Development of Marginal Cost Distributions

in Dairy Production Regions of the EU[1]

Christine Wieck and Thomas Heckelei[2]

University of Bonn

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Abstract

This paper analyses differences and development of regional distribution of marginal costs of dairy production in the EU and how they are affected by structural change in the dairy sector and different national quota regimes. The empirical analysis employs multiple-input-multiple output cost functions, estimated using an unbalanced panel data set of the European Farm Accountancy Data Network. The results show marginal costs for different types of dairy farms and the distribution of marginal costs across farms within the region. A clear tendency towards a more balanced distribution of marginal costs within the regions can be found whereas the impact of different quota regimes on this development remains vague.

Keywords: Dairy production, structural development, marginal costs, quota mobility

JEL classification: C330, D450, Q120, Q180

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[2] Christine Wieck is PhD student and Thomas Heckelei is Professor for Economic and Agricultural Policy, both at the Institute for Agricultural Policy, Market Research, and Economic Sociology, University of Bonn. Email: wieck@agp.uni-bonn.de, heckelei@agp.uni-bonn.de.

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1 Introduction

Since 1984, a quota regime is applied to the milk market in the European Union (EU). The objective of the regulation was to reduce surpluses in production, guarantee a fair income to farmers and maintain farms in production. The introduction of the system was a very controversial issue, because it was expected to slow down structural change considerably, thereby reducing the sector's international competitiveness in the long run. This was especially relevant in the early stages of implementation when quota rights were attached to land and quota trade was not possible. The initial quota allocations to member states and individual producers were made on the basis of production quantities in the years before 1984, freezing production patterns at the levels corresponding to the base year. Already in 1987, some member states started to allow temporary quota exchange using their discretion in implementing the system under the common EU regulation. Since then, considerable diversity in quota trade regulations across member states developed, covering the whole range between a free quota market and no quota transferability.[3]

At any point in time, there is considerable variation in the distribution and development of marginal costs of production among producers and across regions. Without the quota constraint, the more efficient producers would expand in scale whilst the least efficient are likely to abandon milk production. Production quotas together with the high support price for milk in the EU prevent part of these dynamic tendencies by allowing the least efficient producers to remain in business and complicate the expansion of the most efficient ones. The introduction of the quota system fell in a period where strong structural change in the dairy sector took place but farm statistics show that also under quota this trend continued. (European Commission 2002 p.10)

The introduction of the quota regime has inspired a considerable amount of economic research. Besides cost estimations for the dairy sector (e.g. Moschini 1988a, Hubbard 1993, Helming et al. 1993), questions of efficiency in the allocation of quota rights (e.g. Burrell 1989, Boots et al. 1997, Colman 2000), regional competitiveness (e.g. Burton 1989, Boots et al. 1997, Guyomard et al. 1996), resource use and technical efficiency under constrained outputs (e.g. Moschini 1988b, Hallam and Machado 1996, Brümmer et al. 2002, Pierani and Rizzi 2003) were at the centre of discussion. Questions of structural development under the

[3] There had been always strong argument for no transferability of quotas due to political or social reasons as for example dairy production could disappear in some less favourable areas and leave an empty countryside.

quota regime and the impact of quota mobility were other issues considered (Oskam and Speijer 1992, Colman et al. 1998, Barthélemy et al. 2001, Colman et al. 2002). Some of the studies used a profit function framework (Helming et al. 1993, Moschini 1988b, Boots et al. 1997), but most employed cost function approaches (Burrell 1989, Burton 1989, Guyomard et al. 1996, Colman et al. 1998, Colman 2000). The research focused mainly on the development within one member state (e.g. Burton 1989, Helming et al. 1993, Guyomard et al. 1996, Boots et al. 1997) and little has been done on a comparison between different member states (exception Barkaouli et al. 1997, INRA-Wageningen Consortium 2002) and with respect to the analysis of distributions of marginal cost.

This paper provides empirical evidence of the development of marginal costs in dairy production and their distribution across farms for the most important dairy regions in the EU. The analysis of marginal costs will be done via a cost function approach for the representation of behaviour and technology of dairy farmers. It employs a short-run multi-input-multi-output Symmetric Generalized McFadden cost function (SGM). The foundations for this function were laid out in Diewert and Wales (1987) and have received several modifications and extensions since then (Kumbhakar 1994, Peeters and Surry 2000, Pierani and Rizzi 2003). Furthermore, the paper investigates whether the national quota trade regulations affect level and distribution of marginal costs and whether higher quota mobility leads to a more pronounced structural change.

The structure of the paper is the following. The next section presents an overview on main aspects of the dairy sector in the EU. The third section develops a theoretical framework for dairy farming and farm development and how the distributions of marginal costs of dairy farms are affected. Afterwards the econometric implementation and data selection is presented. The paper finishes with the presentation of results and conclusions.

2 Aspects of the Dairy Sector

Distribution of dairy farming and farm structure in the EU

With 14% of total value of agricultural production in 2000, milk production is the most important activity both in the EU as a whole and for a majority of the member states. However, the share of milk in agricultural output varies widely between member states and regions. If we take into account that there exists a strong link between the dairy and beef sector due to dual-purpose breeds, meat originating from dairy cattle contributes to a further 10% of total agricultural output. Worldwide, the EU is both the biggest producer and consumer of milk, with a share of 21% in world production and a share of 21% in world consumption. (European Union 2001)

The most important producer (according to output value) in the EU is Germany, with a share of 22.4%, followed by France (20.1), Italy (10.9%) and United Kingdom (10%). The next five countries which add up to a quarter of total EU production are The Netherlands (8.4%), Spain (5.6%), Denmark (4.0), Ireland (3.8%) and Sweden (3.1%). The other six European countries contribute only a minor part to total European production (around 12%). Important dairy production regions in the member states are Bavaria (29%) and Lower Saxony (21%) in Germany, with a share of 29% and 21% in total German milk production respectively, Brittany and Pays de la Loire/Atlantic coast in France (both 21%), Lombardy (34%) and Emilia-Romagna (30%) in Italy and in the UK, South-West of England and North Britain/Scotland with regional production shares of 32% and 29% respectively. The economic importance of the dairy sector for the total regional agricultural industry in these regions lie around 20% with exception of Bavaria, Germany, where it accounts for 35%. (European Union 2001)

With respect to the size of dairy holdings, we observe enormous structural difference between the member states. In 1999, there was a total of 749 000 dairy holdings in the EU with an average number of 28.2 dairy cows per holding. Most dairy farms are situated in Germany with an average size of 31 dairy cows per holding, followed by France (32 cows/farm) and Italy (22 cows/farm). The UK, Denmark and The Netherlands, being at the lower range with respect to number of dairy holdings, show, however the largest farm structures in the EU with an average of 72, 57 and 47 dairy cows per farm, respectively. (European Union 2001)

EU dairy regulation

The EU dairy regulation mainly consists of two part: the first part, introduced in 1968, covers a wide range of dairy products establishing market support in the form of intervention purchases, consumption and export subsidies and border protection over tariffs and tariff rate quotas (regulations EC 804/68, last amendment by EC 1255/1999) whereas the second part regulates since 1984 the supply of milk by means of the milk quota system (EC 856/84, EC 857/84 last amendment by EC 1256/1999). These different market instruments shall guarantee on the internal market a target price for producers for raw milk (currently at 30.98 €/100kg for milk with 3.7% fat). The milk quota system fixed national reference quantities which are then converted into farmer's individual reference quantities for deliveries to dairies and direct sales from the farm.[4] The basis for the individual allocations was in most member states the year 1983 with a certain percentage deduction in order to meet the global national quota level. A dissuasive levy applies to milk quantities produced in excess of individual quotas. The level of this "superlevy" has been changed several times being currently fixed at 115% of the target price for milk. Up to 1992 the reference quantities were tied to land and couldn't be freely traded.[5] Since then, the EU allowed the transfer of quotas within national borders in order to decrease the rigidity of production structures imposed by the quota system. The specific implementation was left to the member states.

3 Theoretical framework

In this section, a theoretical framework with respect to regional distributions of marginal milk production costs and their development over time is given. After an introductory section with definitions and assumptions, major determinants of dairy farm development are identified. Those are subsequently related to marginal cost distributions across farms leading to hypotheses to be analysed within this study.

3.1 Definition

The technology of the farm is represented by $F(\mathbf{y},\mathbf{x},\mathbf{z},t) = 0$ where $\mathbf{y}$ and $\mathbf{x}$ are vectors of output and input quantities, respectively, $\mathbf{z}$ is a vector of quantities of quasi-fixed production factors and t represents time. Due to the introduction of the milk quota system in 1984, at least one of the outputs of the farm is restricted to the (milk) quota level. The behaviour of the dairy farmer could be described via a dual profit or a cost function approach and both uniquely represent, under certain regularity assumptions, the underlying technology (see Chambers 1988 p. 86, p. 138). In a multiple output case, the assumption of profit maximisation approach assumes that the farmer maximizes profits by adjusting unrestricted output and input quantities subject to the output at quota level and quasi-fixed factors for given prices. The second approach, cost minimisation, assumes that for given outputs, input prices and quasi-fixed factors a cost-minimising set of input factors for the production of the farm will be defined. For both cases, the individual farmer is a price taker in the respective output and input markets.

[4] For details see European Commission 1997.

[5] In 1987, due to a request of the UK, temporary yearly leasing of quotas between farms was allowed.

In this study, we opted for a cost function rather than a profit function approach, because modelling of decisions on output quantity are less relevant for our purpose of production cost distributions and development and this way we could minimize behavioural assumptions. Furthermore, profit maximization falls short as a behavioural assumption in explaining dairy farmer's output decisions in the context of structural change over time. Increasing and decreasing milk production are investment decisions depending on expectations on future income possibilities in dairy production as well as in alternative uses of the available labour resources. These decisions could be captured using expected utility maximizing household models but are represented exogenously in the context of this study. They are represented as changes in fixed net-puts within the cost function employed here:

$$C(\mathbf{y},\mathbf{w},\mathbf{z},t) = \min\left[\mathbf{w}'\mathbf{x} : F(\mathbf{y},\mathbf{w},\mathbf{z},t) = 0\right] \qquad \textbf{(1)}$$

Since the original allocation of milk quotas to producers, member states have implemented various systems to allow quota trade or to redistribute administratively unused or new quota to producers. Dairy farmers with lower production costs and willing to expand production are prepared to pay for additional production rights if the expected profit from additional quota outweighs the costs for those rights. Producers who want to cease dairy farming for some reason are interested in selling or leasing their quota in order to make additional income. Therefore, regardless of member state's specific quota regulations, quotas have begun to manifest as costs in the production process. They can be accounted under variable costs when a farmer temporarily leases quota or be part of fixed costs (depreciation) when producer's quota purchase is treated as investment costs under a medium to long term business strategy.

The cost specification in (1) can accommodate very different types of dairy farms. Depending on, for example, size and degree of specialisation the cost minimizing behaviour of those farms can differ significantly. There are several ways to categorize farms but having in mind the scope of this study, the ones mentioned below are claimed to be the most meaningful ones.[6]

Probably the strongest impact on cost minimizing behaviour has the degree of specialisation. One can differentiate between specialised and non-specialised dairy producers. Under the first category we understand farms that make most of their revenues with dairy

[6] The distinction between part-time and full-time dairy farmers could be another one. But because the data set at hand doesn't contain part-time farmers and we do not look at the decision "part time versus full time" we refrain from discussing it in more detail.

farming and use most of their variable and fix production factors in this production activity. We expect that these farms have good access to (new) dairy technology and – probably even more important – show on average better performance in managing the dairy herd. In most applications farms with at least 70% revenue share from dairy farming were typically categorized as specialised farms (see Guyomard et al. 1996, Boots et al. 1997, Pierani and Rizzi 2003). The non-specialised dairy farm category consists of mixed farms where dairy farming is only one branch within their production mix. Hereunder we find a very broad range of farms reaching from specialised crop, vegetable or fruit producers to cattle farms and even include specialised pig or poultry farms.

A second important categorization is by size taking quantity of milk output or herd size as indicators. The difference here is that the larger farms can benefit from technological economies of scale and lower input prices. Obviously, output related volume bonuses cannot be captured by the cost function approach. Specialised and non-specialised producers will be part of both size groups. Specialised producer being large scale can probably strengthen their ability to produce at low costs, but one would assume that also small highly specialised farms can keep their cost at a low level in favourable production locations and for reasons of better management.

3.2 Factors determining farm development

For better understanding the development of marginal cost distributions over time presented in the empirical section, we identify here the major determinants of dairy farm development in a region. The development over time of each farm depends on a number of technological, socio-economic and market related factors and might be quite different depending on the initial situation. Besides this, the institutional arrangements with regard to quota mobility in a member state can certainly influence farm development. They will be discussed as a last separate factor in this section.

Technical progress

Technical progress on the farm is probably the most important determinant for structural development, as it leads to a more efficient production with lower production costs. In the dairy sector, technical progress is mainly realised through improvements in technical equipment of the farm (milking parlor, animal housing systems, waste handling), improved feeding stuffs and animal nutrition, herd health, and improvements in the genetic material of dairy cows leading to a higher milk yield per cow. The adoption of these techniques allows for increased production efficiency so that the same quantity can be produced at lower cost.[7] This means lower per unit and marginal variable costs. Additionally, technical progress contributes to higher productivity of labour and machines but typically also means a substitution of capital for labour. Buildings and machinery in dairy farming are very specialised and not easily used for other production activities justifying their representation as “fixed” in our approach. Still productive buildings and machinery from past investments work in the direction of maintaining dairy production by lowering variable production cost.

Socio-economic factors

The opportunity cost of labour play an important role for structural development. Non-farm income possibilities and profitability of alternative farm activities (non-dairy) influence the decision on labour use in dairy production. Furthermore, the age structure of dairy farmers is highly relevant in this context. Each year, a certain number of farmers cease production due to retirement. The most important effect of this process under a quantity regulated market is its impact on availability of additional quotas available for farms willing to grow. In the first years of the milk quota regime, national governments tried to encourage this development by means of incentive schemes for farmers to quit production. In 1995, in Greece, Spain, Italy and Portugal, between 40% and 50% of the dairy farmers were older than 55 years whereas in the other member states the share is still quite high but lies between 10% and 30%.

Market aspects

Besides productivity and socio-economic factors the market environment has implications on structural development. First of all, the common market organisation with its guaranteed prices for butter and skim milk powder, intervention system and export subsidies impact strongly on structural development. Even though within the milk quota system prices should have been guaranteed on a high level, there had been several price cuts in the last two decades which lowered dairy farmers’ income and forcing farmers from the lower end of the income scale to quit production.

Additionally, developments in the dairy industry impact indirectly on structural development. The ability of dairies to expand and attract new markets through innovative marketing strategies contributes strongly to the final price for dairy products

[7] Pierani and Rizzi (2003) estimated for a panel of Italian dairy farms an average cost reduction of 3.5% due to technological progress. In a sample of German dairy farms, Brümmer et al. (2002) estimated an average annual productivity growth of about 6% mainly due to technical change. The same study resulted in average annual productivity growth in the Netherlands of around 3%.

(Wissenschaftlicher Beirat 2000, Veautheis 2001) and also to the price for raw milk received by farmers. This leads to the fact, that in some countries big price differentials can be observed.[8] In Germany, for example, the average milk price[9] at the farm gate varies between 269€/t (Mecklenburg-Vorpommern) and 297€/t (Rheinland-Pfalz) in the 'Bundesländer' but if we compare farm gate milk prices for regions with similar production structures in Germany we end up with a price differential of 12€/t (Nordrhein-Westfalen/Rheinland-Pfalz) (ZMP 1998). The same holds if we undertake a comparison of milk prices across the EU: Austria, Belgium, UK and Ireland at the lower end of the range (around 270€/t) and Denmark, Greece, Sweden and Finland at the upper range (around 320€/t) (EUROSTAT). One would assume that these regional price differences also impact on the regional cost structures as farms facing a lower milk price are forced to better control their production costs or cease production.

Another aspect is the ongoing concentration process within the processing industry (see European Commission 1997). This process helps the processing industry to face the changing market environment characterized by a concentration process on the retail side, stronger international export competition and a less favourable political support for the sector. The realization of economics of scale and related cost advantages is a further driving force. Indirectly, these processes affect the farming sector. A positive aspect is that deliveries to dairies which realize a high value added from the raw product can generate higher returns for farmers. However, increasing market power of the dairies negatively impacts on milk prices for farmers.

A final market aspect to be mentioned is the cross-financing of the production branches on farm. Studies report on an increase in dairy farming in arable crop areas, because they have at their disposal sufficient financial liquidity due to high returns from arable crops farming or pig production (Isermeyer 1998). The introduction of the CAP compensation payments in 1992 pushed in the same direction. Originally targeted mainly at the arable crop sector, they later (Agenda 2000) gained relevance for the cattle and beef sector as well, consequently influencing decisions in the dairy sector directly. For those farms with additional arable crops or beef production they had a stabilizing effect on farm income (e.g. through the silage maize premium). As the main premium flow went to farm with intensive

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[8] Isermeyer (1998) provides the example of Nordrhein-Westfalen in Germany where dairy farms close to the Dutch border benefit from the higher milk prices in the Netherlands and invest in farms size growth.

[9] All price for the year 1995 and with standardized protein and fat content.

Grandes Cultures and/or beef production, the farms with a high grass land share specialised in dairy farming could not benefit from these income developments.

Quota transfer regimes

Within the framework of the EU legislation for milk quotas, member states had a high degree of discretion in implementing the system and considerable diversity in quota trade regulations across member states developed. In general, two approaches can be distinguished: Member states may allow an almost free market in trading of milk quota. This “commercial” approach promotes the concentration of quota in the most efficient holdings. Alternatively, member states more or less centrally control all transfers of quota according to certain administrative criteria. This “administrative” approach pursues regional objectives linked to rural, social or economic development.

The quota regime applied in the United Kingdom and The Netherlands can be classified under the first approach (Colman et al. 1998, DEFRA 2004, Boots 1999 p. 27, Hoetjes and Boinon 2001 p. 55f.). They allowed early on temporary leasing and purchasing of limited quantities of quota without land. France and Denmark are examples for the administrative approach in the management of milk quotas (Barthélemy 2001 p. 35f, Sorensen 2002, Danish Milk Board 2004). This approach tends to favour medium sized farms and often supports the release of quota from producers willing to quit the sector by restructuring plans. The reallocation of these quotas often occurs according to priority objectives as for example young farmer promotion, economic indicators or investments plans. In Denmark, in 1997, a quota exchange was established and the link between land and quota was broken up and a geographical equalisation took place. Germany and Italy show very specific national designs and can be ranked somewhere in between these two approaches. Germany, in the course of time, introduced some measures, as allowance of quota sale or temporary leasing within regional border, in order to offset some of the rigidity originally implemented in the system and enhance farm development. Italy, besides facing long-standing problems in the effective application of the system (European Commission 1997, Court of Auditors 2001), allowed after 1996 selling and renting of milk quota within regional borders.

3.3 Marginal costs of dairy production

Within our framework, marginal cost functions defined by

$$s_y = \frac{\partial C(\mathbf{y}, \mathbf{w}, \mathbf{z}, t)}{\partial y} \qquad \textbf{(2)}$$

are a measure for short term competitiveness of dairy production. In a competitive market with market transparency and atomistic structures and under the conventional assumptions of profit maximizing behaviour, producers decide their level of output by equating marginal cost and price.[10] Since, by assumption, all competitive firms face the same price, all firms have the same marginal costs (Varian 1992 p. 216). But when individual producers' decisions concerning output are restricted by their allocated quota based on historical production levels, there is no reason to presume that marginal costs are the same for each farm. Even if all farms had identical marginal cost curves, equality of marginal costs for all farms would not exist unless each received the same quota. The marginal costs can be taken as an indicator for comparisons of farms regarding competitiveness. Low marginal cost producers could sustain production under much lower output prices than high marginal cost producers.

The difference between the actual producer price and marginal cost is called marginal quota rent. If the quota rent is positive, i.e. the marginal costs lie below the milk price it can be seen as a rent (or income) from selling milk. But as the marginal cost presented here only include variable production costs, this rent must be used by the farmer to pay buildings, land, machinery, and family labour. As the quota rent is directly derived from marginal cost, the value (magnitude) of it depends on the same factors as marginal cost. Marginal costs and quota rent can both be used to describe the competitive status of a farm, but quota rent includes output price as an additional relevant factor.

Types of dairy farms and marginal costs

Returning to the dairy farm types described in the previous section, we state the following hypotheses on marginal costs of dairy production:

- Ceteris paribus, more specialised farms have lower marginal cost compared to less specialised (mixed) farms as they focus with knowledge, technology and fixed resources on the management of dairy production.
- Ceteris paribus, larger farms have lower marginal costs than smaller ones due to economies of scale and lower per unit fixed costs.
- Farms with recent investments in technology (measured by higher depreciation and interest payments) will face lower marginal (variable) cost.

[10] Leading also to producers operating at increasing marginal cost.

Development of regional marginal cost distributions

Moving from the static view of a dairy farm to the development of farms over time, we observe changes in the regional distribution of marginal costs. Determinants behind this development are the factors listed in the previous section. We hypothesize that, at constant variable input prices,

- Average marginal cost within a region decreases over time and
- The variance of marginal cost across farms in a region decreases over time.

This follows from the general assumption that low cost producers try to expand production whereas high cost producers quit the sector (Burrell 1989 p.108).

Quota mobility and marginal costs

Along the same line goes the impact of quota mobility on marginal costs. Quota mobility is characterized by the degree of freedom in transferability of quota rights between producers (Oskam and Speijer 1992). A more liberal regime provides not only the possibility of short term, temporary transfer, i.e leasing, and permanent long-term transfer (selling/buying or administrative reallocation), but also imposes less restrictions on the transfer such as, for example, regional transfer zones or maximum traded quota quantities. Therefore, we assume that, ceteris paribus, marginal costs of milk production developed to be more balanced across farms in regions with favourable trading conditions compared to those with restrictive regulations.

However, this general statement requires two qualifications: First, quota transfer also takes place in regions with restrictive quota trading regimes. Theoretically, the administrative process might be just as efficient as the quota market in increasing cost competitiveness by allocating quota rights from departing to growing dairy farms. Second, depending on the share of transferred quota at no cost, an administrative quota transfer regime might even enhance structural development within a region. Farms are willing to expand that would not have done so or at least not as much as under quota market conditions. A comparison of regions with different trading regimes might shed some light on the question whether systematically different developments occur depending on the institutional setting.

4 Empirical application

4.1 The multi-input-multi-output SGM restricted cost function

Empirically we represent the cost function C by means of a multiple-input-multiple-output SGM form because it is flexible in the sense that it is providing a second-order approximation to an unknown function at any point (Diewert and Wales 1987). The Hessian Matrix of the second derivatives with respect to input prices is a matrix of constants, thus the curvature properties hold globally and can be imposed without destroying its flexibility. We use the functional form as it was proposed by Diewert and Wales (1987), adding quasi-fixed inputs (Pierani and Rizzi 2003) and following Kumbhakar (1994) and Peeters and Surry (2000) in using a framework with several outputs. This leads to the following function:[11]

$$\begin{aligned} C_t(\cdot) = {} & \tfrac{1}{2}(\theta' w_t)^{-1}(\phi' y_t) w_t' E w_t + (\phi' y_t)\alpha' w_t + (\phi' y_t)\beta' w_t' t \\ & + w_t' C y_t + w_t' D z_t + (\theta' w_t)(\phi' y_t)^{-1}\left[y_t' G y_t + z_t' F z_t + y_t' H z_t\right] \end{aligned} \qquad \textbf{(3)}$$

Where $\boldsymbol{w}$ is a (n x 1) column vector of input prices (indexed by i,j), $\boldsymbol{y}$ is a (m x 1) column vector of output quantities (indexed by m,n), $\boldsymbol{z}$ is a (k x 1) column vector of quasi-fixed factors (indexed by f,v), t represents time, α is a (n x 1) column vector of unknown parameters, β is a (n x 1) column vector of unknown parameters. **C** (n x m), **D** (n x k), **E** (n x n), **G** (m x m), **F** (k x k) and **H** (m x k) are matrices of unknown parameters. Symmetry is assumed to hold for the elements of the matrixes **E**, **G,** and **F**. Additionally, the matrix **E** is assumed to be negative semi-definite (concave). The two inner products, ($\boldsymbol{\theta}'\mathbf{w}_t$) and ($\boldsymbol{\phi}'\mathbf{y}_t$), can be interpreted as fixed-weight input price and quantity index, respectively.[12] The symmetric version of the Generalized McFadden function has the advantage over the Generalized McFadden that it is invariant to normalisation due to the use of an input price index. The cost function is linearly homogeneous, non-decreasing and concave in input prices, non-decreasing in outputs and reveals constant returns to scale. It is assumed to be continuous and twice differentiable with respect to all its arguments.

Applying Shephard's lemma to the multiple-input multiple-output SGM cost function (3) yields the input demand equations. In order to avoid the estimation of an intercept which

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[11] For clarity, we suppress the index of each individual farm *h*.

[12] We assume that the price indices have weights given by the mean quantities of inputs and outputs respectively. The input price index is equal for all farms in one year whereas the output price index differs between farms in the same year.

depends on the output index, we normalise these input demand functions with the output index. This leads to per unit input demand functions representing the estimated system.

$$\begin{aligned}\frac{x_{it}}{(\phi' y_t)} &= \frac{\partial C_t(\cdot)/\partial w_{it}}{(\phi' y_t)} \\ &= (\theta' w_t)^{-1}\left(E_i w_t - \tfrac{1}{2}\theta_i(\theta' w_t)^{-1} w_t' E w\right) + \alpha_i + \beta_i t \\ &\quad + (\phi' y_t)^{-1}[C_i y_t + D_i z_t] + \theta_i(\phi' y_t)^{-2}[y_t' G y_t + z_t' F z_t + y_t' H z_t]\end{aligned} \quad \textbf{(4)}$$

for $i = 1,\ldots, N$

$\boldsymbol{x}$ is a (n x 1) column vector of input quantities (indexed with i,j) and E_i denote the i-th row of the matrix **E**.

For the empirical assessment of marginal costs, we use the derivative of the cost function (2) with respect to output quantities which leads to the marginal cost function for those products.

$$\begin{aligned}s_{mt} = \frac{\partial C(\cdot)}{\partial y_{mt}} &= \left(\tfrac{1}{2}\phi_m(\theta' w_t)^{-1} w_t' E w_t\right) + \phi_m \alpha' w_t + \phi_m \beta' w_t' t + w' C_m \\ &\quad + (\theta' w_t)(\phi' y_t)^{-1}\left([2G_m y_t + H_m z_t] - \phi_m(\phi' y_t)^{-1}[y_t' G y_t + z_t' F z_t + y_t' H z_t]\right)\end{aligned} \quad \textbf{(5)}$$

for $m = 1,\ldots,M$

s_m is the marginal costs of producing output m, C_m is the m-th column of matrix **C** and G_m and H_m are the m-th rows of the matrices **G** and **H**, respectively.

The marginal cost equations are homogenous of degree one in input prices and homogenous of degree zero with respect to outputs (Chambers 1988 p.65). From (4) we observe that the marginal costs are not linear in output. This is an improvement against other estimations (Guyomard et al. 1996, Boots et al. 1997), as the assumption of linearity might be too restrictive. As the cost function is non-decreasing in y, marginal costs must always be non-negative (Chambers 1988 p.65).

4.2 Econometric implementation

The estimated system is represented by equation (4). Due to the nature of the panel data set and acknowledging that the estimates are not used for prediction, a fixed effects model is chosen.[13] This formulation of the model assumes that differences across units can be captured in differences in the constant term and that all explanatory variables are independent of the error terms (Baltagi 2001 p. 12). Prior to the econometric estimation, additive error terms are appended to each input demand equation. The error terms are assumed to be jointly distributed with zero means and constant but unknown variances and covariances. The estimation of per unit input demand functions lead to farm specific intercepts reflecting differences in farm characteristics. The necessary transformation of the variables (deviation of each observation from the average over time per farm) is applied to the unbalanced panel data. Thus the information of farms which stay only for one year in the sample is lost, affecting the representativeness of the results.

In order to identify all parameters of the estimated system some parametric restrictions have to be imposed: Symmetry conditions are imposed by the following set of parametric restrictions: $\beta_{ij} = \beta_{ji}$, for all i,j; $\beta_{mn} = \beta_{mn}$, for all m,n; $\beta_{iv} = \beta_{fv}$, for all f,v. The adding up constraint for the matrix of the input prices is ensured by $\sum_j \beta_{ij} = 0$. Note that the inclusion of the farm output index leads to linear dependencies with respect to the output quantities. Therefore we eliminate the animal output aggregate from the **y**-vector. Hence, the effects of changes in the animal output aggregate on costs can be determined only using the farm output index and the estimated parameters of the two remaining outputs.

The cost function with respect to input prices must be concave. This implies that the second derivative of the cost function with respect to input prices must be a negative semi-definite matrix (Chambers 1998 p. 58). If this condition is met, the McFadden cost function is globally concave in input prices (Diewert and Wales 1987). Necessary and sufficient condition for negative semi-definiteness is that the principal minors of the matrix of second derivatives with respect to input prices alternate in sign (Chiang 1984 p.324). With the following restrictions on the parameters of the input price matrix these conditions are fulfilled: $\beta_{11} < 0$, $\beta_{22} < 0$.

The parameters of the system of per unit input demand functions of the SGM cost function were estimated using iterative SUR implemented in the econometric software SAS specifically in the MODEL procedure.

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[13] Tests with random effect estimates revealed no significant differences of regional marginal cost distributions compared to the fixed effect model.

4.3 Data description

The study uses an unbalanced panel data set from the European Farm Accountancy Data Network (FADN) covering the period 1991-1999. This large data set contains information on individual farm records regarding the use of inputs, generation of outputs as well as farm structure information. It consists of regional subdivision for member states and regions which are mostly in line with the European administrative units of the so-called NUTS II levels. Regarding the representativity of the farms within the member states and regions, two limitations apply: only farms above a certain size are included and farms must be managed on a professional basis.[14] Associated with a given farm of the sample is the number of holdings belonging to the same type and economic size class of farm. It can be used to aggregate the results from individual to a higher regional level.

The variable definitions for input and output quantities and prices and fixed factors can be found in Table 1. All indices are calculated as Tornquist–Price indices with base year 1995. All farms in one member state of the EU face the same prices. The consistency of the data is checked and implausible observations are deleted during data preparation.[15] The following sub-set of dairy farms is chosen for the estimation: farms that remain the whole estimation period in the sample, that have physically possible milk yields and, a minimum number of cows[16] (at least 10% of regional average herd size). Farms that market their products through (unknown) channels yielding a very high price (farm gate milk price 50% above/below regional price) are suppressed assuming that they operate in a production niche independently from general sectoral price and cost developments. Despite this, no selection according to the degree of specialisation of dairy farming is undertaken, as the marginal costs of all farms of the sector shall be determined.[17]

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[14] The EC Court of Auditors complained that especially the economic size threshold of the holdings is not defined in a uniform manner in all member states and that they rely on different indicators to assess the representativity of the farms in the sample. (Court of Auditors 2004)

[15] The following minimum requirement were defined for inclusion of a farm: some type of land use, at least one output with the respective input quantities, positive fixed factor labour input and non-activity-specific input demand quantity.

[16] The opposite would indicate that dairy farming is rather a leisure activity than an economic branch of the farm.

[17] Here this approach differs to most other studies (e.g. Guyomard et al. 1996, Boots et al. 1997, Pierani and Rizzi 2003) who limited their sample to those exceeding a share of 50% or 75% in total output.

Table 1: Overview on variable definitions

	Variables	Items/Definition	Unit/ Base	Source
Inputs	Crop specific inputs	Seed, fertilizer, plant protection, other crop specific inputs		
	Price index	Tornquist price index	1995	EAA
	Quantity	Expenditure / Price index	Euro	FADN
	Animal specific inputs	Purchased and home-grown feed, other animal specific expenses		
	Price index	Tornquist price index	1995	EAA
	Quantity	Expenditure / Price index	Euro	FADN
	Other inputs	Costs for machinery, buildings, energy, contract work, other direct inputs, wages, paid rents		
	Price index	Tornquist price index	1995	EAA
	Quantity	Expenditure / Price index	Euro	FADN
Outputs	Crop outputs	All outputs (value) from crop production except fodder from arable or grass land		
	Price index	Tornquist price index	1995	EAA/CAPRI[18]
	Quantity	Expenditure / Price index	Euro	FADN
	Animal specific outputs	All outputs (value) from animal production except milk		
	Price index	Tornquist price index	1995	EAA/CAPRI
	Quantity	Expenditure / Price index	Euro	FADN
	Milk	Gross production with standarised fat and protein content	Tons	FADN
	Price		Euro/ton	EAA
	Quantity		Tons	FADN
Fixed factors	Arable crop area	All arable crop production activities except fodder from arable land	Hectare	FADN
	Fodder area	Fodder production on arable land	Hectare	FADN
	Grass land	Permanent grass land	Hectare	FADN
	Number of dairy cows			FADN
	Animal stock	Stock of animals, except dairy cows, in prices of 1995	Euro	FADN
	Family labour	All unpaid labour on farm	Hours	FADN
	Depreciation and interests	Depreciation of all fixed capital assets, calculated at replacement rate	Euro	FADN

EAA = Economic Accounts of Agriculture, CAPRI = Data base of CAPRI modelling system

For the purpose of this paper, results from seven regions will be presented. The summary statistics for the variables used to define the estimated system of those regions can be found in Table 2. Important production regions from the main dairy producers of the EU have been selected. They show a high diversity with respect to farm structures as well as with respect to

[18] Regional production shares stem from the CAPRI data base (see Britz et al. 2002).

institutional arrangements regarding quota trade. For each estimated region, between 200 and 700 farms are available with three to four times the number of observations.

Table 2: Means of variables for estimation samples

Region		Low. Saxony	Bavaria	Pays Loire/ Atl. coast	Brittany	Denmark	N.Britain/ Scotland	South England
Total number of dairy farms		876	1374	729	1006	1386	276	263
Dairy farms in estimation		507	569	547	590	774	197	187
Number of observations		2779	2594	2703	2478	3317	1037	814
Output quantities	Crop	24441	22856	28736	20636	30998	58452	47452
	Animal	43561	30133	38195	49667	45444	39863	41133
	Milk	231	136	201	215	399	482	515
Input quantities	Crop spec.	9610	7110	13691	11460	13711	15661	15911
	Animal spec.	34446	21098	26109	33288	61385	64664	58992
	Other var.	40730	25423	32935	34604	54754	55251	62734
Price index outputs	Crop	0.917	0.960	0.934	0.970	1.014	0.769	0.861
	Animal	0.953	0.939	0.967	0.977	0.978	1.248	1.086
	Milk	290.69	290.90	282.87	283.23	328.98	276.05	275.50
Price index inputs	Crop spec.	0.979	0.980	1.013	1.015	1.005	0.929	0.932
	Animal spec.	0.989	0.990	0.998	0.998	1.017	0.970	0.968
	Other var.	0.992	0.991	1.002	1.004	1.012	0.972	0.969
Fixed factors	Grass land	30	13	13	6	10	63	41
	Labour	3427	3561	3977	3503	2855	3988	4021
	Dairy cows	35	25	33	32	60	77	83
	Stock o. anim.	45095	24221	54223	51573	53864	73609	63462
	Fodder	9	7	28	27	28	34	31
	Arable land	20	19	23	14	33	37	38
	Depr.,Interest	20946	20011	18635	19874	52912	31079	27320

Note: South England contains West of England. Due to space limitations we refer only to South.
Source: FADN data, own calculations

5 Results

Result will be presented and discussed for selected regions in the EU. After a an overview on the estimation results and an introduction to aggregate regional results, in the next section, the determinants for the marginal costs will be analysed and in a detailed manner presented for the different farm types. Afterwards the spread of the marginal costs estimates within the different regions will be shown. The last section focuses on the discussion whether the marginal cost development is consequence of general ongoing structural change or if it reflects specific national quota exchange patterns.

5.1 Overview on estimation and average regional marginal costs

The system of per unit input demand equations (4) are estimated with fixed effects and a Seemingly Unrelated Regression procedure for each of the FADN regions. The parameters of the regional models as well as an overview on the number of significant parameters can be found in the Annex.

Table 3 shows the average variable marginal costs of dairy production in the respective regions, i.e. equation (5) evaluated at the sample mean of the variables. For Denmark and the German and French regions we observe that marginal costs decrease over time whereas marginal cost increase for the UK. According to the EAA, the regions in the UK faced a significant increase in input prices during the period under review. In 1991, North Britain/Scotland shows the lowest marginal costs, followed by the French regions and South/West of England. With some distance, Bavaria and Denmark follow and Lower Saxony is at the upper end nearly doubling the marginal costs of North Britain/Scotland. In the year 1998, we observe a change in the order with respect to marginal cost: At the lower end, Brittany is followed by North Britain/Scotland, Bavaria and Pays de la Loire/Atlantic Coast. Lower Saxony could significantly decrease its marginal costs but still remains in the upper range. South/West England shows a strong increase in marginal costs due to the above explained reasons.

Table 3: Mean of regional marginal costs (€/t)

	Low. Saxony	Bavaria	Pays Loire/ Atl. Coast	Brittany	Denmark	N. Britain, Scotland	South England
1991	171.51	125.07	111.25	106.84	139.33	88.15	108.79
1998	139.51	111.81	112.86	86.94	126.21	106.93	144.07

Source: Own estimations

5.2 Regional average marginal cost according to farm types

Here, a more detailed look at regional results allows drawing some conclusions on the determinants. Due to space limitations, they are restricted to South/West of England, UK, Bavaria in Germany, Pays de la Loire/Atlantic coast in France and Denmark (no regional split-up).

Impact of degree of specialisation

The first two columns in Table 4-7 show the breakdown of the estimated sample in different farm types for the selected regions. Across all regions the hypothesis can be accepted that farms with a high degree of specialisation (measured by their share of revenue from dairy in total revenue) show significantly lower marginal costs than farms with a low degree of specialisation. For Bavaria and Pays de la Loire/Atl. Coast the difference in marginal costs between the less specialised against the higher specialised farms is not as pronounced, but still seems to be the main determinant for differences in marginal cost. Highly specialised dairy farms are characterised, across the regions, by a lower input use, especially for animal specific inputs, less labour use and less area. Note, that due to a, in general, very high degree of specialisation in Denmark and UK the ceiling for farms to be accounted under the group of less specialised producers had to be increased to "below 40%".

Impact of farm size

If we distinguish between large and small farms (measured by herd size), the marginal cost difference between the farm types is much less pronounced (see Tables 4-7, columns 3 and 4). As both size classes show a similar degree of specialisation, it seems that pure size of the holding does not provide an advantage with respect to marginal variable costs. Even though, for example in South/West of England, farms large in herd size show nearly six times the number of dairy cows than smaller farms their marginal cost are on average 6 €/t above the smaller ones. Similar findings hold for Pays de la Loire/Atl. Coast and Denmark. An aspect contributing to the explanation of this – at first sight – surprising effect, is that the reported marginal cost is a measure of short term competitiveness as we employ a restricted cost function. It might still be true that large herds operate at lower marginal and average cost if capital and all labour is considered variable. Therefore, we infer from our analysis that scale economies do not materialize in lower short term marginal variable cost as considered here but must instead be related to savings in labour and capital inputs.

Marginal effects

Evaluating the derivative of the marginal costs equation (5) with respect to outputs, input prices and fixed factors respectively at the sample means allows determining the impact of the different variables on marginal costs. For all regions a change in input prices and grass land leads to higher marginal costs. The marginal effects of the other variables depend on the regional conditions and show no clear tendency across all regions.

Contrary to the other three regions, in Bavaria with predominantly small scale dairy operations, an increase of the number of dairy cows leads to lower marginal costs. This indicates that Bavarian farmers could still exploit positive effects from an increase in herd size and economies of scale. The same holds for changes in depreciation. Whereas in the other regions this contributes to higher marginal costs, in Bavaria the dairy operations can improve their competitiveness by investments in dairy equipment, buildings or machinery.

Table 4: Types of dairy farms and marginal costs in South of England

South England	Degree of spec. > 80%	Degree of spec. < 40%	Size of farm > 50%	Size of farm < 50%	Farms with marginal costs 25% lowest	Farms with marginal costs 25% highest	Marginal effects
	output value from milk		regional average		within 95% quantile		
Crop output	9775.4	202209.7	69357.0	9304.5	31843.6	58124.9	0.004
Animal output	25162.7	446575.1	95360.6	18708.6	36540.6	68789.2	-0.0008
Milk output	611.4	948.0	1119.7	167.2	497.0	564.8	-0.0163
Crop input	11813.9	47368.5	29720.8	4418.0	13250.8	25275.2	15.7302
Animal input	59994.0	325068.4	132832.9	23417.0	46104.4	84004.3	88.9112
Other input	60699.0	248877.6	129488.2	20632.9	46822.7	96433.2	55.7086
Grass land	37.0	81.0	59.2	30.6	40.9	43.2	0.2217
Labour	3785.1	4719.4	4007.2	3549.5	4441.8	3676.7	-0.005
Dairy Cows	97.1	158.1	173.4	31.4	81.4	90.1	0.566
Stock o. animals	43287.6	455622.6	120867.5	31148.8	56429.3	91152.4	1.0055E-06
Fodder	32.8	40.6	56.4	13.6	30.8	31.8	0.9485
Arable land	7.5	127.4	58.3	7.9	28.6	42.9	-2.9087
Depreciation	26442.2	73475.9	50940.2	8295.5	24574.2	38401.0	0.0004
Degree Spec.	0.9	0.3	0.8	0.7	0.8	0.7	
Marg. Cost Milk	113.9	182.8	116.6	110.9	68.2	183.0	

Table 5: Types of dairy farms and marginal costs in Bavaria

Bavaria	Degree of spec. > 80%	Degree of spec. < 20%	Size of farm > 50%	Size of farm < 50%	Farms with marginal costs 25% lowest	Farms with marginal costs 25% highest	Marginal effects
	output value from milk		regional average		within 95% quantile		
Crop output	673.3	35171.4	31953.4	13952.2	25425.1	19038.1	-0.0009
Animal output	13194.7	54301.5	39860.8	24817.9	20967.9	37408.7	0.0004
Milk output	199.2	44.5	292.9	45.5	132.0	112.5	-0.039
Crop input	1201.7	8800.1	11880.0	3704.5	6166.5	6712.6	21.5701
Animal input	20178.0	23602.8	36833.7	11539.9	14507.4	24635.4	145.7642
Other input	17720.0	24929.5	43157.4	14219.6	18774.3	27338.1	38.8722
Grass land	21.9	7.0	20.7	7.2	10.7	13.5	0.7511
Labour	3138.3	3470.7	4267.6	3054.8	3467.5	3426.4	-0.0004
Dairy Cows	31.1	10.2	49.8	9.5	23.5	21.2	-0.0154
Stock o. animals	15160.7	32179.9	37183.4	16595.5	18230.3	27542.0	0.0002
Fodder	1.8	3.7	11.9	3.1	5.8	5.6	0.6056
Arable land	0.4	28.4	25.1	12.0	17.1	18.8	0.5296
Depreciation	11413.9	16970.5	34572.0	10729.3	18595.2	17238.3	-0.0004
Degree Spec.	0.8	0.2	0.6	0.5	0.5	0.4	
Marg. Cost Milk	113.9	140.4	119.4	127.8	72.7	168.8	

Table 6: Types of dairy farms and marginal costs in Pays de la Loire/Atlantic Coast

Pays d.l.Loire/ Atlantic coast	Degree of spec. > 80%	Degree of spec. < 20%	Size of farm > 50%	Size of farm < 50%	Farms with marginal costs 25% lowest	Farms with marginal costs 25% highest	Marginal effects
	output value from milk		regional average		within 95% quantile		
Crop output	6513.3	62678.1	60839.1	16987.3	15041.8	35826.5	-0.0014
Animal output	11328.4	147308.7	93247.9	23450.0	19829.1	53121.5	-0.0006
Milk output	212.3	101.3	459.3	69.1	133.3	193.1	-0.3786
Crop input	7071.9	18462.7	28920.9	7701.9	8246.4	15640.2	5.8142
Animal input	16765.5	93922.7	66309.3	11268.8	9984.8	39297.9	86.0402
Other input	22518.6	50943.6	73521.0	16341.4	17891.6	40848.7	34.1137
Grass land	10.8	13.0	15.8	14.1	13.9	10.9	0.2332
Labour	3305.7	4875.1	5978.7	3449.9	3588.2	3934.3	0.0013
Dairy Cows	34.5	19.6	67.3	13.1	25.5	32.0	0.4063
Stock o. animals	22843.2	171503.7	118420.9	35531.4	44500.7	58621.2	-0.0002
Fodder	23.1	27.7	48.2	18.4	23.9	24.9	-0.0823
Arable land	5.0	37.7	51.0	13.7	11.7	26.6	-0.0954
Depreciation	11938.5	27242.7	43091.0	7785.3	10914.7	21627.3	0.0005
Degree Spec.	0.8	0.1	0.6	0.5	0.6	0.5	
Marg. Cost Milk	102.7	134.8	115.4	108.2	63.3	150.1	

Table 7: Types of dairy farms and marginal costs in Denmark

Denmark	Degree of spec.		Size of farm		Farms with marginal costs		Marginal effects
	> 80%	**< 40%**	**> 50%**	**< 50%**	**25% lowest**	**25% highest**	
	output value from milk		regional average		within 95% quantile		
Crop output	16381.4	79740.7	47502.4	16721.2	23995.6	47955.3	0.001
Animal output	23079.4	221552.8	78202.0	20272.7	23472.6	108446.5	2.7884E-05
Milk output	466.5	324.5	819.8	132.3	319.4	411.5	0.0306
Crop input	10543.5	22030.5	22805.9	6331.1	11339.9	16465.6	10.1324
Animal input	54708.7	161023.5	117922.2	23421.9	35849.0	106624.3	76.5435
Other input	51570.9	98239.5	115174.1	18216.6	34818.0	80922.1	47.8538
Grass land	9.7	12.2	15.6	5.4	6.9	12.8	0.1049
Labour	2844.6	2972.0	3225.1	2231.8	2914.7	2708.7	-0.0015
Dairy Cows	68.0	49.6	123.2	21.1	47.8	64.0	0.2602
Stock o. animals	43315.2	149153.7	101584.0	22483.7	34740.9	95292.2	0.0008
Fodder	31.7	19.3	54.7	10.4	27.7	23.1	-1.0119
Arable land	16.5	78.1	48.1	18.9	28.2	46.4	-0.7097
Depreciation	52042.5	89631.1	103615.3	17128.4	39173.8	68740.1	0.0003
Degree Spec.	0.8	0.3	0.7	0.7	0.7	0.6	
Marg. Cost Milk	116.8	187.8	138.0	99.0	70.7	187.4	

Source for Table 4-7: Own calculations. Degree of specialization is measured by dairy revenue share in total revenue. Farm size is measured by number of dairy cows. Note that for the input lines (lines 4-6) the columns with respect to the different farm groups present *expenditures in 1995 prices* and that the marginal effects (last column) present marginal effects with respect to *input prices*.

5.3 Regional distributions of marginal costs

The use of farm data allows drawing conclusion not only on regional averages but also on marginal costs for each single farm and the distribution of those estimates across the sample. The distributions of the estimated marginal costs within a region are presented as nonparametric Kernel density estimates. A normal Kernel function has been employed and the bandwidth is determined by a Maximum Likelihood procedure based on Lewis and Orav (1989 p. 171).

Figure 1 - 4 show the distributions for the analysed regions. The development over time reveals a movement towards a more centred and balanced distribution In general, the distributions are much steeper with less spread in the tail of the function. The higher density values indicate less variation in production technology within the region: The significance of outliers as encountered in the years 1991 and 1995 seems to decrease. The estimated negative marginal costs in some regions indicate that monotonicity of the cost function with respect to outputs is violated for some farms. In the French region Pays de la Loire/Atl. coast the distribution shows a comparatively small spread of marginal costs from the outset resulting in the steep appearance. A significant decrease between 1991 and 1998 in the share of high marginal cost producers can be found in Denmark and Bavaria.

Figure 1: Distribution of marginal costs for South/West of England

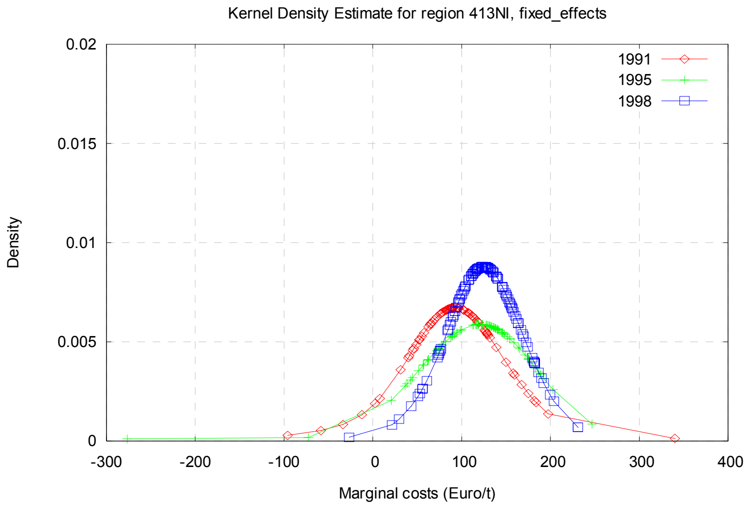


Figure 2: Distribution of marginal costs for Bavaria

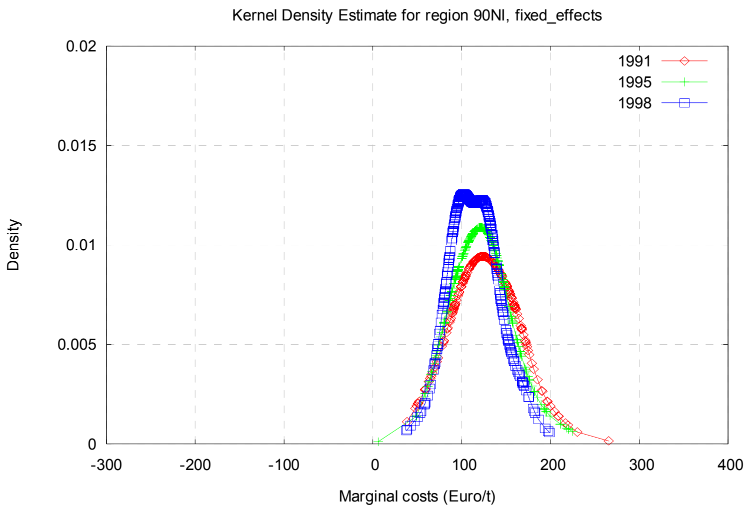


Figure 3: Distribution of marginal costs for Pays de la Loire/Atlantic coast

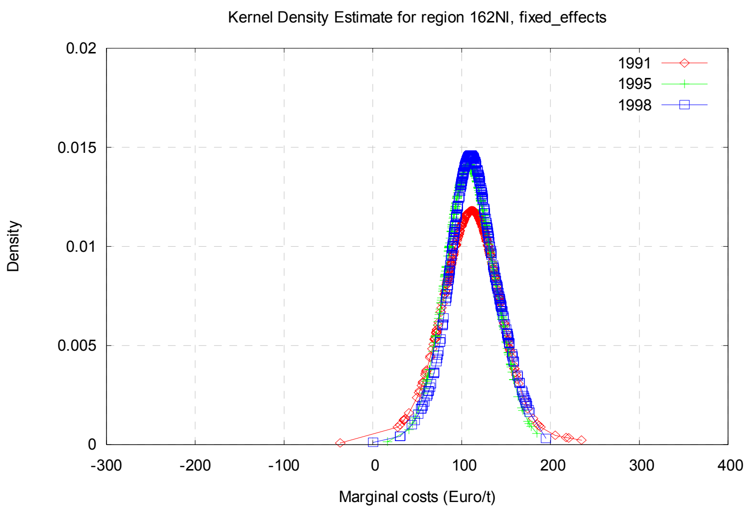
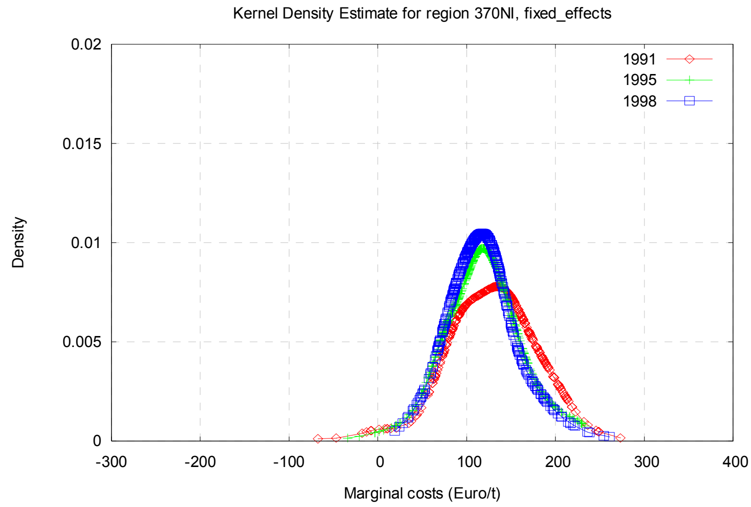


Figure 4: Distribution of marginal costs for Denmark



Source for Figures 1-4: Own calculations

The characteristics of the farms at the lower and upper end of the distribution are depicted in the Table 4-7, columns 5 and 6, of the previous section. The difference in marginal costs between the two groups is not determined just by the degree of specialisation or size of farm, but instead the interaction of all factors contributes to the classification. In general, much higher crop and animal output, slightly higher herd sizes (exception Bavaria), more labour (exception Denmark) and land use, higher investments, but especially the higher variable input quantities characterize farms in the upper range of marginal costs. In line with the findings from the previous section are that farms at the lower end of the distributions reveal a higher degree of specialisation and smaller herd sizes than the ones from the upper range. For Bavaria – as expected from the marginal effects – the opposite holds with respect to herd sizes. A second characteristic of the farms in the lower group (compared to those of the opposite group) is their low level of depreciation and interest payments which indicate that they haven't invested recently to a larger extent. This short term competitiveness of stagnant or departing dairy farms has been frequently cited in the discussion on what type of farms will be hurt most by a redistribution of premiums related to milk production potentially following from the EU- CAP reform. It is surprising, however, that well invested, growing farms are not only threatened by liquidity constraints, but also show a tendency of higher marginal variable cost.

In order to get a better indicator for the different regional developments, the spread of the marginal costs within the 95% quantile and within the 75% quantile of the estimated results as well as the variance is depicted in Table 8. Leaving aside outliers those quantiles are used as indicators for the spread of marginal costs within the region. Whereas the inference from the 95% quantile is ambivalent, the development of the 75% quantile clearly shows (with the exception of Brittany), that there is a tendency towards a more balanced distribution of marginal costs within the regions. For South/West of England and Denmark, one can observe a strong move towards more balanced marginal costs whereas in Lower Saxony only a very slight decrease took place.

Table 8: Spread of marginal costs (in €/t)

	Low. Saxony	Bavaria	Pays Loire/ Atl. Coast	Brittany	Denmark	N. Britain, Scotland	South England
Inter-quantile spread (95%)							
1991	282.89	182.47	192.53	216.8	295.77	279.37	255.94
1998	288.45	143.98	146.04	218.64	214.13	269.28	182.21
Difference	-5.56	38.49	46.49	-1.84	81.64	10.09	73.73
Inter-quartile spread (75%)							
1991	248.26	156.59	152.38	191.95	258.09	279.37	255.95
1998	238.08	111.22	119.71	210.07	175.06	226.14	152.92
Difference	10.18	45.37	32.67	-18.12	83.03	53.23	103.03
Variance							
1991	3275	1527	1111	1564	2655	2752	3431
1998	3284	901	783	1458	1653	2255	1799
Difference	-9	626	328	106	1002	497	1632

Source: Own calculations. The 95% (75%) quantile is defined as the interval covering marginal cost values excluding the 2.5% (12.5%) tails of the distribution. The spread is calculated as the difference between upper and lower bound of the intervals.

The variances of the estimated samples of marginal costs confirm these observations even if those tendencies are less pronounced. For Brittany, we observe a decrease in the variance but a slight increase in the 95% quantile and a strong one in the 75% quantile. This indicates that the marginal costs distribution gets fatter in the tails for this region.

5.4 Marginal cost development: Impact of different quota regimes or "just" structural change?

The impact of the milk quota system on the structural development of the dairy farming sector is a very controversial issue. Whereas the Court of Auditors stated in its 2001 special report on milk quotas that the quota system "has not, to any great extent, prevented the restructuring of the dairy sector within each Member State" (Court of Auditors 2001 paragraph 67), other sources say that "the presence of milk quotas is tending to slow down the move towards concentration in production which was a feature of the years prior to the implementation of the system" (Barthélemy et al. 2001 p. 100). The introduction of the milk quotas fell in a period where the dairy sector was "in the middle of a drastic change" (Barthélemy et al. 2001

p. 83) showing decreasing rates of number of dairy farms by 4.1% on average over the period between 1971 and 1984 (European Commission 2002 p. 10). For the EU-9, as present in the year 1984, the rate of decline increased to 4.6% between the years 1985 and 1997 (European Commission 2002 p.10), whereas Barthélemy et al. found for UK (and The Netherlands), that the rate of decrease slowed down in the period 1984 to 1998 (Barthélemy et al. 2001 p. 85).

The previous sections showed that even though strong structural change took place, marginal costs of farms are far from being balanced. Apart from the general observations that marginal cost distributions concentrate over time, one can still observe considerable variance across farms. The comparison of marginal cost distributions across regions with different quota trading regimes does not allow identifying advantages of liberal regulations. This becomes clear when we look at the case of the French region: even though the administrative setting for quota management in France implies comparatively regulated and restrictive quota transfer possibilities, no significant differences to regions with liberal trading regimes could be observed in this study. Strong incentives for participation in cessation and restructuring schemes also allowed for a more balanced distribution of marginal costs over time as in other regions. The success of this administrative restructuring measures are also indicated by the fact that for overall France, the rate of decline of the number of dairy farms even increased in the period from 1984 to 1992 to 9.1% (Barthélemy et al. 2001 p. 85).

The case of the regional distribution of South/West of England shows that the single fact of tradable milk quotas is not enough in order to ensure an efficient distribution within the region. Against common expectations within the framework of tradable quota rights, Barthélemy et al. showed that “the level of milk production per British farm, the highest in Europe, increased less rapidly than elsewhere in the 1988-99 period” (Barthélemy et al. 2001 p.92). Hence, the problem must be in the implementation of the system of quota trade. The analysis on inefficiencies in the UK milk quota system of Colman showed that a significantly higher volume of quota trade would be needed to be transferred from less to more efficient producers in order to maximize the gains in the dairy sector, that a large number of producers is still not managing their quota and production with maximal efficiency (leading to individual overproduction and costs for the payment of the superlevy) and lastly that the costs imposed by the quota market on those wishing to expand milk production is substantial (Colman 2000). All these arguments indicate that the transfer rules are too complicated (e.g. existence of a last leasing date somewhere in the milk marketing year, the link of quota to land) or that they are designed in favour of the (original) owner of the quota right ("sofa farmer") and not the active producer needing these rights.

Having France with its strong restructuring under an administrative system on one side of the picture and the UK with its inefficiencies in the liberal approach on the other side, we can try to evaluate the findings of the German and Danish regions. The German milk quota system, marked by some rigidity in the beginning of the introduction of milk quotas, gradually adapted and released towards a more market oriented approach in the quota administration. Therefore it combines all the disadvantages of both approaches: The early phasing out of support for cessation and restructuring schemes at the beginning of the nineties (Barthélemy et al. 2001 p. 88) left the German farmers with a very rigid system and the introduction of some liberal elements certainly doesn't offset this rigidity as probably most of the inefficiencies analysed by Colman for the British system will apply to the German system as well. Barthélemy et al. analysed that the German rate of change in the number of dairy farms, after slowing down in the first years of the introduction of milk quotas, gained speed in the years 1990 - 1998 and overtook even the rates of decline of France (Barthélemy et al. 2001 p. 87). This trend is clearly reflected in the distributions. A second argument put forward by them for the explanation of the slow rates of decline in the first years is "the greater resistance put by small-scale German dairy farms, able to rely on the income derived from mixed farming" (Barthélemy et al. 2001 p. 87) which he attributed as a common feature of agriculture in Germany, contrary to e.g. French agriculture. In Denmark with the milk quota system being somewhere between an administrative approach and a market oriented one, we have a similar case as Germany in this respect, which is reflected as well in the estimated regional marginal cost distributions.

6 Conclusions

The paper analyses by means of a panel data estimation for several dairy production regions of the EU the marginal cost development and distributions. As an important determinant for lower marginal costs a high degree of specialisation could be identified. Size of farm (accounted for by number of dairy cows) tends to have no clear effect which might be due to the case that the reported marginal costs must be taken as a short-term competitiveness indicator as they are estimated from a restricted cost function. With respect to changes in the variables we found that input prices have the highest (positive) impact on marginal costs. Recent farm investments surprisingly contribute as well somewhat to higher marginal costs.

The nonparametric Kernel density estimators employed to show the distribution of regional marginal costs disclosed that there is still considerable variance in marginal costs across farms of a region. In the course of time we observed a decrease in marginal costs with the exception for the British regions and a decrease in the spread of the marginal costs within the region. The classification of farms at the lower and upper range of these distributions revealed that higher crop and animal output, slightly higher herd sizes, more labour and land use, higher investments, and especially the higher variable input quantities characterize farms in the upper range of marginal costs.

Even though strong structural change took place, marginal costs of farms are far from being balanced. The comparison of marginal cost distributions across regions with different quota trading regimes does not allow identifying advantages of liberal regulations. Further research is necessary in order to identify the factors preventing the liberal trading approach from being more efficient.

Although the chosen approach seems to serve the purpose of the analysis of the development of marginal costs well further methodological improvement will be considered. New approaches to impose "regional regularity" of the cost function might be able to address the problem of negative marginal costs for some farms in the sample and improve interpretability of the results.

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Annex

Estimated parameters

	Lower Saxony		Bavaria		P.Loire/Atl.Coast		Brittany		Denmark		N. Britain/Scotl.		South of England	
	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
$E_{C.C}$	-5.11	3.88	-6.35	3.99	-18.81	8.13	-9.09	4.28	-11.29	5.31	-0.01	0.18	-0.19	1.12
$E_{A.A}$	-119.55	40.72	-118.85	41.80	-109.94	18.48	-126.83	18.78	-0.07	1.65	-149.08	61.09	-66.93	65.26
$E_{A.C}$	-24.72	8.81	-27.48	7.94	45.37	11.48	33.95	8.73	-0.92	10.12	-1.46	8.87	3.54	11.84
β_A	-2.01	0.29	-2.83	0.31	-0.85	0.14	-2.73	0.19	0.33	0.17	-1.76	0.67	1.34	0.64
β_T	1.86	0.34	2.89	0.38	1.09	0.16	1.51	0.20	0.17	0.28	3.24	0.62	2.21	0.60
β_C	-0.48	0.11	-0.41	0.11	0.34	0.08	-0.39	0.07	-0.96	0.15	-0.16	0.13	0.09	0.14
$C_{C.CR}$	0.08	0.03	0.06	0.04	-0.28	0.04	0.08	0.03	0.11	0.06	-0.05	0.12	-0.13	0.30
$C_{C.MI}$	30.80	6.57	13.56	8.82	-30.01	8.94	-2.22	5.28	20.03	12.33	-14.91	13.59	-19.77	21.79
$C_{A.CR}$	-0.01	0.07	0.24	0.09	-0.43	0.04	-0.31	0.10	0.07	0.14	-0.19	0.22	-0.35	0.42
$C_{A.MI}$	89.38	14.87	77.85	19.31	-41.43	9.61	-92.00	20.73	49.27	28.36	44.44	24.94	7.26	31.18
$C_{T.CR}$	0.05	0.10	0.18	0.12	-0.81	0.09	-0.46	0.08	0.24	0.15	-0.15	0.28	-0.77	0.68
$C_{T.MI}$	82.20	20.62	50.65	26.54	-126.06	20.20	-141.62	16.76	71.43	31.16	-22.00	30.97	-47.35	49.43
$D_{C.GR}$	8.60	20.59	-12.66	27.80	8.49	17.85	119.13	31.70	-27.24	47.61	13.13	12.79	24.92	46.08
$D_{C.LA}$	0.03	0.12	0.14	0.10	-0.19	0.15	-0.17	0.13	-0.67	0.30	-0.12	0.28	-0.87	0.45
$D_{C.DC}$	2.01	36.77	29.18	44.33	25.34	36.79	-13.12	31.19	133.34	52.57	113.35	50.12	234.55	88.12
$D_{C.SOA}$	0.05	0.02	0.06	0.02	-0.02	0.01	0.01	0.01	0.11	0.03	0.02	0.02	-0.02	0.04
$D_{C.FO}$	98.16	31.83	98.08	38.97	26.74	19.31	19.30	16.93	145.30	33.36	-15.55	33.14	148.51	73.66
$D_{C.AR}$	65.98	33.82	133.27	40.28	274.78	41.85	50.35	31.66	145.77	43.19	391.43	174.60	364.79	371.90
$D_{C.DP}$	0.05	0.03	0.02	0.02	-0.13	0.04	0.12	0.02	0.00	0.03	0.04	0.04	-0.06	0.09
$D_{A.GR}$	40.79	46.65	17.17	60.11	19.17	21.46	258.98	123.90	-125.89	109.30	19.13	26.00	-28.84	70.09
$D_{A.LA}$	-0.05	0.27	0.10	0.22	-0.29	0.18	-1.51	0.49	-2.27	0.69	-0.74	0.54	-1.38	0.68
$D_{A.DC}$	-63.71	83.25	-71.33	96.99	-59.31	39.67	-358.60	124.60	278.98	121.30	168.32	95.00	588.82	127.40
$D_{A.SOA}$	0.14	0.04	0.14	0.05	0.02	0.01	-0.03	0.03	0.38	0.08	0.16	0.04	0.11	0.05
$D_{A.FO}$	275.99	72.19	233.75	85.32	38.45	20.77	-11.36	67.69	97.20	76.74	-123.03	64.25	166.96	108.00
$D_{A.AR}$	145.82	76.62	42.24	87.73	69.34	44.03	-195.39	125.30	100.49	99.30	498.25	318.80	335.60	524.20
$D_{A.DP}$	0.19	0.06	0.06	0.05	-0.12	0.05	0.53	0.09	0.09	0.06	0.05	0.07	-0.10	0.13
$D_{T.GR}$	410.54	64.60	157.70	84.08	96.79	40.11	393.60	100.50	71.86	120.50	138.65	30.65	106.30	108.50
$D_{T.LA}$	0.06	0.37	0.32	0.30	-0.15	0.35	-0.71	0.41	-3.35	0.76	-2.15	0.65	-2.94	1.06
$D_{T.DC}$	12.53	115.40	21.71	133.50	54.84	83.11	-20.34	99.47	427.99	132.80	459.42	116.00	746.83	201.00
$D_{T.SOA}$	0.06	0.05	0.16	0.07	-0.11	0.03	-0.09	0.03	0.24	0.08	0.03	0.05	-0.01	0.09
$D_{T.FO}$	525.31	99.63	507.66	115.80	150.89	43.66	120.89	54.06	366.75	84.34	-5.81	77.51	443.74	169.60
$D_{T.AR}$	356.41	106.10	211.24	121.50	454.67	94.64	156.06	100.70	276.58	109.20	649.72	397.00	978.00	836.30
$D_{T.DP}$	0.12	0.09	0.16	0.07	-0.39	0.10	0.17	0.07	0.06	0.07	0.05	0.09	-0.21	0.21
$G_{CR.CR}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
$G_{MI.CR}$	-0.39	0.19	-0.32	0.20	0.39	0.12	0.22	0.16	0.15	0.22	0.73	0.49	2.54	0.94
$G_{MI.MI}$	-81.94	43.78	-55.17	60.09	44.80	35.31	112.57	43.26	-34.51	60.24	48.37	56.89	161.05	85.54

Note: C = crop specific inputs, A = animal specific inputs, T = other variable inputs, CR = crop output, MI = milk output, GR = grass land, LA = labour, DC = dairy cows, SOA = stock of other animals, FO = fodder production, AR = arable land, DP = depreciation and interest payments.

Cont'd	Lower Saxony		Bavaria		P.Loire/Atl.Coast		Brittany		Denmark		N. Britain/Scotl.		South of England	
	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
$F_{GR.GR}$	1054.07	220.80	893.89	388.30	72.48	123.70	-2907.69	1329.30	-414.53	598.50	80.49	44.66	-262.94	423.30
$F_{LA.GR}$	-1.07	1.58	-0.34	1.38	-1.04	0.85	-2.24	4.22	3.55	3.97	-0.60	0.99	-6.17	3.46
$F_{LA.LA}$	-0.01	0.01	0.00	0.01	-0.02	0.01	-0.01	0.02	0.10	0.04	0.06	0.02	0.13	0.04
$F_{DC.GR}$	-721.18	355.40	-150.88	503.70	-189.09	127.20	-710.06	622.70	-1762.44	713.40	-505.97	168.30	328.26	678.20
$F_{DC.LA}$	1.19	2.63	-2.58	2.37	0.96	1.43	4.16	3.53	4.76	4.83	2.72	3.72	-3.69	6.47
$F_{DC.DC}$	-320.28	843.60	139.46	1323.80	-169.06	464.20	542.81	854.30	1606.45	1327.50	-2243.49	1276.70	-112.82	1493.40
$F_{SOA.GR}$	-0.80	0.15	-1.00	0.34	-0.10	0.07	0.88	0.27	1.10	0.42	0.01	0.07	0.45	0.29
$F_{SOA.LA}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$F_{SOA.DC}$	-0.32	0.28	0.46	0.60	-0.07	0.13	-0.32	0.28	-3.58	0.50	-0.07	0.31	-0.57	0.53
$F_{SOA.SOA}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$F_{FO.GR}$	1667.96	455.20	2154.75	652.20	45.54	115.50	-73.44	454.60	-527.02	488.30	1161.87	384.80	213.67	940.10
$F_{FO.LA}$	7.55	2.48	-1.52	2.13	-3.13	0.76	-3.96	2.08	2.53	2.66	-4.19	3.32	0.14	6.18
$F_{FO.DC}$	-836.89	785.80	-1716.20	947.10	-245.18	162.00	-54.58	403.90	1786.26	475.90	-911.63	577.00	720.51	1037.80
$F_{FO.SOA}$	-1.83	0.38	-0.92	0.52	-0.16	0.07	-0.23	0.13	0.45	0.34	-0.08	0.25	-0.19	0.52
$F_{FO.FO}$	-362.07	1391.70	123.78	1586.60	250.44	87.53	1233.39	321.00	-196.10	398.00	2623.17	637.40	2605.61	1467.80
$F_{AR.GR}$	94.28	475.70	-340.54	842.50	-99.38	243.20	-2870.03	1166.50	729.85	522.70	302.58	1373.90	147.23	2426.70
$F_{AR.LA}$	-1.57	2.26	3.09	2.40	-5.50	1.54	2.26	4.09	-2.55	3.90	21.99	15.91	-27.84	19.48
$F_{AR.DC}$	-905.00	1002.30	-1351.77	1023.50	-255.73	412.60	-427.49	909.70	1603.07	728.20	-22.23	3784.20	13609.95	4988.80
$F_{AR.SOA}$	-0.85	0.40	0.42	0.54	-0.20	0.19	0.83	0.35	-0.32	0.47	-0.46	1.13	-5.22	2.05
$F_{AR.FO}$	-2073.81	1020.40	11.80	833.60	-754.51	222.40	-1277.80	526.20	-1281.79	426.90	-201.60	2202.80	13756.00	3713.30
$F_{AR.AR}$	265.99	601.50	-785.20	780.50	-916.61	359.80	478.42	973.90	-289.66	466.80	-3928.96	3499.00	7074.07	4813.00
$F_{DP.GR}$	-0.69	0.35	0.15	0.30	0.48	0.25	-2.44	1.08	0.08	0.40	0.25	0.18	-0.27	0.66
$F_{DP.LA}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01
$F_{DP.DC}$	0.22	0.55	-0.41	0.49	-0.68	0.50	1.96	0.79	-1.09	0.48	1.09	0.74	-1.54	1.10
$F_{DP.SOA}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$F_{DP.FO}$	2.11	0.67	-0.66	0.52	0.90	0.26	0.24	0.38	-0.79	0.30	1.36	0.60	-1.62	0.87
$F_{DP.AR}$	-0.57	0.74	0.11	0.56	0.94	0.48	-1.25	0.80	1.22	0.37	6.59	2.15	-2.34	5.08
$F_{DP.DP}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$H_{CR.GR}$	-1.50	1.05	-2.98	1.61	0.11	0.57	2.47	1.60	1.94	1.75	2.16	2.20	-3.30	4.89
$H_{CR.LA}$	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01	-0.03	0.02	0.10	0.03
$H_{CR.DC}$	5.41	1.96	4.63	2.03	1.40	0.99	1.42	1.63	-3.14	1.83	-2.32	5.59	-26.36	8.63
$H_{CR.SOA}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
$H_{CR.FO}$	-0.58	1.98	-0.40	1.65	1.45	0.52	2.96	0.94	2.68	1.16	2.61	3.04	-33.48	6.92
$H_{CR.AR}$	0.66	0.69	1.02	1.25	0.45	0.73	-0.88	1.37	-0.34	1.08	1.41	4.24	-20.15	10.54
$H_{CR.DP}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.01
$H_{MI.GR}$	70.67	171.20	-18.34	216.80	165.22	86.31	-121.71	342.00	324.25	342.60	98.03	80.11	98.61	325.30
$H_{MI.LA}$	-0.78	1.12	-0.15	0.97	2.94	0.75	2.42	1.37	1.28	2.32	-0.50	1.87	1.48	2.97
$H_{MI.DC}$	600.30	354.00	356.81	490.00	348.15	197.40	351.60	356.80	-241.84	483.50	378.92	435.80	-1205.29	618.60
$H_{MI.SOA}$	0.23	0.14	-0.01	0.25	0.08	0.08	0.21	0.11	0.34	0.26	0.06	0.15	0.28	0.26
$H_{MI.FO}$	-724.67	323.70	-35.16	391.00	10.82	103.20	-29.02	176.30	-1118.16	252.90	47.83	221.50	-839.87	461.00
$H_{MI.AR}$	341.29	401.10	256.74	403.30	-318.10	228.60	661.84	377.70	-790.36	351.10	-2147.50	1429.30	-5221.85	2315.80
$H_{MI.DP}$	-0.63	0.22	-0.13	0.24	0.63	0.25	-1.80	0.29	0.23	0.23	-0.17	0.32	1.40	0.57

Source: Own estimations

Number of significant parameters

	No. significant parameters		
Region	at 1% level	at 5% level	at 10% level
Low. Saxony	67%	9%	8%
Bavaria	50%	9%	8%
Pays Loire/Atl. Coast	72%	10%	8%
Brittany	63%	14%	12%
Denmark	58%	17%	5%
N. Britain, Scotland	50%	6%	13%
South England	51%	10%	14%

Source: Own estimations