied the probabilistic constraints (see Zepeda 1995a,b for applications). However, there degrees of freedom problem often remains, which restricts the researcher to the choice of a limited number of explanatory variables. Even if sufficient degrees of freedom are available there can be problems with the convergence of the estimation algorithms (see Geurts, 1995). In this paper therefore an information theoretic estimation approach will be followed (maximum entropy estimation). See Golan et al. (1996) for a general discussion of maximum entropy estimation. We largely follow the literature on recent Markov model applications using this approach by Golan and Vogel (2000), Courchane et al., (2000), and Karantininis (2001). The main difference of our approach is that we more intensively exploit different sources of prior information in the inference procedure.

The Generalized Cross Entropy (GCE) formalism is used to recover coefficients of the effects of exogenous variables on individual transition probabilities when a specific (linear) functional form of the relationship is imposed. This method allows the use of an extensive set of explanatory variables. The impact of each variable on the individual probabilities and size categories is evaluated in the form of impact elasticities. Prior information on the TPM is introduced using the GCE formalism.

Assume the firm size in the dairy industry is divided into  $J$  size categories and denote by  $n_{jt}$  the number of firms in the  $j$ -th size category ( $j=1, \dots, J$ ). Then a Markov chain process can be expressed as

$$n_{jt} = \sum_{i=1}^I p_{ij} n_{i,t-1}; \quad j = 1, \dots, J \quad (1)$$

where  $p_{ij}$  is the probability of transition from size  $n_i$  at time  $t-1$  to size  $n_j$  at time  $t$ , and  $i$  and  $J$  similar to  $j$  and  $J$ . The total number of farms existing at time  $t$ ,  $N_t$ , is equal to  $\sum_{i=1}^I n_{it}$ . In matrix notation equation (1) can be written as  $\mathbf{n}(t) = \mathbf{P}' \mathbf{n}(t-1)$  where  $\mathbf{n}(t) = (n_{1t}, \dots, n_{Jt})'$  is a  $K \times 1$  column vector and  $\mathbf{P} = (\mathbf{p}_1 \ \mathbf{p}_2 \ \dots \ \mathbf{p}_K)$  is the transition probability matrix (TPM) with each vector  $\mathbf{p}_i = (p_{1i}, p_{2i}, \dots, p_{Ki})$ . The probability matrix is a stochastic matrix satisfying  $p_{ij} \geq 0$  and

$$\sum_{j=1}^K p_{ij} = 1.$$

Besides the evolution of the size distribution an important and related issue is the modelling of entry and exit from the industry. The number of assumed potential entrants to the industry is known to have an important effect on both (short-run) projections and equilibrium solutions, even though it will not affect the estimated proportions of active firms falling in each size category (Stanton and Kettunen, 1967). By defining 'no production' as an additional category (say corresponding with state  $i=0$ ) it allows the modelling of entry and exit in the industry as well as the change in the size

distribution of the 'active' or producing firms. In a fully competitive environment the number of 'firms in the 'no production' category is indeterminate, but might be expected to be large relative to the total number of 'active' farms (Stanton and Kettunen, 1967, 639). However, with respect to the dairy industry, in particular under the milk quota system, entry conditions seem a limiting factor. Therefore, the total number of dairy farms at the initial date will be used as an indicator of the total number of firms implying that the number of firms in state  $i = 0$  at that date is zero.

The probability matrix  $\mathbf{P}$  is unlikely to be constant but will rather be dependent on the economic situation both inside and outside the dairy industry. For that purpose it is assumed that  $p_{ij}$  is a function of a set of explanatory variables, or

$$p_{ij}(t) = f_{ij}(\mathbf{z}(t-1), \beta_{ij}) \quad (2)$$

with  $f_{ij}(\cdot)$  denoting a general function of a vector of  $N$  exogenous variables  $\mathbf{z}(t-1) = (z_{1,t-1}, \dots, z_{N,t-1})$  and  $\beta_{ik}$  a vector of parameters. This corresponds to  $\mathbf{P}(t)$  now being a time dependent or non-stationary transition probability matrix.

## 4 The information approach to recovering Markov transition probabilities

### 4.1 The GCE estimator for the non-stationary Markov Model with prior information

The statistical model to be estimated consists of (1) and (2), to each of which a vector of disturbances is added ( $\mathbf{u}(t)$  and  $\mathbf{e}(t)$ ).

$$\mathbf{x}(t) = \mathbf{P}' \mathbf{x}(t-1) + \mathbf{u}(t) \quad (1a)$$

$$p_{ij}(t) = f_{ij}(\mathbf{z}(t-1), \beta_{ij}) + e_{ij}(t) \quad (2a)$$

and  $\mathbf{x}(t)$  the vector of proportions, obtained after normalization of the farm numbers in each size class  $n_{it}$  by the total number of farms in the first period,  $N_0$ .

A stationary TPM estimator using GCE is developed by Lee and Judge (1996), and Golan, et al., (1996). Assume  $\mathbf{u}(t)$  is a vector of disturbances with zero mean bounded within a specified support vector  $\mathbf{v}$ . Each element of the  $\mathbf{u}_T$  is parameterised as  $u_{it} = \sum_m^M v_m w_{itm}$ , where  $\mathbf{w}$  is an  $M$ -dimensional vector of weights (in the form of probabilities) for each  $u_{it}$ ,  $\mathbf{v}$  is an  $M$ -dimensional vector of supports. With  $\mathbf{x}(t)$  being a vector of proportions, the support vector can be set to  $(n_{it} \in [0,1])$  or to

$$\mathbf{v} = \left[ -1/K\sqrt{T}, \dots, 0, \dots, 1/K\sqrt{T} \right]' \quad (\text{e.g. Golan and Vogel, 2000 and Golan et al., 1996, 96-100}).$$

By using GCE, any prior information about  $\mathbf{P}$  can be incorporated in the form of a matrix of priors  $\mathbf{Q}$ . Some research has indicated that farms typically do not decrease in size without going out of business, whereas other studies argue that might scale up or down in size, but with no more than one size category per transition (Zepeda, 1995b, 842). The latter assumption, which seem to be rather plausible when growth is considered as a continuous process, would imply that in general

$$x_{it} = p_{i-1,i,t} x_{i-1,t-1} + p_{i,i,t} x_{i,t-1} + p_{i+1,i,t} x_{i+1,t-1} \quad (3)$$

with all other elements in the  $i$ -th row of the probability matrix expected to be equal to zero. Rather than imposing this as a restriction which should be satisfied, like was done in Zepeda (1995b), here this information is used as prior information, which seems likely, but may be overruled by the data. Since the number of dairy farms is consistently diminishing over time, Geurts (1995) assumes that the probabilities of re-entry are equal to zero, or  $p_{0j} = 0$  for all  $j = 1, \dots, K$ , with the zero subscript denoting the entry-exit category. Another prior restriction could be to limit the number of non-movers to be not lower than a certain fraction  $c$ . The prior information can be directly included in the  $\mathbf{Q}$  prior-matrix of the GCE estimator (see below).

The objective of the GCE estimator is to minimize the joint entropy distance between the data



and the priors. Let  $H(\cdot)$  be the measure of cross entropy, then the GCE is:

$$\min_{\mathbf{p}, \mathbf{w}} \left\{ H(\mathbf{P}, \mathbf{W}, \mathbf{Q}, \mathbf{W}^o) = \sum_i \sum_j p_{ij} \ln(p_{ij} / q_{ij}) + \sum_i \sum_t \sum_m w_{itm} \ln w_{itm} \right\} \quad (4)$$

subject to three sets of constraints: (a) The  $K \times T$  data consistency constraints (Equations (2)); (b) The normalization constraints for both the transition probabilities ( $K$  constraints) and the error weights ( $K \times T$  constraints):  $\sum_j p_{ij} = 1$ ,  $\sum_m w_{itm} = 1$  (proper distributions); and (c) the  $K^2$  non-negativity constraints for  $\mathbf{P}$  and the  $K \times T \times M$  constraints for  $\mathbf{w}$ :  $\mathbf{P} \geq 0$ , and  $\mathbf{w} \geq 0$ .  $H(\cdot)$  can be interpreted as a dual-loss function, which gives equal weights to prediction and precision. The solution to the above system of equations is derived Golan, et. al., (1996, Chapter 6).

#### 4.2 Introducing structural information: The non-stationary model

Following Golan and Vogel (2000) and Karantininis (2001) a generalized cross entropy (GCE) estimator, which appears to be very similar to the multinomial Logit model used by among others MacRae (1977) and Zepeda (1995). Moreover it can easily take into account prior information of various forms. An additional advantage is that the GCE-approach can deal with so-called ill-posed problems (for example data limitations). Assume there exists a  $T \times N$  matrix  $\mathbf{Z}_{tn}$  of  $N$  structural variables or covariates in the  $T$  time periods. These can be thought of as policy variables influencing the transition probabilities and as non-policy variables approximating the state of the 'environment' the dairy sector is facing. Starting with the moment condition or data consistency constraint (1a) and following an instrumental variable approach (Golan and Vogel, 2000) the information in  $\mathbf{Z}_{tn}$  can be incorporated in the GCE model as

$$\sum_t z_{tn} \cdot y_j = \sum_t \sum_i z_{tn} \cdot x_{it} \cdot p_{ij} - \sum_t \sum_m z_{tn} \cdot v_m \cdot w_{jtm}, \forall j = 1, \dots, K, n = 1, \dots, N \quad (5)$$

Equation (5) is an expression similar to the instrumental variable approach and reflects the belief that the structural variables are correlated with the  $x$  and  $y$  data. No specific functional relationship is assumed, leaving open the exact relationship between the  $z$ -s and the  $x$  variables.

#### 4.3 Introducing prior information

Within the GCE approach it is relatively easy to include prior information in the estimation procedure. One way is to add information about the transition probabilities by means of the  $\mathbf{Q}$ -matrix<sup>7</sup>. These kinds of priors can be "educated" guesses made by the researcher, preferably based on previous empirical research, experiments or economic theory. For example, here the principle is followed that for each size class the annual (continuous) per annum growth rates are calculated. 1-these rates is a first proxy for the fraction of farms which each period stays in its own size class, and is used as a prior estimate for the diagonal elements of the TPM. The remaining probability is in a balanced way spread over exit, 'moving one size class down', and 'moving one size class up'. By doing this, implicitly the prior information regarding the structure of the transition probability matrix as expressed in equations 5 and 6 is taken into account. Note that this type of prior does not have to be exactly satisfied, but can be overridden by the sample data. It is also possible to add other types of prior information (see Jongeneel, 2005).

## 5 The Dutch dairy sector: data and estimation results

The data represent the Dutch dairy farms size distribution from 1972-2003 and comprise 7 size classes. A graphical illustration of the evolution of the dairy farm size distribution in the Netherlands is given in Figure 1. The smaller size classes show a strong decline over time. The two largest size classes (70-99 and 100-...), in the following labelled as the 'large' farms, show an increase over the pre-quota period, a decline in the first 5 years after the introduction of the quota, and more or less

stabilise thereafter. Class 50-69 shows a similar pattern, but is still going to slightly decrease from 1989 onwards. The mid-size class (30-49) shows a cyclical behaviour, with, however, a clear downward trend. In the following the size classes 30-49 and 50-69 are labelled as the category medium-sized farms. The 'small farms', consisting of size classes (1-29), show a sharp decline up till 1984, which is continued after the introduction of the milk quota, but at a lower rate of decline.

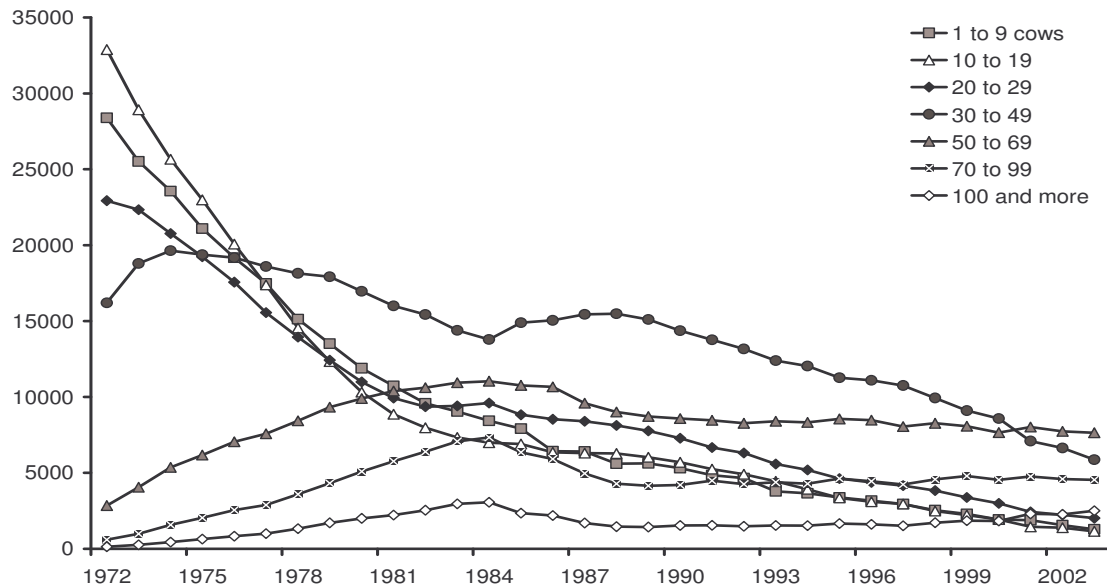


Figure 1. Dairy farm size evolution (absolute number of farms)<sup>8</sup>

A first inspection of Figure 1 suggests that the introduction of the milk quota system slowed down farm size adjustment in the Dutch dairy sector. However, the sectoral adjustment process did not come to a standstill but continued also after 1984. The tradability of milk quota in the Netherlands contributed to this. Over the period 1984-1999 the total number of active farms declined by 72,235 farms or about 70%. The annual decline in the total number of active dairy farms for the pre-quota period (1972-1984) was 4.45%, whereas for the with-quota period (1983-2003) it was 4.52%. Concluding, the introduction of the milk quota regime cannot be said to have slowed down the percentage of dairy farm exits in the Netherlands.

The estimation results are given in Table 1 (left side). The entropy information measure for the system as a whole is 0.162 and the Pseudo  $R^2$  was 0.838. Roughly seventy percent of the estimated parameters were significant.

Table 1. Transition probability matrix and impact elasticities for the Netherlands

Size class	Estimated probability matrix								Explanatory variables			
	0	1 - 9	10 - 19	20 - 29	30 - 49	50 - 69	70 - 99	100 - +	Trend	Milk output	Milk price	Quota dummy
0	1.00								-0.0003	0.0053	-0.0027	0.0001
1 - 9	0.05	0.88	0.07						0.0000	-0.0010	0.0008	0.0000
10 - 19	0.05	0.02	0.81	0.12					0.0008	0.0042	-0.0003	-0.0004
20 - 29	0.06		0.02	0.82	0.10				-0.0011	-0.0123	-0.0006	0.0001
30 - 49				0.02	0.90	0.08			0.0023	0.0058	-0.0003	-0.0014
50 - 69					0.02	0.93	0.05		-0.0026	-0.0053	0.0038	0.0014
70 - 99						0.02	0.95	0.03	0.0001	0.0010	-0.0015	0.0004
100 - +							0.01	0.99	0.0000	0.0003	-0.0003	-0.0001

Source: own calculations

The percentage mean square prediction errors are 0.016, 0.234, 0.314 and 0.156 for the inactive and 1-9, 10-19 and 20-29 size classes and (rounded) zero for the other size classes. The estimated matrix

rather closely follows the prior matrix<sup>9</sup>. When the transition probability matrix was estimated excluding a dummy variable to take into account the quota policy-shock the exit probabilities for size classes 1-9, 10-19 and 20-29 were slightly higher. Moreover, the diagonal elements were slightly lower. Together these differences suggest that the introduction of the milk quota increased rather than decreased the farm mobility of size classes, although the changes are only marginal. It should be realized that within the Netherlands the milk quota are tradable (buy/sell and lease), which facilitates over time farm size restructuring.

The impact of the exogenous variables on the number of farms in each class size is given by the impact-elasticities (Table 1 right part). The explanatory variables used (except for a constant) were a trend, milk production, milk price and a dummy variable (zero until 1984, and one from 1984 and onward). As the Table shows, all the policy elasticities are low, suggesting that changes in dairy policy induce only slightly changes in the dairy farms size distribution.

It is somewhat strange that an increase in the trend leads to a decline in the number of inactive farms (*ceteris paribus*). However, the value for the trend factor can also be interpreted as a correction to the normal number of exits. As the total number of active farms declines over time, the absolute number of farms exiting over time declines, even if the percentage exit rate remains constant. The trend negatively affects the number of farms in the size classes 29-29 and 50-69. Looking at the data (see Figure 1) it can be seen that it are these classes, which show a relative strong decline, in particular in the with-quota period. The trend variable seems to pick this up. A dummy variable was introduced to account for the imposition of the milk quota regime. The model was also estimated without a dummy: including the dummy improved the prediction accuracy for both sub periods. Although the milk quota introduction restricted over time output growth, and as such was taken into account by the (total) milk production variable, still adding the dummy variable contributed to the model's performance (improved entropy information measure and pseudo R-square). The milk quota dummy lowers the number of farms in size classes 10-19, 30-49 and 100-+. It slightly increases the number of inactive farms. It should be noted that in order to approximate the total impact of the milk quota the properly combined effect of the quota dummy and the reduction in milk production should be taken into account.

An increase in the total milk production has a negative impact on the number of farms in size classes 1-9, 20-29, and 50-69. It increases the number of inactive farms or farm exits of inactive farms. A milk price increase lowers the number of farms in the inactive size class, *viz.* increasing profitability helps farms in surviving. A milk price increase has a negative effect on the number of all active dairy farms, except for those in size class 1-9 and 50-69. It should be realized that the elasticities show partial effects: the impact of changing one explanatory variable while keeping everything else constant. Of course in reality several explanatory variables will move together and being correlated with each other. A quota increase, for example, will lead to an increase in milk supply and therefore most likely be accompanied by a simultaneous milk price decline. Likewise, abolition of the quota will affect milk production, milk price and quota dummy altogether.

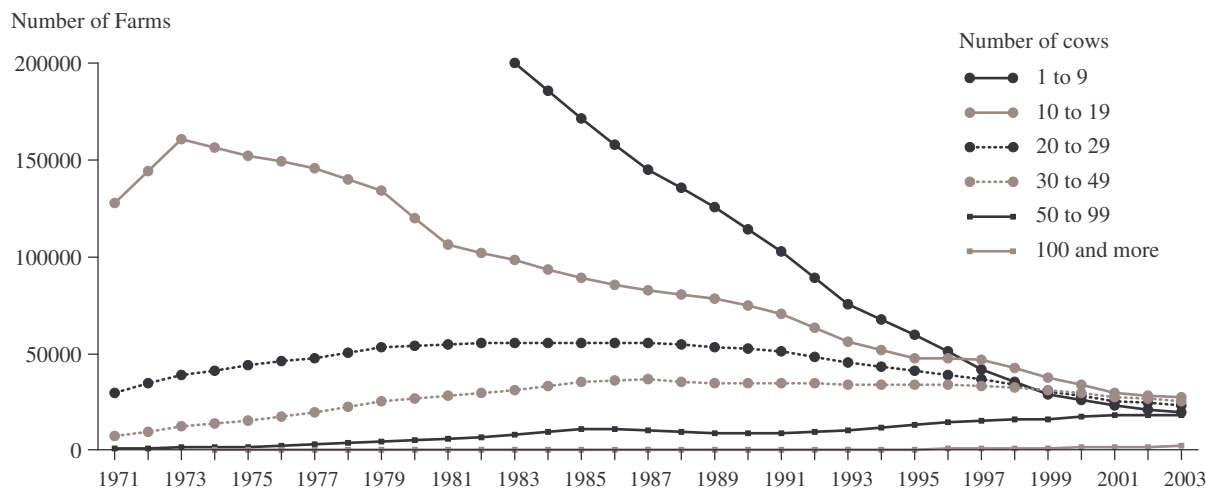
## 6. The German dairy sector: Data and estimation results

The respective data represent German dairy farm size distribution are separated between East and West Germany because of different historical developments. For West Germany data represent the distribution of dairy farms in the period 1971-2003 and data for East Germany represent the period from 1991-2003. Data was only available for every two years and the intermediate values were interpolated.

Dairy farming in **West** Germany is mainly based on family farms. It can be further differentiated between North and South, whereby in southern Germany dairy farms are rather small compared to the North due to a divisional inheritance system. Figure 2 gives a graphical illustration of the evolution of dairy farm size distribution in West Germany for six size classes. Small size classes (< 20 cows) show a strong decline over time, even in pre-quota period (1984). The medium size classes (20-29 and 30-49) increased in the pre-quota period and declined slightly in the first five years in the quota period and then stronger after 1990. Larger size classes (50-99 and > 100) increased in the pre-quota period and became more or less stable. At first glance the introduction of milk quota in 1984 only slightly affected farm size distribution.. In the 1990s the number of farms in the large size class increased which might be explained by the introduction of



the possibility of leasing in/out milk quota (1990/91) and milk quota transfer without being attached to land (1992/93). Since 2000 these upper classes increased even stronger; in 2000 milk quota transfer via regional auctions was introduced. To account for these changes 2 dummy variables are used: a dummy variable for quota (beginning 1984) and a dummy variable for regional auctions (beginning 2000). Over the period studied, the number of dairy farms decreased by about 80 % from 711 064 in 1971 to 116 392 in 2003.



Source: Statistisches Jahrbuch ueber Ernährung, Landwirtschaft und Forsten, diverse volumes.

Figure 2. Dairy farm size evolution (absolute number of farms) in West Germany

The estimation results are presented in Table 2. The entropy measure for the whole system is 0.079 and the Pseudo- $R^2$  is 0.921. The percentage mean square prediction errors are 0.113 for the inactive class, 0.014 for class 1-9, 0.007, 0.004 and 0.001 for the classes 10-19, 20-29 and 30-49, respectively. For the remaining classes the mean square prediction errors are rounded zero. The estimated probability matrix (left side in Table 2) follows closely the prior probability matrix (not presented here).

Table 2. Estimated transition probability matrix and impact elasticities for West Germany.

Size class <sup>1)</sup>	Transition probabilities							Impact elasticities				
	0	1-9	10-19	20-29	30-49	50-99	> 100	Trend	Milk supply	Milk price	Quota dummy	Auction dummy
0	1.000	0	0	0	0	0	0	-0.00027	0.00300	-0.00082	-0.00004	0.00000
1-9	0.100	0.900	0	0	0	0	0	0.00039	-0.00400	0.00090	0.00017	-0.00001
10-19	0.033	0.036	0.931	0	0	0	0	0.00017	0.00017	0.00020	-0.00004	0.00000
20-29	0.019	0	0.019	0.952	0.010	0	0	0.00004	-0.00017	0.00006	0.00001	0.00000
30-49	0.006	0	0	0.006	0.986	0.003	0	0.00000	-0.00003	0.00002	0.00000	0.00000
50-99	0.001	0	0	0	0.004	0.990	0.004	0.00000	0.00000	0.00000	0.00000	0.00000
> 100	0.001	0	0	0	0	0.009	0.990	0.00000	0.00001	-0.00001	0.00000	0.00000

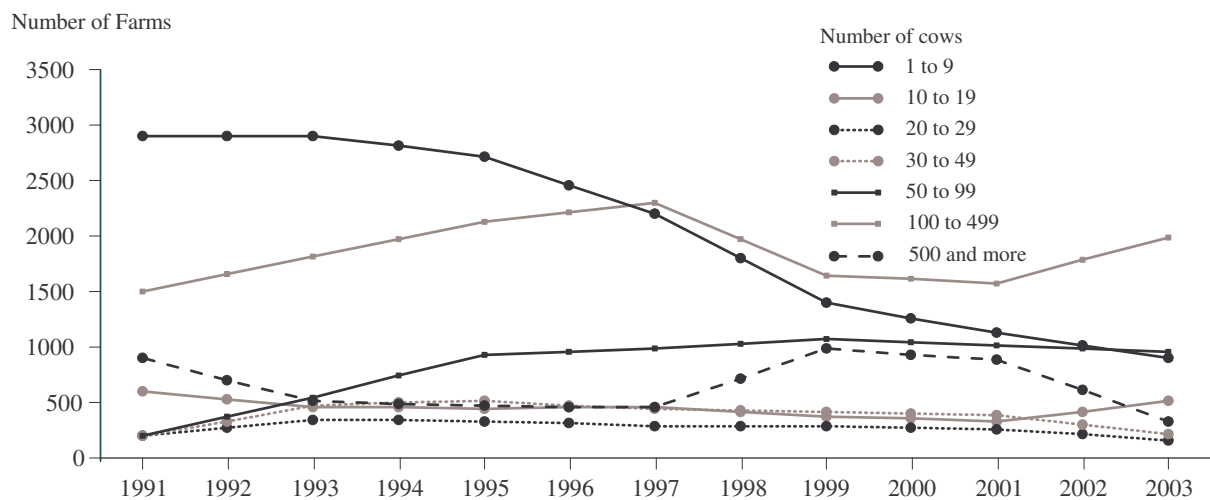
1) No. of cows

Source: own calculations

The used explanatory variables for West Germany were a constant (not presented), a trend variable, total milk supply, milk price, a milk quota dummy (for the milk quota system starting 1984) and a second quota dummy variable for the introduction of the regional auctions system (starting in 2000). All variables show low values of the respective impact elasticity, even estimations for two sub

periods (1984-2003 and 2000-2003) show low impacts on the farm size distribution. The trend variable indicates a slight decline in the number of inactive farms as the results for the Netherlands already showed. This can be interpreted as a correction factor to the normal number of farms exits because the number of active farms also declines over time. An increase in total milk production increases the number of inactive farms and lowers slightly the number of farms in class 1-9, 20-29 and 30-49. A milk price increase improves the profitability and lowers the number of inactive farms. It further increases the number of farms except class (> 100) in the remaining size classes. The low values of the quota dummy indicate that the respective policy system only slightly affects farm size distribution. It decreases slightly the number of farms in the inactive and in class 10-19. It does not affect farms in classes 30-49, 50-99 and >100. The auction quota dummy lowers only the number of farms in the small size class 1-9 and considers the strong decline of this class since 2000. At this stage it must be taken into account that the variable only act ceteris paribus and correlations are not considered.

The evolution of dairy farm size distribution in **East** Germany from 1991 until 2003 is visualised in Figure 3 and comprise seven size classes. Small farms (< 10 cows) decline until 1999, afterwards the decline slows down. The size class 10-19 only slightly decreases over time. Medium size classes (20-29, 30-49 and 50-99) increase in the first years after reunification until 1995 and the latter one even until 2001 and then declined. The increase in the first years of the 1990ies is due to the re-entries after reunification. To consider this evolution a dummy trend variable is introduced starting in 1996. Class 100-499 increases until 1997, then declines and slightly increased since 2001. The largest size class (> 500 cows) declined until 1997, then increases again and after 2001 it declines again. This evolution is due to an ongoing trend of farm transformations. It has to be considered that the model is not able to deal with changing upheavals and the instability over time of the upper classes might cause problems in the prediction. The total number of farms declined about 21 % from 6 500 in 1991 to 5 132 farms in 2003.



Source: Statistisches Jahrbuch ueber Ernaehrung, Landwirtschaft und Forsten, diverse volumes.

Figure 3. Dairy farm size evolution (absolute number of farms) in East Germany.

The estimated transition probabilities for East Germany are presented in Table 3 (left side). The entropy measure for the whole system is 0.106 and the Pseudo-R<sup>2</sup> is 0.894. The percentage mean square prediction errors are 0.009 for the inactive class, 0.001 for class 1-9, 0.001 for class 50-99, 0.005 for class 100-499 and for the remaining size classes rounded zero. Even more in this case, with less sample observations than for The Netherlands and West Germany, the estimated matrix closely reflects the prior probabilities. The used exogenous variables for East Germany were a constant, a trend variable, milk supply and milk price as well as a dummy trend variable that accounts for the break in the data in the mid-nineties<sup>10</sup>. The impact elasticities except the constant were presented on the right hand side in Table 3 and show higher values than for West Germany.

Table 3. Estimated transition probability matrix and impact elasticities for East Germany.

Size class <sup>1)</sup>	Transition probabilities								Impact elasticities			
	0	1-9	10-19	20-29	30-49	50-99	100-499	> 500	Trend	Dummy trend	Milk supply	Milk price
0	0.990	0.001	0.001	0.001	0.001	0.001	0.001	0.002	-1.3730	0.1680	-0.4030	1.5570
1-9	0.075	0.925	0	0	0	0	0	0	0.0060	-0.0010	0.0010	-0.0050
10-19	0.005	0.005	0.99	0	0	0	0	0	0.0004	0.0000	0.0001	-0.0002
20-29	0.033	0	0.033	0.917	0.017	0	0	0	0.0007	-0.0002	0.0000	-0.0004
30-49	0.043	0	0	0.044	0.891	0.022	0	0	0.0010	-0.0004	0.0000	0.0001
50-99	0.008	0	0	0	0.022	0.945	0.025	0	0.0007	-0.0002	-0.0004	-0.0030
100-499	0.003	0	0	0	0	0.012	0.972	0.013	0.0002	0.0000	0.0007	0.0020
> 500	0.001	0	0	0	0	0	0.017	0.980	-0.0006	0.0001	-0.0010	-0.0030

1) No. of cows

Source: own calculations

An increasing trend has a strong impact and lowers the number of farms in the inactive class. It further declines the number of farms in class > 500 and increases the number in the remaining size classes. The instability over time of the upper class seems to be considered by the trend variable. The dummy trend variable starting in 1996 increases the number of inactive farms and lowers slightly the number in class 1-9 and in the medium size classes (20-29, 30-49, 50-99). The trend and the dummy trend variable give account for the evolution in the past. Increasing milk supply lowers the number of inactive farms that might be due to increasing revenues and a stabilising effect that is confirmed by the increasing number of farms in the size classes except classes 50-99 and > 500. Rather surprising seems the impact of an increasing milk price that increases strongly the number of inactive farms and declines the number of farms in the small and medium size classes except class 30-49. The upper classes react different whereby class 100-499 increases and class > 500 declines. The unstable development in the past seems to be captured by the milk price variable.

## 7 The Polish dairy sector: data and estimation results

For Poland only observations for the years 1987, 1996, and 1998 till 2000 were available (see Table 4). For 1997 no observation was available, but this year was interpolated. The pre-transition observation of 1987 was discarded, so that only four observations remained. Four size classes are distinguished. The smallest size class is comprised of farms having 1 or 2 cows. This are clearly so-called subsistence farms, the milk of which is usually not delivered to dairies, but used for home consumption and or local direct sales. The second class contains farms with 3 to 5 cows, the third class farms with 6 to 10 cows, and the fourth class farms with 11 cows or more. As can be seen from Table 3 in 1996 about 70 percent of the farms are subsistence farms. Even when accounting for the fact that the milk yields realized in these subsistence farms might be only 75% of the cow milk yields realized in the larger commercial farms, it can be easily calculated that their (average) share in total milk output is about 25%.

It seems that during the second half of the 1990s the situation more or less stabilized after an unstable situation in the early 1990s, just after the transition. The most right column of Table 4 gives the (exponential) growth rates over the second half of the 1990s (period 1996-2000). As can be seen the number of farms in size class 11+ is the only size class which is growing, and which grows at a substantial rate of about 24% per annum. The number of farms in all other size classes, as well as the total number of dairy farms decline, be it at more moderate levels. Total production more or less stabilized in the late 1990s. Anticipating EU accession the milk price in Poland strongly increased (50%) since 1996, although the 2000 milk price was still about 35% below the average milk price in the EU-15.

Table 4. Base year data for Poland

Size class <sup>1)</sup>	unit	1981	1987	1996	1997	1998	1999	2000	% growth
1-2	1000 holdings	1275	979	910	899	863	871	866	-0.012
3-5	1000 holdings	578	407	250	240	247	225	211	-0.041
6-10	1000 holdings	109	76	127	126	136	127	125	-0.003
>11	1000 holdings	11	7	21	26	21	33	49	0.236
Total	1000 holdings	1973	1468	1307	1290	1266	1256	1251	-0.011
Milk production	million tons			11.7	12.1	12.6	12.3	11.9	0.004
Milk price	PZL per litre			0.51	0.59	0.61	0.61	0.78	0.111
idem	EUR per litre			0.15	0.16	0.16	0.14	0.19	0.069

1) No. of cows

The estimated (non-stationary) transition probability matrix and the impact elasticities with the structural variables are given below in Table 5. The entropy information measure for the system as a whole is 0.0067. The Pseudo  $R^2$  was 0.93 and the percentage mean square prediction errors were 0.047, 10.963, 0.654, 0.229, and 0.035 respectively. The model performs worst with respect to predict the number of farms in size class 1-2, although the overall performance is quite good. According to the estimated TPM the number of subsistence farms declines somewhat faster than according to the data. This phenomenon of overestimating the exit probability for the lowest farm size class is a phenomenon also found in other Markov chain studies.

Table 5. Estimated transition probability matrix and impact elasticities

Size class	Size class					Trend	Milk output	Milk price
	0	1-2	3-5	6-10	11- +			
0	0.99					0.026	-0.411	-0.088
1-2	0.02	0.96	0.02	0.01		-0.003	0.037	0.009
3-5	0.01	0.02	0.95	0.02	0.01	0.005	-0.064	-0.016
6-10		0.01	0.02	0.95	0.03	0.002	-0.031	-0.008
11- +			0.01	0.02	0.98	-0.001	0.017	0.003

Source: own calculations

Table 5 (right part) represents the impact elasticities, which give the percentage change in the number of farms in a certain size class due to a percentage change in one of the structural variables. The explanatory variables taken into account were a trend variable, total milk production and the milk price (except for a constant). As Table 5 shows, the autonomous trend (technology shift) has the impact to increase the number of inactive farms (exits) and the number of farms in the size classes 3-5 and 6-10. The smallest size class (3-5 ; subsistence) is slightly declining over time. The same holds for the largest size class (11- +). As can be seen milk production and milk price affect the different size classes in a similar way. Increasing milk production and milk prices negatively affect the number of active farms (see exits in size class 0). Moreover they lead to an increase in the number of dairy farms in class 11- +, but to a decline of the number of farms in size classes 3-5 and 6-10. On average the impact elasticities appear to be rather low, indicating that the explanatory variables tend to only marginally change the transition probability matrix and thus the farm size distribution.

## 8. The Hungarian dairy sector: data and estimation results

For Hungary only two observations about the farm size structure were available (years 2000 and 2003). These data were provided by the Hungarian Statistical Office. The data for 2003 appear to closely match the data as was available from Eurostat. The data for the year 2000 were commented on by other Hungarian experts and criticized. So the data base is very weak. Despite this limitation, we tried to estimate a model for Hungary using this data, since at least for 2003 it closely matched with

the Eurostat source. In order to increase the number of observations the missing years in the period 2000-2003 were interpolated, assuming that the number of farms in each farm size class developed according to an exponential growth process. This assumption seems plausible, at least when applied to a short period of adjacent years. This lead to the following data, as presented in Table 6.

As can be seen from Table 6 the total number of dairy farms substantially declines (-14.5% per annum). As can be seen this decline is largely due to the strong decline in the farms of size classes 1-2 and 3-9. Also the decline of large farms (size class 100 - ) is remarkable, and suggests that there are still a number of large old state farms dissolving. Both the number of very small farms (size classes 1-2, 3-9 and 10-19) and very large farms (100 - ) tend to decline, whereas the intermediate farm size classes (20-29, 30-49, and 50-99) grow.

Table 6. Farm size structure evolution in Hungary

Size class <sup>1)</sup>	unit	2000	2001	2002	2003	% growth
1-2	No. of holdings	21847	18400	15497	13052	-0.158
3-9	No. of holdings	11035	9409	8022	6840	-0.147
10-19	No. of holdings	1134	1081	1030	982	-0.047
20-29	No. of holdings	265	271	278	284	0.023
30-49	No. of holdings	166	173	180	188	0.042
50-99	No. of holdings	142	151	161	172	0.066
>100	No. of holdings	604	565	529	495	-0.064
Total	No. of holdings	35193	30051	25698	22013	-0.145
Milk production	million tons	1924	1900	1875	1851	-0.013
Milk price	HUF per litre	63.00	68.50	72.20	71.40	0.043
idem	EUR per litre	0.24	0.27	0.30	0.28	0.051

1) No. of cows

Table 6 also includes information about the evolution of total milk production and the milk price. Whereas milk production declined with 1.3 percent per annum, the milk price increased anticipating EU accession.

Table 7. Estimated transition probability matrix and impact elasticities for Hungary

Size class	Estimated probability matrix								Impact elasticities		
	Size class								Trend	Milk output	Milk price
0	1 - 2	3 - 9	10 - 19	20 - 29	30 - 49	50 - 99	100 - +				
0	0.985				0.005	0.005	0.005		-0.00027	-0.00300	0.00022
1 - 2	0.158	0.842							0.00008	0.00100	-0.00017
3 - 9	0.122	0.029	0.849						0.00012	-0.00011	0.00014
10 - 19	0.080	0.010	0.010	0.900					0.00001	0.00000	0.00001
20 - 29			0.010	0.040	0.900	0.040	0.010		0.00011	-0.00003	0.00009
30 - 49				0.010	0.040	0.900	0.040	0.010	0.00016	-0.00004	0.00013
50 - 99					0.010	0.040	0.900	0.050	0.00017	-0.00004	0.00015
100 -	0.050						0.020	0.930	0.00000	0.00000	0.00000

Source: own calculations

The Markov model for Hungary was estimated taking into account a prior matrix and the prior information constraints, as they were specified in Section 4. The estimated transition probability matrix is given in Table 7 (left part). The final estimates closely follow the (not-reported) prior TPM. One conclusion could be that the sample (only 4 farm size structure observations) are relatively uninformative and not changing the probability distribution. Another conclusion could be that the prior matrix is well-chosen and not inconsistent with the data. The entropy information measure for the



system as a whole is 0.249. The pseudo  $R^2$  was 0.82 and the percentage mean square prediction errors for the size classes were 0.00, 9.64, 2.46, 0.03, 0.00, 0.00, 0.00 and 0.01 respectively.

The explanatory variables taken into account were a trend variable, total milk production and milk price. The elasticity of the number of farms in each size class with respect to the explanatory variables are also presented in Table 7 (see right part). As can be seen the elasticities are nearly all equal to zero. Given the limited data and the associated uncertainty with respect to the estimated parameters it seems not worth to attach too much value to the differences between the numbers.

## 9 Simulated structural changes

In this section some first simulation results are presented. Since within the EDIM project no policy simulations have been done yet, and the impact of the policy variables on the TPMs appear to be rather limited, here only status quo predictions are made. For all three countries the farm size distribution for 2010 is predicted, using endogenous simulation. The results are presented in Table 8. For the Netherlands and Hungary the starting year is 2003, while for Poland the starting year is 2000. Although the starting years were different, for all countries the entries for 2003, 2005 and 2010 are given in Table 8.

Table 8. Predicted farm size distributions in 2010

				Number of holdings			
Size class <sup>1)</sup>	2003	2005	2010	Size class	2003	2005	2010
<b>Netherlands</b>				<b>West Germany</b>			
1-2	1284	1032	604	1-9	19498	17610	13621
3-9	1153	978	639	10-19	27392	24594	18856
10-19	2010	1791	1338	20-29	23595	21684	17640
20-29	5869	5468	4594	30-49	25460	25341	24904
30-49	7643	7627	7420	50-99	18099	17920	17494
50-99	4539	4907	5678	> 100	2209	2327	2604
>100	2506	2734	3372				
Total	25004	24538	23644	Total	116253	109475	95118
<b>East Germany</b>				<b>Hungary</b>			
1-9	914	794	566	1-2	13052	11196	5195
10-19	519	527	548	3-9	6840	5820	2613
20-29	171	169	169	10-19	982	897	626
30-49	223	229	233	20-29	284	330	697
50-99	970	929	842	30-49	188	253	709
100-499	1999	1956	1859	50-99	172	240	682
> 500	336	382	487	>100	495	471	438
Total	5132	4986	4704	Total	22013	19207	10960
<b>Poland <sup>2)</sup></b>							
1-2	866	721	607				
3-5	211	233	242				
6-10	125	142	155				
>11	49	67	86				
Total	1251	1161	1090				

1) No. of cows

2) 1000 farms

Source: own calculations

As Table 8 shows in the Netherlands the number of farms in size classes with less than 70 cows declines, with size class 50-69 just keeping its relative position. The trend of increasing farm scale will go on. The total number of active farms is predicted to decline, but at an over time declining rate. West Germany is characterized by a somewhat bipolar farm size distribution (peaks for 10-19, 39-49

size classes), which however fades away over time. In particular the number of small farms (< 20 cows) declines strongly and the number of medium farms (20-29) declines only slightly. The remaining size classes increase over time which confirms the ongoing trend of an increasing farm scale. The total number of farms is expected to decline by 18 % until 2010.

For **East** Germany the total number of farms is expected to decline less than in the past by 8 %. The increase of class 10-19 and the evolution of the medium size classes are directly opposed to the increasing scale expressed by increasing shares of class > 500 and decreasing shares of 100-499. This might be due to the problems considering the unstable development in the past of the upper size classes (for further estimations the upper size classes could be aggregated to one class to avoid these problems).

With regard to Hungary and Poland, the predicted total number of active dairy farms also decline over time. For Hungary the total number of active farms roughly halves over the period 2003-2010. Although this is a substantial decline, it is less than the past trend observed in the (limited) available data. For Poland the total number of active farms over the same period declines with 13%, which is largely in line with the past trend. The number of subsistence farms (size class 1-2) for both Hungary and Poland is predicted to decline over time, but much faster for Hungary than for Poland. For both countries the subsistence sector (size class 1-2) will also in the coming years consist of a significant number (the shares in the total number of farms for Hungary and Poland are 47% and 55% respectively). For Hungary, in the long run only farms with 20 cows or more are likely to survive. For Poland a farm needs a size 6 cows and more to be likely to be able to survive in the long run. Results indicating the persistence of small farms are also found by other empirical studies (e.g. Zepeda, 1995b).

## 10 Concluding remarks

Since this paper reflects work in progress these results still have a preliminary character. The information based approach facilitated estimation of a non-stationary Markov model explaining the over time change in the dairy farm size distribution, even for cases where limited data were available. The final estimated TPMs followed the prior information rather closely. On one hand, the use of prior information appears to be rather crucial for obtaining plausible results, for the many parameters that have to be estimated. At the same time, its impact in the cross entropy approach seems so strong that the quality of the final estimates is to an important degree determined by the quality of the used prior TPM estimate. It could be interesting to look for alternative ways of including the prior information, in which it can be given less weight. The priors used in this study take into account a learning effect from other studies (see reference list), as well as rather general knowledge about the change of the farm size structure. As such the general structure of the estimated TPMs is in line with results found in other studies. Also the goodness of fit appeared to be satisfactory, which suggests that generation of the prior information was done in an efficient way.

For Hungary and Poland very low farm size classes (in particular 1-2) are taken into account. These farms were often labelled to be subsistence farms, but are a group which is likely to behave rather different from normal farms. However, in this study they were treated in a symmetric way with other size classes. One option could be to exclude this special category from the analysis and to try to explain it in a different way, taking into account different, probably more relevant, explanatory variables. Several studies, for example, indicate that subsistence farms are rather isolated from and insensitive to market signals. This, however, implies that the selected variables chosen now are not the most fortunate choice.

From the multiplicity of explanatory variables mentioned in the literature, only a few were included in the final model specification. As such, the estimated models have clearly a partial character. However, as the calculated pseudo R-squares and percentage mean square errors indicated, even with such a limited number of explanatory variables a large part of the actual farm size distribution evolution could be explained.

It is planned to improve this modelling exercise by in a better way taking into account price as well as non-price support. Moreover, at this stage no simulations with alternative dairy policies have been done, but at a later stage within the EDIM project these are planned to be done.

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## Endnotes

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<sup>1</sup> Sometimes a distinction between the set of variables affecting entry/exit category and the set of variables affecting other categories (examples are Chavas and Magand, 1988, and Zepeda, 1995)

<sup>2</sup> Farm operated by the family, not necessarily owned by the family.

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<sup>3</sup> Scale economies include both the narrowly defined economies of scale in production (e.g. lumpiness of inputs and specialization of labour) and on scale related transaction costs in input and output markets (e.g. information costs and scale economies in transport and marketing).

<sup>4</sup> See the results from other Work Packages of the EDIM-project.

<sup>5</sup> As such this implies that no direct information is used about observed transitions from and to size classes, but only the resulting net effect is taken into account.

<sup>6</sup> Reviewing a number of studies I have the feeling that Markov approaches tend to underestimate the number of small farms being active in the equilibrium (see also Zepeda, 1995b, 850).

<sup>7</sup> Note that when no Q-matrix is specified an implicit prior TPM is assumed in which the probabilities are equally distributed over the entries. Actually, in that case the implicit prior assumes a lot of circular dynamics or transitions between the various size classes, which seems rather unlikely when taking into account what is known from basic empirical evidence.

<sup>8</sup> The figure is similar to the figure which one would get when the proportions (expressed in terms of the total number of active and inactive farms of the initial period 1972/73) would have been calculated. So Figure 1 gives the pattern of proportions the model has to explain.

<sup>9</sup> Because of space limitations the prior transition probability matrices (Q) are not presented in the text but are available from the authors upon request. See Sections 4.2 and 4.3 for more information about how the prior matrices were generated.

<sup>10</sup> Until 1996 net entry was positive, whereas from 1996 and onward there is a net exit from dairy farming.