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Structural change in the West German agricultural sector

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Abstract

This article explains regionally differentiated patterns of structural change based on a theoretical framework dealing with strategic interaction of farms on the land market. The main research question focuses on the causes of regionally persistent structures. An empirical Markov chain model is defined for the West German agricultural sector. The model is used to explain the probabilities of farm growth, decline, or exit in terms of the current and former regional farm size structure. Further, the impact of variables describing the regional farm structure, thereby indicating market power of the large, the potential of high competition for land within a region, and possibly high rents of the status quo in combination with sunk costs, is quantified. The results confirm the relevance of strategic interaction as a crucial determinant of persistent regional differences in the farm size structure over time.

JEL classification: D43, L16, Q12

Keywords: Structural change; Strategic competition; Land market; Markov chain

1. Introduction

A frequently observed phenomenon in the agricultural sector is the persistence of farms in a size category (Balmann, 1997; Boehlje, 1992). Consequently, regionally differing structures remain. Furthermore, differing patterns of farm growth like differing regional processes of concentration and de-concentration with respect to the number of farms in respective size categories are observed (Glauben et al., 2006). For instance, the phenomenon of a disappearing middle class has been detected in some regions (Weiss, 1999). The more or less stable share of small farms and the particular role of the small within structural change is still an enigma. However, to our knowledge, the literature does not provide a clear explanation whether small farms represent a transitory state or a stable size category with the ability to survive motivated by considerations other than current profits. Small farms may also benefit from low opportunity costs of fixed factors due to sunk costs. Further, the shadow price of labor mainly determined by off-farm work opportunities is of importance (Goetz and Debertin, 2001; Roeder et al., 2006).

In general, such persistence is related to the reluctance of farms to exit or to grow. In the relevant literature this is explained by sunken investment costs (Balmann et al., 2006), uncertain future revenues (Chavas, 1994), and the presence of imperfect markets for labor and/or capital (Huettel et al., 2007). These factors cause a rent of the status quo that itself creates range in which inactivity is optimal. These issues impose economic restrictions on single farms such that reluctance to grow, decline, or exit is a result of economically “correct” behavior (Balmann, 1997). From a more general perspective, initial (historic) differences in the farm size lead to different organization structures of farms (Ciaian and Swinnen, 2009; Foltz, 2004). Thus, persistent regional differences may also be explained by differing initial conditions. In addition, divergent opportunity costs induce different local optima with respect to scale efficiency.

Against this background, this article aims to improve the understanding of regionally different patterns of structural change. In the authors’ opinion, the exclusive focus on isolated behavior of single farms in the relevant literature does not suffice in order to explain the different patterns of regional structural change. Quite the contrary, the continuous interaction among agents and

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failures of coordination in different historic environments need to be taken into account.

Interaction among farms occurs on the regional land market. Land is an important factor for growth. It is not renewable and without land farm growth is only possible to a limited extent. The immobility and shortage of this factor causes a strong interdependence of farms within a region and direct competition among farms (Chavas, 2001). Due to the relatedness on the land market, the immobility of one farm hinders growth of other farms as shown for instance by Weiss (1999), Harrington and Reinsel (1995), or Balmann et al. (2006). The direct competition among a limited number of farms enables each farm to influence the market directly taking other farms' anticipated action into account. We argue that this observed strategic behavior is a key element to understand the dynamics of regionally differing structural change. Because experiences shape expectations and determine strategic behavior, regionally differing development paths evolve and tighten regional differences of farm structures. As a result, the farms' development depends on the initial structure and the farm size distribution at the regional level. This resulting endogenously evolving heterogeneity is further affected by exogenous factors. Changing macroeconomic conditions affect all farms in the same manner and support a parallel development of farms. However, the reaction of farms to altered conditions differs according to their different strategic options. This counterbalancing competition effect differentiates farm size development.

Only few studies deal with strategic competition among farms on the land market. The influence of market power on land transactions for instance is shown with respect to very large farms in Hungary (Vranken and Swinnen, 2004).[1] The long lasting continuous interaction between participants, as shown by Kellermann et al. (2008) or Hurrelmann (2005), influences the character of this strategic behavior. However, such analyses and explanations of regionally differentiated patterns of structural development are so far mainly based on ad hoc assumptions. Within this work, we make use of existing theoretical models to characterize the specific interaction among farms on specific land markets and its respective impact on farm growth, decline, and exit. The main objective is to show how the identified region specific interactions can explain regionally differing structural evolvements. The crucial hypothesis that these patterns rely on strategic interaction of farms in the land market is aimed to be tested empirically. A further objective is to show the dependence of the structure today on initial (historic) conditions. For these purposes, we rely on a Markov chain model to calculate individual farm moves between defined size classes from farm individual data from the agricultural census. The moves between the size categories are explained in a further step at the Nomenclature des Unités Territoriales Statistiques (NUTS) III level by historical and actual distribution of land among farms and additional exogenous factors.

[1] Further details can be found for instance in Amir et al. (2006).

2. Theoretical background and hypotheses

In the following, we stress the importance of considering the *interaction* of farmers. We handle the interaction formally within the theoretical framework of strategic competition of microeconomics. Based on the theoretical considerations, we derive the hypotheses about the impact of strategic interaction on structural change.

Classical oligopoly theory offers a starting point to analyze the interaction among farms on the land market.[2] The regional land market refers formally to an oligopsony, which is characterized by a restricted number of demanders and farms have an incentive to alter their relative position through strategic behavior. The single demander is able to directly influence the price of land, thereby each farmer anticipates other farmers' reactions. The overall objective of such behavior is to increase long-run profits and it is manifested in price bids on the land market. Strategic behavior results from the existence of status quo rents in limited markets. These rents arise for example from sunk costs or organizational adoption to the existing farm structure. Rents of the status quo result in inertia on the land market within certain ranges of prices.

Given that the land market is oligopsonistic, it is possible to explain different patterns of regional structural change by means of different local optima that are driven by different initial (historic) and current conditions. We derive the possible local optima from the theory of strategic competition.

Cournot equilibrium. If there are no short-term technical or organizational restrictions implying constant returns to scale, the same market equilibrium as in the polypsonistic market would result. In such a case of constant marginal products of land, we would expect price competition on the land market. The setting of an auction with competitive bidding (Varian, 1992, p. 292) can simulate this Bertrand competition. As in the polypsonistic market, in the Bertrand equilibrium land rents will go to land owners. This is often assumed in agricultural economics (Ciaian and Swinnen, 2009). However, in the agricultural sector we expect diminishing returns to scale at least in the short or medium term due to existing market imperfections. Thus, the rule that the marginal cost of land should equal its marginal production value dictates the demanded quantity. Because a higher demand raises the price for land, the farmers react with lower demand towards anticipated rising demand of others. If farms act rational and expectations are symmetric a Cournot equilibrium results (Varian, 1992, p. 286). Farms grow less than they would in an environment with price competition and the price for land is lower.

Based on the Cournot equilibrium we deduce our first hypothesis: *If land is distributed equally among farms, we expect a constant but slow growth for a considerable share of farms.*

[2] Models of strategic competition restrict the sales quantity. However, markets for land resources are limited and restrict the expansion of production capacities. This has to be considered in formal elaborations.

This is expected to be accompanied by rather low exit mobility. We deduce as a second hypothesis: *Sunk costs and high capital intensities raise the rents of the status quo. Consequently, we expect an even more pronounced passive behavior of farms on the land market. This holds in particular for regions characterized by a capital intensive production, e.g., livestock production.*

Stackelberg equilibrium. A Stackelberg equilibrium arises if we assume diminishing returns to scale and at the same time farms are heterogeneous due to historical reasons. One can justify the assumption that one farm follows the strategy of quantity leadership, whereas others abandon this option (Varian, 1992, p. 298). The irreversibility of investments is important in that it allows the quantity leader to signal believably the strategy of inevitable growth (Woeckener, 2007, p. 22). Therefore, quantity followers assume an inelastic reaction of quantity leaders. In turn, the followers reduce their demand stronger than in the case of a Cournot equilibrium. A so-called Stackelberg equilibrium results (Varian, 1992, p. 296). Based on the Stackelberg equilibrium, we deduce our third hypothesis: *If only few large farms exist in a region, these are expected to grow rather rapidly. At the same time, the smaller farms grow even less, causing the effect of a "disappearing middle."*

The equilibria above are derived under the assumption of linear reaction curves. However, under rents of the status quo it seems more plausible to presume nonlinear reaction curves. A rather elastic reaction of followers is expected, in particular if they face a highly consolidated demand of the quantity leaders. However, the rents are connected with the existence of a farm, thus, the single quantity leader cannot expect strong reactions in certain ranges of the followers' reaction curve. Two alternative scenarios could appear subsequently. First, in the presence of rents of the status quo, a further rise in demand of a single quantity leader does not cause a further reduction of demand on the followers' side. This would be a threat for the farms' stability and therefore for the realization of status quo rents. Second, due to diminishing returns to scale and imperfect markets for labor and capital the potential quantity leader would be restricted with respect to his individual growth strategy. If the quantity leaders expand their demand for land in a coordinated manner due to favorable macroeconomic conditions, a strong reaction of the followers would be expected: the followers lose trust in the midterm stability of their farm due to the jeopardized competitiveness on the market for land. As a result, the followers switch their role towards suppliers for land and this relaxes the situation on the land market.

Based on these alternatives, we deduce our fourth hypothesis: *If in regions with a high share of potential quantity leaders or with a few large farms in times of favorable economic conditions these farms simultaneously raise their demand for land and might clear the market for land. For these regions, under favorable economic conditions a high exit mobility of smaller farms and a high upward mobility of larger farms is expected. This results in a higher mobility that fosters a further differentiation of medium farms. Therefore, a differentiated reaction of farms towards macroeconomic changes is expected, depending on the regional distribution of land due to the competition effect.*

Finally, we aim to test the impact of the initial conditions on structural development. Decisions of farmers rely on expectations about the decisions of the surrounding farms. Expectations of farmers are determined by the development of the regional farm structure in the past and therefore by the initial (historic) conditions and the respective situation (equilibrium) on the land market. The fifth hypothesis deals with different historic farm size structures: *In regions with dominant farms on the land market in the past we expect less mobility of medium farms today, regardless of the current farm size structure.*

3. Empirical model

We describe how we attempt to test the derived hypotheses. In a first step, we analyze farm growth, decline, and exit jointly by means of a Markov chain model. In a second step, we aim to explain the growth, decline, and exit by means of structural variables. We calculate mobility measures in a further step; these are used to compare the adjustment behavior of farms in different regions. Lastly, we derive the technical hypotheses based on the mobility measures and the impact of the explanatory variables.

3.1. The Markov chain model

We refer to an intertemporal value function maximization approach. It is assumed that a representative farm maximizes its expected utility over an infinite planning horizon. The usual constraints involve agricultural production, income, and uncertainty of future revenues. Presuming that all farms behave according to this optimal stochastic control problem, based on such a model it can be shown that the optimal farm size evolves according to a Markov chain (a similar approach can be found in Stokes (2006)).

The Markov chain model characterizes a stochastic process in terms of a sequence of random vectors that have the Markov property. The Markov model is defined by a set of states, i.e., the size classes, and the respective transition probabilities. The transition probabilities reflect the probability of a farm to move from one size class to another within one period or alternatively to stay. Such moves reflect farm growth, decline, exit, or persistence in the respective size category. Thus, the Markov chain approach allows investigating responses at the micro level in an aggregate manner without directly modeling these farm-level responses. Such behavior is reflected by the transition probabilities. The Markov chain model combines farm growth, decline, and exit of farms and allows the analysis of the interaction among farms within a pre-defined region.

We assume that firm size in the agricultural sector can be divided into three size categories (small, medium, and large) measured in terms of acreage. To these size classes we add an additional inactive category that allows modeling exit from the active size categories. The Markov chain model relates the vector of the regional farm size distribution at time t and the farm size distribution at time $t-1$ by means of the transition probabilities reflecting the likelihood of each farm to move from one size class to another or to remain. The model is given by

$$n_{itj'} = \sum_{j=0}^{J} n_{it-1,j} \cdot p_{ijj'}(t), \tag{1}$$

where n_{itj} denotes the number of farms in the jth category at time t in region i where $i = 1, \ldots, N$, $t = 1, \ldots, T$ and $j = 0, 1, \ldots, J$, and $j' = 0, 1, \ldots, J$. The probability of transition from size class j at time $t-1$ to size j' at time t is denoted by $p_{ijj'}(t)$; all probabilities fulfill the following properties

$$\sum_{j=0}^{J} p_{ijj'}(t) = 1 \quad \forall i = 1, \ldots, \mathrm{N};\ \forall t = 1, \ldots, T, \tag{2a}$$

and

$$0 \leq p_{ijj'}(t) \leq 1. \tag{2b}$$

The transition probabilities are unknown and must be recovered by use of the data. The maximum likelihood estimator of the transition probabilities coincides with the direct derivation of the probabilities if the individual transitions are observed (Gourieroux, 2000). The transition probability of moving from j to j' is derived as the relation between the number of transitions from class j to j' and the number of firms in class j. The resulting regional transition probability matrices (TPMs) are subject to further analysis.

It is very unlikely that the Markov chain is stationary and it is expected that the transition probabilities vary over time. Our data allow us to derive regional transition probabilities that vary over two periods (1999–2003; 2003–2007). By means of the multinomial formulation it is possible to express the series of the log of a ratio of probabilities as a linear function of the explanatory variables. The Markov chain model has J sets of probabilities, one for each row of the TPM (MacRae, 1977). Thus, there are J sets of ratios whereby the transition probability from the last column of $\mathbf{P}$ is used as the denominator. Additionally, we add an error term $u_{itj'}$ with zero mean and finite variance to account for disturbances that are not observable. The log odds ratio model is

$$\log\left(\frac{p_{ijj'}}{p_{ijJ}}\right)_t = Z_{it}\beta_{jj'} + u_{itjj'}, \tag{3}$$

where Z_{it} denotes a k by TN matrix of explanatory variables that vary over the regions and/or time, where $j = 0, 1, \ldots, J-1$, $j' = 0, 1, \ldots, J-1$, $i = 0, 1, \ldots, N$, and $t = 1, 2$. The use of the log odds ratio maps the range of the endogenous probability from a zero-one interval to the range of minus infinity to plus infinity for the log odds ratio.

The model of Eq. (3) refers to a system of equations. Due to the regularity-constraints of the transition probabilities (2a) and (2b) the equations are not independent. We allow for cross equation correlations and implement the system as a set of seemingly unrelated regressions (SUR).[3] We employ joint estimation of all equations by the generalized least squares method, thereby accounting for possible correlations among the error terms in different equations. The estimated parameters in the k by $J-1$ vector $\beta_{jj'}$ denote the impact of the respective explanatory variables on the log odds. These are calculated based on the relation of the transition probability from category j to j' relative to the move from j to J in region i.

3.2. Mobility measures

The region specific TPMs reflect a certain degree of farm mobility over the size classes (Jongeneel and Tonini, 2008). In order to compare the results we use mobility indices, which map the mobility information inherent in the TPM into a scalar metric. Referring to Shorrocks (1978) an overall mobility index M_{it}^{OV} is defined for TPMs that have the quasi-maximal diagonal property. This implies that the highest values are on the main diagonal such that the trace of the TPM is at least one, $tr\{\mathbf{P}(t)\} \geq 1$. Thus, the overall mobility is defined as

$$M_{it}^{OV} = [J - tr\{\mathbf{P}(t)\}] \cdot [(J-1)]^{-1}, \tag{4}$$

where $tr\{\mathbf{P}(t)\}$ denotes the trace of the TPM. If there is no mobility the TPM would be an identity matrix and the trace of the TPM would be equal to J. In this case, M_{it}^{OV} would be equal to zero. In case of perfect mobility and given the quasi-maximal diagonal property, M_{it}^{OV} is equal to one. In order to be more precise with respect to the direction of mobility changes, we refer to Huettel and Jongeneel (2008), and use three further mobility indicators that allow decomposing the mobility into upward, downward, and exit mobility. These can be interpreted as shares of the overall mobility and sum up to one. Probabilities in the lower (off-diagonal) triangle part of the TPM indicate downward mobility. In contrast, the upper triangle represents upward mobility. The aggregation of the diagonal mobility elements gives a sum, which is exactly equal to the aggregated value of all off-diagonal terms. This sum of the mobility part of the diagonal, $\sum_{j'}(1 - p_{ij'j'}(t))$, is used as a "deflator" in the upward and downward mobility indices (Huettel and Jongeneel, 2008).

The upward mobility index M_{it}^{U} is defined as

$$M_{it}^{U} = \left[\sum_{j}\sum_{j'>j} p_{ijj'}(t)\right] \cdot \left[\sum_{j'}(1 - p_{ij'j'}(t))\right]^{-1}. \tag{5}$$

If there is full upward mobility and no other mobility the index would be equal to one, because the sum of the probabilities

[3] We refer to SAS 9.1.3 "Proc Syslin."

in the upward triangle of the TPM would then exactly equal the sum of the mobility part of the diagonal elements. If there is no upward mobility the index would be zero because then the sum of the probabilities of the upper triangle of the TPM would be equal to zero. It should be noted that the upward mobility usually includes also entry-probabilities; however, as these are negligible in our data set, we abstained from modeling them and therefore exclude them from the upward mobility measure.

Likewise, the downward mobility, M_{it}^D is defined as

$$M_{it}^D = \left[\sum_j \sum_{j'<j, j'\neq 0} p_{ijj'}(t)\right] \cdot \left[\sum_{j'} (1 - p_{ij'j'}(t))\right]^{-1}. \quad (6)$$

If only downward mobility existed this index would be one, and if no downward mobility is present, this measure would be equal to zero. With regard to exits, we define the following mobility index:

$$M_{it}^E = \left[\sum_j p_{ij0}(t)\right] \cdot \left[\sum_{j'} (1 - p_{ij'j'}(t))\right]^{-1}. \quad (7)$$

3.3. Hypotheses

We aim to explore the differences between the transitions for two periods within eight years. The first period refers to 1999–2003; the second period refers to 2003–2007. The two periods allow further to account for differing macroeconomic conditions. In the appendix we provide in Fig. A.1 the German farmers' assessment of their economic situation and future prospects. It clarifies that period one is characterized by a more positive initial situation followed by a negative development, whereas the reversed characterization holds true for period two. Unfortunately, it remains unclear whether expectations are coined more strongly by the initial situation or the following trend.

With reference to the theoretical hypotheses outlined above, we define the hypotheses technically in terms of the mobility indicators. These technical hypotheses are those that are tested.

We expect less **overall mobility** in regions with an equal distribution of land among farms compared to regions with a more concentrated land distribution. Regions showing equally distributed land imply less competitive behavior on the land market (first hypothesis).

Higher **downward and exit mobility** is expected in regions with higher competition, i.e., in regions that show a rather unequal land distribution among farms (third hypothesis).

For regions characterized by farm size structures that allow farms with a high growth potential to crowd out competitors on the land market, we expect the most pronounced differences in the **overall mobility between years** of good and years of bad economic conditions (fourth hypothesis).

The classification of the regions is obtained by means of a cluster analysis. The consolidation of the land distribution among farms is measured by the Gini coefficient of 1999. In order to be precise about the concentration, further the average farm size in the available region (NUTS III), the share of small farms, the share of farms with more than 100 hectares (ha) and the share of part time farms are used to classify the regions.

For the second stage log-linear model as shown in Eq. (3), we consider several exogenous factors in order to quantify the impact of those on the log odds ratio of the transition probabilities. The technical hypotheses are as follows.

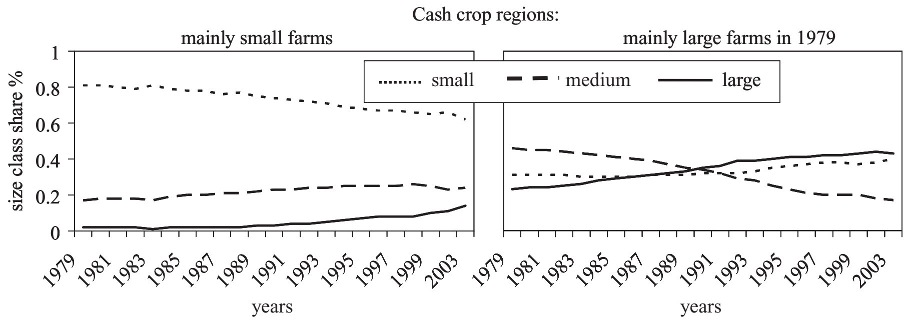
Gini coefficient 1999. This coefficient represents the inequality of the distribution of land among farms within a region in the year 1999. It accounts for a dependence on the current farm size structure. The higher the inequality of the land distribution the higher is the expected mobility in these regions (first and third hypothesis).

Share of the small farms 1999. This measure gives the percentage share of the number of small farms in 1979. Only by controlling the share of small farms, the Gini coefficient unambiguously expresses the dominance of large farms in terms of occupied land. On the other hand, in the presence of many small farms the possibility to exert market power of large and medium farms is reduced. According to hypothesis one, the mobility of the many small farms is also expected to be relatively low. Thus, we expect in terms of the transition-probabilities that the chance to persist in the respective class increases with the share of small farms (first hypothesis).

Gini coefficient 1979. This Gini coefficient for the year 1979 accounts for a possible dependence of the current decision to grow, decline or exit on the initial farm size distribution. The simultaneous significance of the Gini coefficients of 1979 and 1999 indicate the impact of initial (historic) and current conditions on structural change (fifth hypothesis). An initially high market power of the dominant large farms should have caused little opportunity for growth for small and medium-size farms. Due to the resulting expectations on their future perspectives, farms in such regions are expected to show a rather low level of mobility inevitable of the current farm-size structure.

Share of the small farms (1–30 ha) 1979. A significance of this measure indicates the dependence of the structural change today on the historic economic environment (fifth hypothesis). A high share of small farms allowed these farms a slow but constant growth. Therefore, in the respective regions a relatively high upward mobility of small and medium farms is expected, independent of the current farm-size structure.

Gross value added 1999. This measure reflects the regions' potential of the primary sector in 1999. The higher the potential of primary production, the higher are the potential status quo rents. Further, high capital intensity and sunk investment costs



Source: Statistisches Jahrbuch ilber Ernahrung, Landwirtschaft und Forsten, diverse Volumes.

Fig. 1. Development of the farm size distribution of cash crop regions.

are more likely compared to regions with a low gross value added. Both aspects are expected to reduce overall mobility further in regions, which are dominated by quantity-followers (second hypothesis).

Number of cows per hectare in 1999. The higher the number of cows per ha in a region the higher is the capital specifity and we expect higher rents of the status quo. Higher rents of the status quo are expected to reduce the mobility (second hypothesis).

Years/time. Our only time-related hypothesis concerns expected differences between regions (hypothesis 4). We test it by the mobility-indices (see above). In the current model, the covariate for time is introduced in order to control for simultaneous differences between all regions without taking into account the expected heterogeneity of the coefficient.

4. An application to structural change in the West German agricultural sector

A rather strong consolidation process characterizes the West German agricultural sector.[4] The number of farms declined from 827,200 farms in 1979 to 374,500 farms in 2007, whereas the average farm size increased from 14.4 ha to 46 ha in 2007. This indicates an ongoing structural change. The West German agricultural sector offers many regionally differentiated farm distributions by land, by size, and by specialization. In order to explore these differences further we start with some background information and the descriptive analysis of the data set, this is followed by the results of the Markov model and the log-linear regression system.

4.1. Background information and data

Regionally differing patterns of structural change can already be shown by means of the development of the share of the size class counts over time. In Fig. 1 the development of the farm size distribution from 1979 until 2005 for two cash crop regions is shown. The left part represents the evolution for a clustered cash crop region that showed a small average farm size in 1979 (12 ha) and in the right part, the farm size distribution is presented for a clustered cash crop region with a large average farm size in 1979 (28 ha). Comparing both developments it becomes obvious that the share of the medium and large farms in the small-sized cash crop region increases slowly whereas the small farms' share declines slowly. Contrarily, the share of the medium farms in the large-sized cash crop regions shows a strong decline over time with a more or less stable share of the small. This already indicates how structural change might depend on initial conditions and might lead to different local optima.

In order to explore this relation we refer to the data provided by the Research Data Centre of the Federal Statistical Office and the statistical offices of the German Laender (FDZ). These data refer to the Agricultural Census including 441,485 active farms in the Western Federal States in 1999. The years 1999, 2003, and 2007 are available and used for the subsequent analysis. The resulting transition probabilities are aggregated at the NUTS III level (Landkreis) leading to 327 region specific TPMs. We define three size classes, viz. small (1–30 ha), medium (30–50 ha), and large (>50 ha) and the additional exit class; we use the same size class classification for all regions to ensure the comparability between the regions.

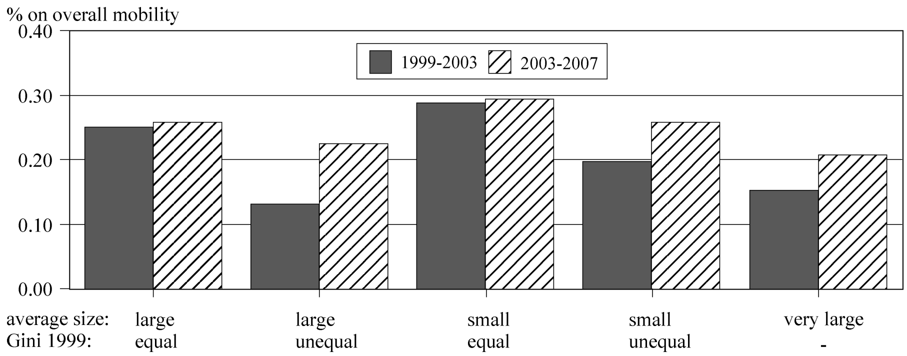
For the explanatory variables, we use further data from the agricultural census, which is available for the years 1979–2005. Because these data represent the farm individual data in an aggregate manner, it is possible to combine both data sets. In the regression analysis, we refer to the centered variables derived as the deviation from their mean. The centering of variables does not affect the estimated coefficients or standard deviations. It only simplifies the interpretation of coefficients in the subsequent step. This is done by comparison of their partial effect in relation to the intercept. Due to the centering of the variables, the intercept is meaningful, because it represents the transition-probability when all covariates take on their mean value. Further, the number of farms within a region and a dummy indicate

[4] We abstract from analyzing the East German sector. The East German agricultural sector shows a number of peculiarities that we cannot account for.

Table 1
Summary statistics of the main explanatory variables

Variable	Mean	Standard deviation	Minimum	Maximum	N^*T
Gini 1979	0.446	0.100	0.275	1.053	646
Share of the small in 1979	0.683	0.168	0.239	1.000	646
Gini 1999	0.541	0.080	0.315	0.742	654
Share of the small in 1999	0.298	0.149	0.025	0.786	654
Gross value added 1999 per ha	51.948	38.948	1.739	217.437	649
Number of cows per ha 1999	0.285	0.212	0.000	1.085	654

Source: FDZ, Agricultural Census 1979, Arbeitskreis Volkswirtschaftliche Gesamtrechnung.
Note: The different observation numbers are due to missing values in the data set.



Source: Own calculations based on FDZ 1999–2007.

Fig. 2. Upward mobility.

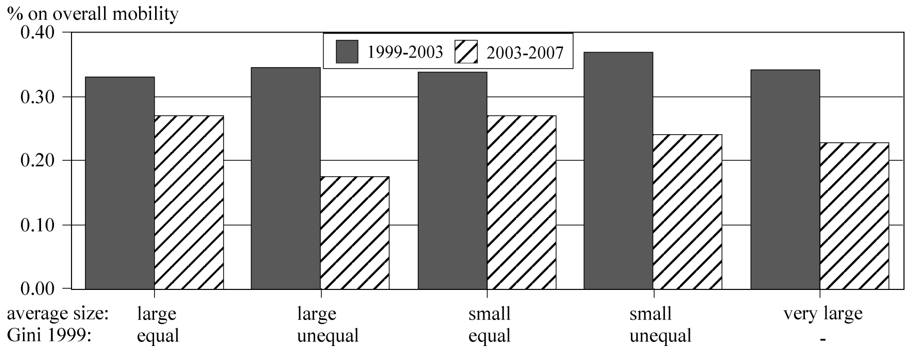
regions with only few farms (less than 60) are used as additional variables to reduce the overall high heterogeneity of the data set. The summary statistics of the main variables can be found in Table 1.

4.2. Results

The means of the derived transition probabilities are presented in the appendix in Table A.1. The regional transition probabilities are difficult to present. Instead, we use the mobility indicators for different regional clusters of representative farm structures to compare the probabilities to grow, decline, and exit for all farm sizes. In what follows, we explore the variation in mobility over the regions. According to the cluster analysis (see subsection 3.3), we differentiate between five different regional groups. "Small and equal" represents cluster regions with a rather low average farm size of 23 ha in the mean and a more or less equal distribution of land among farms. "Small and unequal" describes the cluster regions with 20 ha farm size on average and a rather unequal land distribution according to the Gini coefficient. "Large and equal" describes the cluster regions with a comparably large average farm size (mean of 32 ha) and equal land distribution (Gini 0.51). "Large and unequal" refers to a large average farm size in combination with a high Gini coefficient (0.58). Further, we use "very large" as cluster regions with an average farm size of 53 ha in the mean. Further details can be found in Table A.2 in the appendix.[5] The mobility indicators are visualized in Figs 2–4.

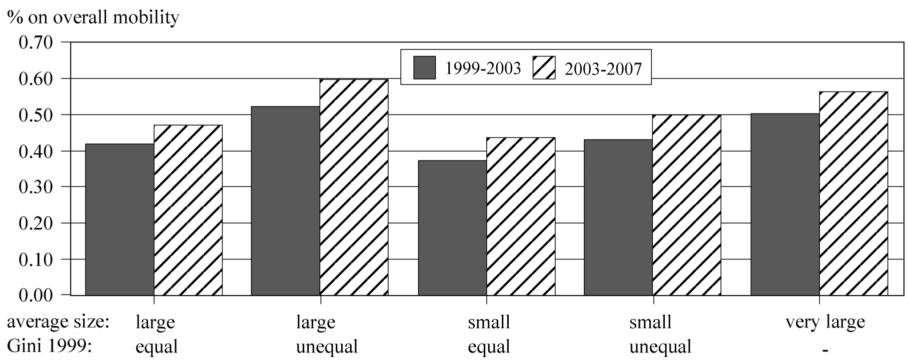
The *upward mobility* (Fig. 2) can only be detected for small and medium farms due to the size class definition. It is highest in regions characterized by a small average farm size and an equal distribution of land among farms. This finding supports the hypothesis that in such regions many farms grow, but rather slow whereas the differences between the years are negligible. For the "unequal" regions and those characterized by very large farms, the upward mobility is higher in the second period (2003–2007). The second period is characterized by a positive trend in economic conditions (as shown in Fig. A.1 in the appendix) that probably stimulates positive expectations and therefore enables simultaneous growth of farms with high potential for growth.

[5] In a similar manner regional clusters with respect to regionally dominant types of production and the economic environment are derived. These clusters serve to control for further exogenous influences, which might be correlated with defined farm structure. The detailed characteristics of the clusters are summarized in the appendix in Tables A.3 and A.4. The variance of the mobility indices then has been partitioned among clusters with the help of a variance analysis (MANOVA), the results are shown in the appendix (Table A.5). The respective mobility indicators for the farm structure clusters have been derived as conditional means by controlling for the impact of economic and production type clusters in the variance analysis.



Source: Own calculations based on FDZ 1999–2007.

Fig. 3. Downward mobility.



Source: Own calculations based on FDZ 1999–2007.

Fig. 4. Exit mobility.

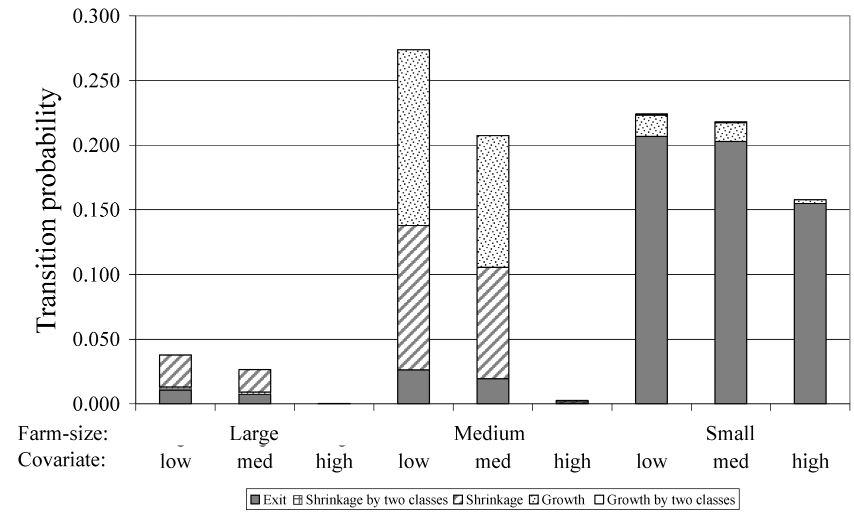
Correspondingly, the highest difference for the *downward mobility* (Fig. 3) is observed in the "large-unequal" region, too. The simultaneous growth of farms with a high potential to grow ousts less competitive farms out of the land market in years characterized by economic booms (second period). The stabilizing strategy of shrinking in period two is mainly realized within regions characterized by an equal distribution of land.

This interpretation is further confirmed by the increase in the exit mobility in contrast to the decrease of downward mobility in the second period (Fig. 4). Farms with low competitiveness on the land market prefer exiting towards shrinking as a strategic option in years of economic booms, which is due to rising demand and willingness to pay for land of competitive farms.

As expected the *exit mobility* (Fig. 4) shows the highest shares for regions characterized by a large average farm size. The exit mobility is even higher in regions with a large average farm size and an unequal land distribution. This indicates a higher competition in such regions and the pressure on small farms to exit the sector.

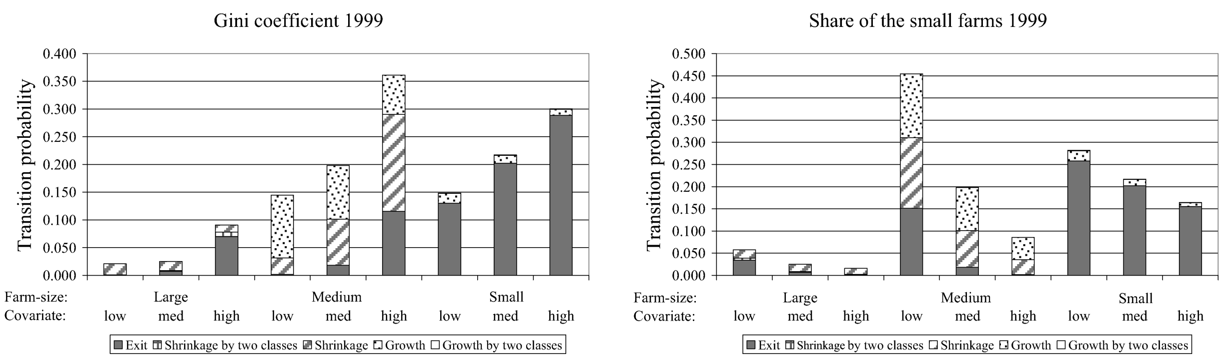
In a second step, the derived transition probabilities are analyzed using the log-linearized model as given in Eq. (3). The R^2 shows with 0.24 an acceptable value in the presence of the high heterogeneity of the data set. The resulting parameter estimates are presented in Table A.6 in the appendix. The coefficients express the covariates' influence on the relation between the transition probabilities and the probability to move to (remain in) the class of large farms (the odds). However, the estimated coefficients are difficult to interpret due to the simultaneous variation of enumerator and denominator. A direct interpretation of the coefficients in the light of the hypotheses is not possible. In order to relate the results directly to our hypotheses, a direct dependency of each probability to the respective covariates is derived. Transforming the log-odds ratio given in Eq. (3) and using the row sum condition from Eq. (2a), it is possible to derive the effects of the covariates on the probabilities. Due to the multiplicative relationship of the coefficients we present the effects of a specific covariate with low, medium, and high values adding the intercept and holding all other covariates fixed.

Figure 5 shows that the overall mobility is lower, the higher the gross value added. Even the exit mobility of the small decreases the higher the gross value added. This has been expected due to possibly higher capital intensity and rents of the status-quo. For some of the medium class' moves the impact of the gross value added is not significant (see Table A.6).



Source: Own calculations based on FDZ 1999–2007.

Fig. 5. Partial effect of the gross value added on the transition probabilities.

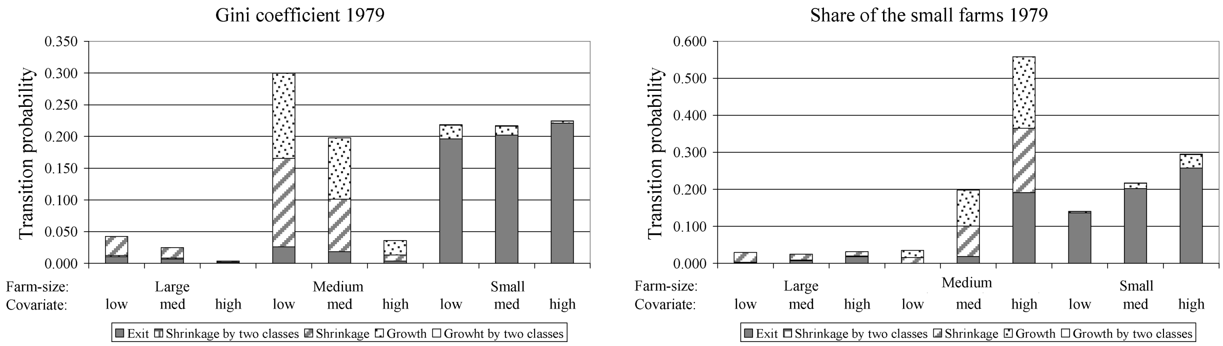


Source: Own calculations based on FDZ 1999–2007.

Fig. 6. Partial effect of the current conditions on the transition probabilities.

The current structural conditions measured in terms of the Gini coefficient and the share of the small farms are significant for the medium and large size class moves and show only a low impact for the small farms' transition probabilities (see Table A.6). Figure 6 shows the partial effects of both covariates. The covariates show opposed effects. The higher the inequality of the land distribution (the Gini coefficient) is in 1999, the higher is the overall mobility for all size classes. A more detailed analysis reveals that it is exit and downward mobility, which grows, whereas upward mobility of small- and medium-size farms declines. This shows that regional concentration tendencies lead to growth of the large on the one hand and farm closure and possible part-time farming on the other hand. Contrarily, the higher the share of the small farms in 1999, the lower the overall mobility. With respect to small and large farms mainly the exit mobility is reduced, whereas for medium-size farms less downward and upward mobility is observed, too. This corroborates the hypotheses that if small farms dominate, a Cournot-equilibrium with reduced mobility prevails, which in this case hinders especially the growth of medium-size farms.

The initial farm size structure conditions measured in terms of the Gini coefficient 1979 and the share of the small in 1979 are significant for the medium and large farms' probabilities (Table A.6). For the small farms' transition probabilities, the impact is rather low and not significant. As shown in Fig. 7, the initial conditions affect the mobility in more recent years (1999–2007) regardless of the current structure, which has been controlled for. The higher the former inequality of the land distribution (Gini coefficient 1979) is, the lower is the observable mobility today, except for the small farms. The exit probability of the small slightly increases the higher the inequality was in 1979. As expected in regions with historically unequal land distribution upward mobility of medium farms is especially low. The opposed effect to the concentration in the past is the de-concentration that is measured in terms of the share of the small farms. The higher the share of the small farms was in



Source: Own calculations based on FDZ 1999–2007.

Fig. 7. Partial effect of the initial conditions on the transition probabilities.

the past, the higher is the mobility of small and medium farms today. A high initial share of small farms corresponds to a potential for restricted growth for a maximal number of farms. On the other hand, large farms have significant lower potential for growth. Maybe as a consequence, their exit mobility is significantly higher, where the share of small farms was higher initially (Table A.6). These findings indicate that farm level decisions depend on expectations, which concern the decisions of others and have been coined in the past.

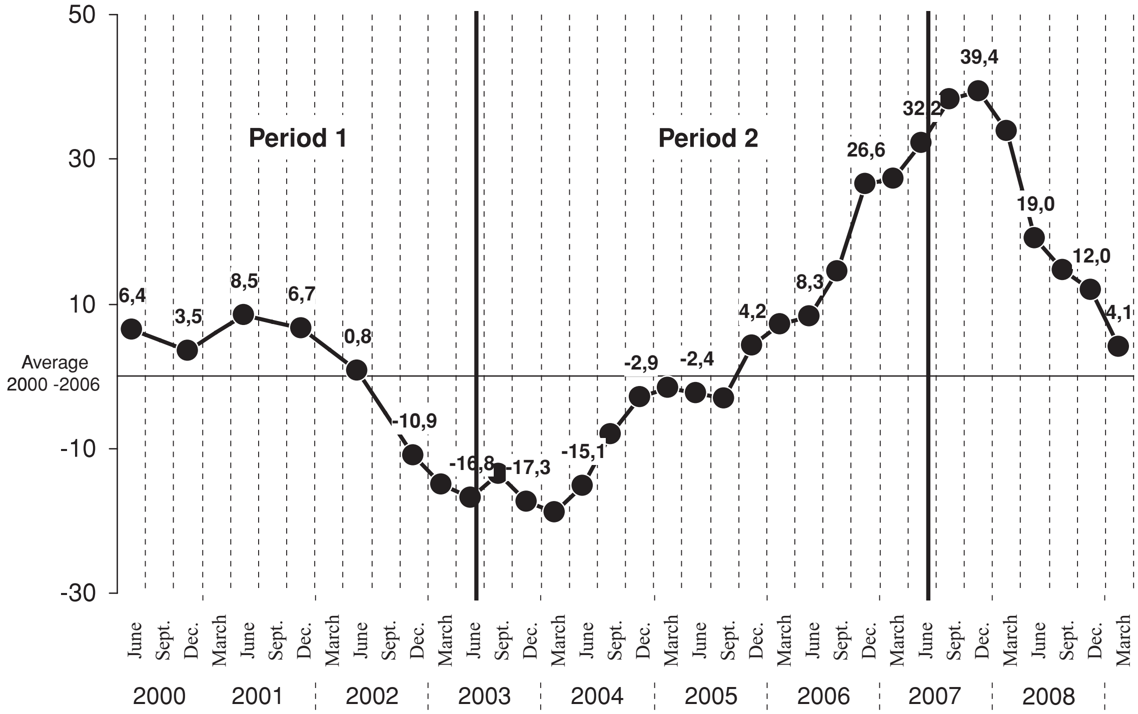
According to a joint *F*-test for the estimated system of equations the number of cows per hectare does not have a significant impact upon the transition-probabilities. Therefore, we abstain from a further interpretation of the estimated coefficients. The differences between the periods have been analyzed in a regionally differentiated manner based on the mobility measures above. The single transition-probabilities only show general significant differences in time with respect to transitions of small farms (Table A.6). In the light of the results of the analysis of the mobility-measures this might be a hint on the fact that actually the expected heterogeneity of the effect is too big in order to be significant.

5. Summary, conclusions, and outlook

The objective of this article is to explain regionally differentiated patterns of structural change based on a theoretical framework. The crucial hypothesis that these patterns rely on strategic interaction of farms on the market for land is tested empirically. Relying on a Markov chain model, we explain individual farm moves between predefined size classes. We make use of now available panel data from the agricultural census including all farms in the West German agricultural sector for the years 1999–2007. The use of mobility indicators allows comparing regions and periods. By means of the multinomial specification of the transition probabilities explaining farm growth, decline, or exit, it is possible to quantify the impact of the current and former farm size structure in the respective region. Further we quantify the impact of variables describing the regional farm structure, thereby indicating market power of the large, the potential of high competition for land within a region, and possibly high rents of the status quo in combination with sunk costs. The results confirm the relevance of strategic interaction as a crucial determinant of regionally different structural change and persistent regional differences in the farm size structure over time. Thus, we conclude that the classical view that farm individual restrictions cause the persistence of regionally differing structures does not suffice and should be expanded by the implications of strategic interaction among farms. In future work we aim to consider also market entries as an issue that should be tested, even though entries are expected to be negligible. Furthermore, a differentiation between production types in the calculation of transition probabilities and the application of more flexible definitions of growth and decline should be used in future work.

Besides the academic exercise, our results have policy implications such that earlier findings about regionally different patterns of structural change should be corrected in light of our results. First, the effect of structural policies might have been *overestimated* in earlier studies without consideration of the strategic interaction among farms. Our estimation results show that farmers' decisions to exit, decline, or grow depend among other factors on the past development of the farm size structure in the respective region. Further, we can demonstrate that the competitiveness of farms on the land market has a considerable impact on structural decisions. These findings show that structural policies might mainly have supported existing paths rather than having directed the development into certain favored directions. Second, many policy interventions exist in agriculture that do not directly aim at influencing structural change. The nonintended impacts of such policies might have been *underestimated* in the past. In general, subsidies create rents of the sector that might further induce rising status quo rents at the farm level. Our results show that the impact of status quo rents on the regional structural development is not negligible. Due to the repeated interaction of farms on the land market, farmers' reaction towards increasing rents is strategic. Future structural policies should consider these findings.

Appendix



Source: Business- and Investment Barometer of Agriculture, March/April 09. http://www.bauernverband.de/?redid=301312.

Fig. A.1. Assessment of economic situation and future prospects of German farms.

Table A.1
Means of the derived transition probabilities

Probability	Mean	Standard deviation	Minimum	Maximum	N^*T
P_{10}	0.204	0.070	0.054	1.000	653
P_{11}	0.766	0.077	0.000	0.946	653
P_{12}	0.026	0.018	0.000	0.250	653
P_{13}	0.004	0.021	0.000	0.500	653
P_{20}	0.065	0.083	0.000	1.000	649
P_{21}	0.110	0.071	0.000	0.667	649
P_{22}	0.687	0.121	0.000	1.000	649
P_{23}	0.138	0.072	0.000	0.500	649
P_{30}	0.032	0.051	0.000	1.000	651
P_{31}	0.014	0.022	0.000	0.333	651
P_{32}	0.043	0.047	0.000	0.500	651
P_{33}	0.910	0.069	0.000	1.000	651

Source: Own calculations based on FDZ 1999–2007.

Table A.2
Characteristics of structural clusters

Cluster	N	Average farm size	Gini coefficient	Share of farms <30 ha	Share of farms >100 ha	Share of part-time farms
Small—equal	79	22.64	0.46	0.74	0.01	0.5
		(3.25)	(0.05)	(0.06)	(0.01)	(0.09)
Small—unequal	134	20.12	0.59	0.8	0.03	0.59
		(6.09)	(0.07)	(0.08)	(0.02)	(0.15)
Large—equal	49	31.85	0.51	0.59	0.04	0.36
		(4.21)	(0.05)	(0.06)	(0.02)	(0.10)
Large—unequal	26	36.03	0.58	0.62	0.09	0.58
		(4.22)	(0.03)	(0.04)	(0.03)	(0.06)
Very large	39	53.23	0.54	0.45	0.15	0.36
		(10.24)	(0.07)	(0.10)	(0.05)	(0.09)
All regions	327	27.7	0.54	0.7	0.05	0.51
		(12.24)	(0.08)	(0.14)	(0.05)	(0.15)

Note: Standard deviation in parentheses.
Source: Own calculations based on FDZ 1999–2007.

Table A.3
Characteristics of production-type clusters

Cluster	N	Share of dairy farms	Share of pig and poultry farms	Share of horticulture farms	Share of arable farms	Cows per hectare	Pigs (animal-units) per hectare
Horticulture	38	0.09	0.01	0.63	0.47	0.09	0.11
		(0.06)	(0.01)	(0.16)	(0.21)	(0.08)	(0.10)
Dairy	122	0.64	0.02	0.06	0.16	0.47	0.18
		(0.14)	(0.02)	(0.09)	(0.11)	(0.20)	(0.13)
Mixed	84	0.33	0.03	0.11	0.53	0.20	0.29
		(0.09)	(0.02)	(0.09)	(0.12)	(0.08)	(0.18)
Pig and poultry	35	0.39	0.13	0.07	0.31	0.29	1.03
		(0.11)	(0.04)	(0.07)	(0.10)	(0.11)	(0.41)
Arable farms	37	0.13	0.02	0.19	0.82	0.06	0.16
		(0.07)	(0.01)	(0.13)	(0.10)	(0.06)	(0.12)
Intensive pig prod.	11	0.36	0.29	0.02	0.18	0.27	2.32
		(0.09)	(0.07)	(0.00)	(0.08)	(0.11)	(0.83)
All regions	327	0.40	0.04	0.15	0.38	0.28	0.36
		(0.23)	(0.06)	(0.20)	(0.25)	(0.21)	(0.51)

Note: Standard deviation in parentheses.
Source: Own calculation based on FDZ 1999–2007.

Table A.4
Characteristics of economic clusters

Cluster, characterized by:		N	Share of area covered by buildings	Share of agricultural GVA 1992	Relative change in number of employees	1992: Nonagricultural employees per inhabitant	GDP per inhabitant 1992	Relative change of GDP	2006: Nonagricultural employees per inhabitant	GDP per inhabitant 2006
Population density	Econ. development									
Rural	Positive	105	0.17	0.02	0.10	0.39	18,429	0.41	0.40	24,199
			(0.08)	(0.01)	(0.07)	(0.06)	(3,445)	(0.15)	(0.06)	(5,040)
Purely rural		71	0.11	0.05	0.12	0.35	16,122	0.52	0.38	22,134
			(0.02)	(0.01)	(0.08)	(0.06)	(2,615)	(0.17)	(0.06)	(4,392)
Rural	Negative	51	0.10	0.03	−0.05	0.42	18,657	0.27	0.40	23,253
			(0.03)	(0.01)	(0.06)	(0.06)	(2,632)	(0.12)	(0.05)	(3,427)
Urban	Positive	45	0.50	0.00	0.06	0.74	36,145	0.39	0.76	48,947
			(0.28)	(0.00)	(0.11)	(0.12)	(6,656)	(0.24)	(0.12)	(12,489)
Urban	Negative	53	0.72	0.00	−0.02	0.54	25,695	0.24	0.53	32,023
			(0.41)	(0.00)	(0.06)	(0.09)	(5,073)	(0.12)	(0.09)	(6,077)
All regions		325	0.28	0.02	0.06	0.46	21,599	0.38	0.47	28,302
			(0.30)	(0.02)	(0.10)	(0.15)	(7,735)	(0.19)	(0.15)	(10,978)

Note: Standard deviation in parentheses.
Source: Own calculation based on Arbeitskreis Volkswirtschaftliche Gesamtrechnung and INKAR (Federal Ministry for Civil Engineering and Regional Planning).

Table A.5
Description of variance analysis (MANOVA)

Source	Degrees of freedom	Upward mobility		Downward mobility		Exit mobility	
		Sum of squares	Pr > F	Sum of squares	Pr > F	Sum of squares	Pr > F
Economic	4	0.11	0.024	0.12	0.074	0.07	0.342
Production type	5	0.04	0.548	0.07	0.396	0.10	0.241
Structure	4	0.70	<0.0001	0.06	0.339	0.60	<0.0001
Year	1	0.00	0.640	0.10	0.008	0.07	0.029
Year*economic	4	0.08	0.084	0.08	0.225	0.02	0.792
Year*production type	5	0.04	0.553	0.04	0.649	0.05	0.610
Year*structure	4	0.11	0.019	0.16	0.019	0.01	0.982
R^2		0.18		0.08		0.20	
Pr > F		<0.001		0.00		<0.001	

Note: 642 observations (321 districts for two time periods)
Source: Own calculation based on FDZ 1999–2007, Arbeitskreis Volkswirtschaftliche Gesamtrechnung: SAS Proc GLM.

Table A.6
Results of the log-linearized estimation

Dependent variable	Intercept	Year	Gim 1999	% small 1999	Gim 1979	% small 1979	Gross value added 1999	Number of cows per ha	Number of farms	Dummy if <60 farms per region
$\log(P_{10}/P_{13})$	5.769	0.632	2.720	4.601	0.017	−0.931	1.195	1.537	−0.860	1.505
	(0.153)***	(0.210)***	(2.152)	(1.642)***	(1.529)	(1.266)	(0.461)***	(0.698)**	(0.108)***	(0.598)***
$\log(P_{10}/P_{13})$	7.123	0.714	0.396	7.003	−0.145	−2.028	1.336	1.385	−0.900	1.231
	(0.153)***	(0.209)***	(2.145)	(1.636)***	(1.542)	(1.261)	(0.459)***	(0.695)**	(0.107)***	(0.596)**
$\log(P_{12}/P_{13})$	3.107	0.755	−0.237	2.989	−2.633	1.330	0.626	1.752	−0.670	−1.889
	(0.176)***	(0.242)***	(2.480)	(1.892)	(1.762)	(1.459)	(0.531)	(0.804)**	(0.124)***	(0.689)***
$\log(P_{20}/P_{23})$	−1.662	0.029	10.679	−12.396	−0.152	5.229	−0.067	0.253	0.630	2.336
	(0.193)***	(0.265)	(2.717)***	(2.073)***	(1.930)	(1.598)***	(0.581)	(0.881)	(0.136)***	(0.755)***
$\log(p_{21}/p_{23})$	−0.157	−0.553	5.266	−1.859	−1.140	0.170	0.186	1.065	0.156	1.631
	(0.174)	(0.239)**	(2.447)**	(1.868)	(1.739)	(1.440)	(0.524)	(0.793)	(0.122)	(0.680)**
$\log(P_{22}/P_{23})$	2.115	0.224	0.418	5.684	2.705	−4.054	1.956	0.553	−0.200	3.421
	(0.126)***	(0.173)	(1.774)	(1.354)***	(1.261)**	(1.044)***	(0.380)***	(0.575)	(0.089)**	(0.493)***
$\log(P_{30}/P_{33})$	−4.936	−0.189	11.778	−11.687	−2.410	3.020	−1.918	−0.719	1.044	−1.107
	(0.160)***	(0.219)	(2.245)***	(1.713)***	(1.595)	(1.320)**	(0.480)***	(0.728)	(0.144)***	(0.624)*
$\log(P_{31}/P_{33})$	−6.405	−0.261	8.437	−8.592	−2.009	0.955	−1.971	−0.058	1.279	−1.079
	(0.178)***	(0.245)	(2.508)***	(1.914)***	(1.782)	(1.475)	(0.537)***	(0.813)	(0.125)***	(0.697)
$\log(P_{32}/P_{33})$	−4.091	−0.304	−0.912	−1.273	−3.632	−1.118	−1.917	−0.217	0.607	−3.191
	(0.146)***	(0.200)	(2.052)	(1.566)	(1.458)***	(1.207)	(0.439)***	(0.665)	(0.102)***	(0.570)***

Source: Own calculations based on FDZ 1999 − 2007; SAS Proc Syslm, SUR.
Note: The variables are centered around their mean. ***, **, and * denotes significant at the 1%, 5%, and 10% level.

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