Farm Growth and Land Concentration

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Selected Paper prepared for presentation at the 2020 Agricultural & Applied Economics Association Annual Meeting, Kansas City, MO
July 26-28, 2020

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Abstract

Structural change in agriculture is characterized by the interdependency of farms' growth decisions due to the limited availability of the production factor land. This paper adds to the sparse empirical literature on the relation between land market concentration and farm size changes, considering different definitions of the relevant market. Using data from the Integrated Administrative Control System (IACS) from 2005 until 2017 for Brandenburg, Germany, we find that about half of the land transactions occur beyond municipality borders. This emphasizes the importance of carefully defining the relevant market. The descriptive analysis shows that although concentration rates, on average, did not increase over time, spatial differences are present. In the econometric analysis, we apply a two-stage model to analyze how competition for agricultural land impacts the probability and level of expansion. It shows that for farms that remained active between 2005 and 2017, farms that defragment are less likely to expand. Moreover, we find that the expansion behavior between groups of small and large farms differs with increasing inequality. One potential reason for this might be the existence of market power in land markets.

Keywords: farm growth, concentration measures, agricultural land markets, structural change, IACS

JEL codes: Q13, Q24

Acknowledgements

Financial support from the German Research Foundation (DFG) through Research Unit 2569 "Agricultural Land Markets – Efficiency and Regulation" (https://www.forland.hu-berlin.de/) is gratefully acknowledged. Moreover, we are grateful to the Ministry for Agriculture, Environment and Climate Protection (MLUK) Brandenburg for granting us access to the IACS dataset.

1 Introduction

Structural change in the agricultural sector of developed economies is broadly characterized by a declining number of farms and an increasing size of surviving farms. Accordingly, the strategic choice of farms is often summarized as “grow or go”. Much effort has been spent in the agricultural economics literature to describe the dynamics of structural change and to understand its drivers. Piet et al. (2012) provide an overview on these drivers that were identified in empirical studies. Among these drivers is the profitability of farming, which covers aspects such as input and output prices, the efficiency of farming activities, return to farming, animal diseases, and off-farm employment possibilities (e.g., Foltz 2004, Breustedt and Glauben 2007, Ihle et al. 2012). More potential drivers are the age or education of the farm holder, clustered under the term human capital (e.g., Möllers and Fritzsch 2010, Saint-Cyr et al. 2019). Furthermore, the (treatment) effect of agricultural policy instruments on structural change and farm survival have been extensively studied. This includes the analysis of (de-)coupled governmental payments and the general policy environment (e.g., Breustedt and Glauben 2007, Key and Roberts 2007, Ihle et al. 2012, Bartolini and Viaggi 2013, Storm et al. 2015).

The phrase “grow or go”, however, highlights another important feature of structural change: the interdependence of strategic farm decisions due to the limited availability of the core production factor land. Clearly, expansion in farm size is only feasible if other farms decide to shrink or quit. This interdependency relates structural change in agriculture to competition in land markets. Competition in land markets is explicitly considered in agent-based models of regional structural change, as suggested in the seminal paper of Balmann (1997). These studies focus, in general, on a switch in the policy regime (e.g., Happe et al. 2008, Brady et al. 2009) and more specifically on effects induced by the implementation of single policy measures, such as the introduction of the German Renewable Energy Act (Appel et al. 2016) or implementation of Ecological Focus Areas in the European Union's Common Agricultural Policy (Sahrbacher et al. 2016).

Though it is widely acknowledged that spatial competition in land markets constitutes the mechanism by which farm size adjustment takes place, it is hard to implement this idea in empirical models of structural change (in contrast to optimization models, such as spatially explicit agent-based models). Nevertheless, there are a few attempts to capture competition and neighborhood effects when explaining farm size changes or farm exit. Storm et al. (2015) investigate farm survival in Norway in a spatially explicit setting by emphasizing spatial interdependencies. They find that farm survival not only depends on the amount of own direct payments received, but on the direct payments neighboring farmers receive and argue that ignoring this spatial interdependency would overestimate the effect of own payments. Saint-Cyr et al. (2019) further develop spatial dependency concepts in a structural change context by evaluating the impact of the limited production factor land. Analyzing exits from farming in Brittany, France, they argue that a neighbor's farm size may affect a farmer's decision to remain active. Identifying three farm types, they find both positive and negative effects of neighboring farm size on farm survival.

Against this background, this paper adds to the sparse empirical literature on the relation between land market competition and farm size changes. Hereby, it takes advantage of the spatially explicit and detailed information included in the Integrated Administrative Control System (IACS) dataset. We exemplarily show how this data can be applied to track farm size development over time and to measure the concentration of agricultural land. This helps answer a couple of relevant research questions: How concentrated is the agricultural land market in Brandenburg and does land concentration steadily increase over time? How to define the relevant market size for the assessment of concentration in land markets? How do internal farm characteristics, such as size and fragmentation, and land market competition affect land acquisition decisions? Our results add to the discussion about tighter regulations of agricultural land markets (cf. Balmann 2015, Odening and Hüttel 2018). A major concern about unregulated land markets is that the resulting allocation of land fosters an undesired agricultural structure in a sense that large industrialized farms gain competitive advantage over smaller family farms and that young farmers with financial constraints cannot compete with financial investors.

The remainder of this article is structured as follows: In the next section, we describe the theoretical framework of our analysis by briefly reviewing economical concepts and the relevant literature; Section 3 describes our study region and the available data; Section 4 describes the spatial development of farm sizes and derives land concentration indicators based on alternative definitions of the relevant market; Section 5 applies these concentration indicators to assess the impact of land market competition in the expansion behavior of farms by means of a Heckman model; and Section 6 concludes and discusses the policy implications of our findings.

2 Theoretical Background

The dynamics of firm growth is subject to various theoretical models and empirical studies. Perhaps the most basic model is Gibrat's law. It states that firm size and growth are independent, meaning that firms in an industry grow proportionally at a constant rate, irrespective of the initial size and past growth pattern (Sutton 1997). Assuming further that firms' (stochastic) growth rates are independent of each other implies a lognormal distribution of firm sizes. The validity of Gibrat's law can be tested under different scenarios. In its most general form, this "law" applies to all firms in an industry, including shrinking and exiting firms, while more restrictive analyses consider only firms that survived in a given time period. Most empirical studies conclude that Gibrat's law is rejected in general, but that it may hold true for subsamples of some industries (Santarelli et al. 2006). For the agricultural sector, Weiss (1998) provides evidence against proportionate effects. This finding is not too surprising because the independence assumption of growth rates among farms is apparently violated due to the fixed supply of land, at least if farm size is measured by land endowment. Another concern about Gibrat's law is that it has little economic content. Actually, it claims that individual growth rates are random. Since Weiss (1998), many studies have proposed economic variables that should condition the growth rate distribution of farms based on behavioral assumptions, particularly profit maximization. In the context of our analysis, it is useful to group the variables that impact the incentive to grow into two categories, namely internal farm characteristics and land market competition measures.

Internal farm characteristics affecting farm growth

It is widely acknowledged that agricultural production is characterized by both economies and diseconomies of size, which is reflected by an s-shaped relation between size (land) and farm output (e.g., Raup 1969, Alvarez and Arias 2004, Zhang et al. 2019). Economies of size may result from the indivisibilities of production factors, such as machinery, buildings, and (family) labor. Diseconomies of size can be explained by increasing transportation costs and complexity of coordinating and monitoring production processes in large farms. These counteracting forces suggest the existence of an "optimal" farm size. Clearly, optimal farm size differs between farm types and changes over time according to technical progress. In addition, it is likely that minimal average production costs are constant for a broad range of farm sizes (Rasmussen 2011). Thus, we hypothesize that medium sized farms have a larger incentive to grow compared to large farms, which are already close to the region of optimality (Hypothesis 1). The indivisibility of some production factors also implies a minimal farm size, below which farm income does not cover living costs. Since rapid growth is accompanied by large adjustment costs, quitting agriculture or switching to part-time farming is often the only feasible option for small farms.

Another strand of literature relates productivity to size adjustments, as well as to the entry and exit of firms. Hopenhayn (1992) analyses the dynamics of an industry with endogenous entry and exit. The model considers a perfectly competitive but heterogeneous industry where firms differ with respect to their productivity level, which is stochastic. The firm-specific optimal output (i.e., their size) is a function of the endogenous output price and productivity. In this modeling framework, the size distribution is stochastically increasing with age, meaning that larger firms have a higher probability of survival. Kersting et al. (2016) extend Hopenhayn's model by introducing a sectoral constraint for a production factor.[1] They find that a tradable limited production factor does not necessarily reduce the speed of adjustment within the industry since a tradable quota increases the liquidation value and provides an incentive for inefficient firms to cease production.

The aforementioned stochastic dynamic equilibrium models consider productivity as an exogenous variable, but many attempts have been made in the literature to disentangle the relation between production efficiency and farm size by linking efficiency to other factors, e.g., natural conditions or managerial skills (cf. Ford and Shonkwiler 1994, Lakner 2009, Byma and Tauer 2010). In the context of a spatial analysis of land allocation, the fragmentation of farmland is of particular interest as it is directly linked to transportation costs (Deininger et al. 2012). Case studies for France (Latruffe and Piet 2014) and the Czech Republic (Curtiss et al. 2013) confirm expectations that land fragmentation increases production costs and decreases yields, revenue, profitability, and efficiency. Therefore, we conjecture that the willingness to grow is higher if a farm's expansion helps improve consolidation of land plots and decrease land fragmentation (Hypothesis 2).

[1] Kersting et al. (2016) consider a milk quota, but their modeling idea applies to the production factor land as well.

Land market competition and farm growth

While the willingness to pay for land acquisition is primarily driven by internal factors, the costs of farm expansion are strongly influenced by the intensity of competition in local land rental markets. If, for example, a farm has no competitors, it may act as a monopsonist on the land market, reduce lease rates below marginal revenues, and expand further than under fierce competition. The intensity of competition is commonly measured by absolute or relative concentration indicators, such as the concentration rate (CR), Herfindahl-Hirschmann Index (HHI), or the Gini coefficient (Gini). The implications of farmland concentration on farm growth, however, are thus far not fully understood. Back et al. (2018) investigate how concentration and disparity of agricultural land at the county-level affect land values. They find a negative correlation between concentration measures and land values, which makes it easier for larger farms to expand. Using game-theoretic arguments, Hüttel and Margarian (2009) conjecture that farm growth is rather slow if land is distributed equally among farms because their willingness to pay is similar and sunk costs may prevent them from exiting. In contrast, if only few large farms exist in a region, these are expected to grow rather rapidly. At the same time, smaller farms grow even less than they would have if farm size were more equally distributed (Hüttel and Margarian 2009). More recently, Saint-Cyr et al. (2019) use concentration measures at the municipality-level to explain exit probabilities. By distinguishing between several farm types, they identify heterogeneous effects of neighboring farm size on the survival probability of farms. With respect to unequally distributed farm sizes in a region, they discover that inequality leads to increased structural change. However, the reactions differ according to farm type. This supports the hypothesis that expansion is less likely in equally distributed regions, while increasing inequality triggers the expansion of larger farms (Hypothesis 3).

A prerequisite for the empirical measurement of concentration is the definition of the relevant geographical market size. Often administrative units are used as a pragmatic approach (e.g., Piet et al. 2012). However, this has three problems. First, which regional level should be chosen for the empirical analysis, e.g., counties or municipalities? Second, the size of administrative units can largely differ, which hampers a comparison of concentration measures across regions. Third, competition for land will take place across borders of administrative units. Ideally, the relevant regional market is defined by the viewpoint of active farmers who operate the land. Again, the concept of substitutability is helpful, but now it refers to land plots with different locations. This suggests the calculation of isodistance lines or isochrones around a farmstead. Accordingly, all farmers located in a "reasonable" economic distance from a land plot can be considered as competitors on the demand side of the rental market. The implementation of this concept requires the determination of an acceptable distance (in kilometers or travel time) between a farmstead and a land plot, which is difficult to identify. Some authors suggest a fixed radius around a farm to determine the potential area of interest for a tenant. Cotteleer et al. (2008) derive the size of the local land market from the empirical distribution of distances between farms and land plots. They find that 90 percent of all land plots lie within a radius of 6.7 kilometers in the Netherlands. Interest for land in terms of willingness to pay, however, will not be constant within this radius. Spatial competition models assert that willingness to pay for land declines with distance (e.g., Graubner and Balmann 2012). Moreover, it will depend on the size of the tract and its distance to other plots that are already operated by the tenant.

Finally, it should be noted that the interpretation of concentration measures is ambiguous. The Structure-Conduct-Performance (SPC) paradigm in the tradition of Bain (1951) postulates a clear link between market structure and firms' profits and predicts a higher degree of market power with a decreasing number of competitors. This view is challenged by the efficient market hypothesis, according to which firms have heterogeneous cost structures (Demsetz 1974). Due to competition, firms with low production costs grow and expand their market shares and profits while firms with higher production costs are driven out of the market. Thus, higher profits would not be the result of market power exertion, but of superior efficiency.

3 Study Region and Data

The study is conducted in the federal state of Brandenburg, Germany in former East Germany. During the division of Germany, East and West German agricultural structures evolved differently. While in East Germany the agricultural sector consisted of state-owned farms (*Volkseigene Güter*) and collective farms (*Landwirtschaftliche Produktionsgenossenschaften,* hereafter, LPGs), the West German agricultural sector consisted primarily of privately-owned farms. Moreover, with an average farm size of 4,500 ha in the LPGs, the East German agricultural sector was subject to larger farm structures (Jochimsen 2010). In the aftermath of the reunification, several land reforms and laws were put in place to manage the transition and privatization in East Germany. As a result, the East German agricultural sector today is subject to a dual agricultural structure with large agricultural cooperatives and smaller privately-owned farms.

As of 2017, Brandenburg consists of 14 counties (without cities) and 417 municipalities. The total agricultural land in Brandenburg amounts to 1,322,900 ha, which is operated by approximately 5,400 farms. This results in an average farm size of approximately 245 ha in 2017, which is among the highest in Germany. With an increase in average farm size of about 41% since 1991, Brandenburg has one of the largest increases in farm size compared to the other states in East Germany (Statistisches Bundesamt 1993, 2018). Its history and characteristics render Brandenburg an interesting candidate for this analysis.

For the descriptive and econometric analysis we use data from IACS which contains all plots that are registered to receive European subsidies based on a geo-referenced land parcel identification system. Each plot is associated with a farm registration number indicating the farm operating this plot, irrespective of the farmstead's location or if the land is owned or rented. This allows us to draw a more precise and spatially explicit picture of the farms' activities. However, a farm registration number is associated with either a natural or legal person, so that a disappearing farm number does not necessarily indicate the farm exiting the market, but can be the result of a farm succession or a change in the farm's legal form. Moreover, holding structures with many operators cannot be detected.

We have access to IACS data for Brandenburg from 2005 to 2017, which allows us to derive information characterizing structural change on the agricultural land market in Brandenburg in detail. In Table 1, we provide an overview of the relevant information derived from the IACS dataset together with corresponding information from official statistics (if available). Both the numbers from official statistics and the IACS dataset report a decrease in the total agricultural area and the number of farms, as well as an increase in the average farm size. Differences between both datasets may be explained by specifics of the registration procedures and by a higher accuracy of the IACS dataset in recent years. Interestingly, the number of land plots registered in the IACS dataset increased over the study period, which is in line with the decrease in the average plot size. For all plots, the operating farm changed 44,112 times between 2005 and 2017. This was assessed by a change in the farm registration number. This means that on average, more than half of the plots changed the operator once. However, it is also possible that there are plots that changed the operator more than once.

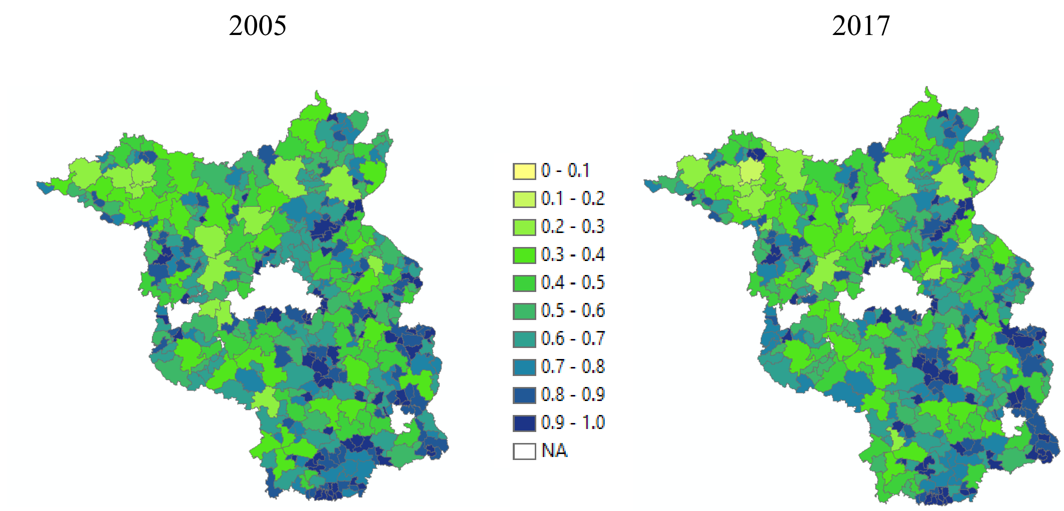
Table 1: Descriptive data of the agricultural land market in Brandenburg, 2005 and 2017 provided by the IACS dataset (corresponding values from the Statistisches Bundesamt (2006, 2018) are shown in parentheses)

	Total agricultural area in 1,000 ha	Number of farms	Average farm size in ha	Number of land plots	Average land plot size in ha	Changes of farm registration number for all plots since 2005
2005	1,325 (1,347)	5,695 (6,668)	233 (202)	76,044	17.4	-
2017	1,309 (1,323)	5,248 (5,400)	249 (245)	83,816	15.6	44,112

4 Descriptive Analysis of Concentration in Brandenburg

To analyze the interdependency of farm growth and concentration in the agricultural land market in Brandenburg, it is important to provide a comprehensive and spatially explicit overview of concentration indicators. Earlier studies focusing on the measurement of concentration on agricultural land markets (e.g., Piet et al. 2012, Back et al. 2018, Saint-Cyr et al. 2019) suggest different methods. We follow Back et al. (2018) and apply common concentration measures that originate in welfare economics. Figure 1 displays the concentration rate (CR) of the three largest farms that are active in the respective municipalities in 2005 and 2017. The CR measures absolute concentration in a region as it focuses only on the largest farms in a region. In our case, a value equal to one indicates that the whole agricultural area is operated by a maximum of three farms. Figure 1 shows that the temporal and spatial development of farming structures is heterogeneous. While municipalities in the north of Brandenburg are less concentrated, concentration is stronger in the south of Brandenburg. There are pronounced changes in concentration between 2005 and 2017, but it is noteworthy that there is no clear tendency towards higher concentration over time. Both increasing and decreasing concentration can be observed in the study period.

Figure 1: Concentration rates of the three largest farms at the municipality level in Brandenburg



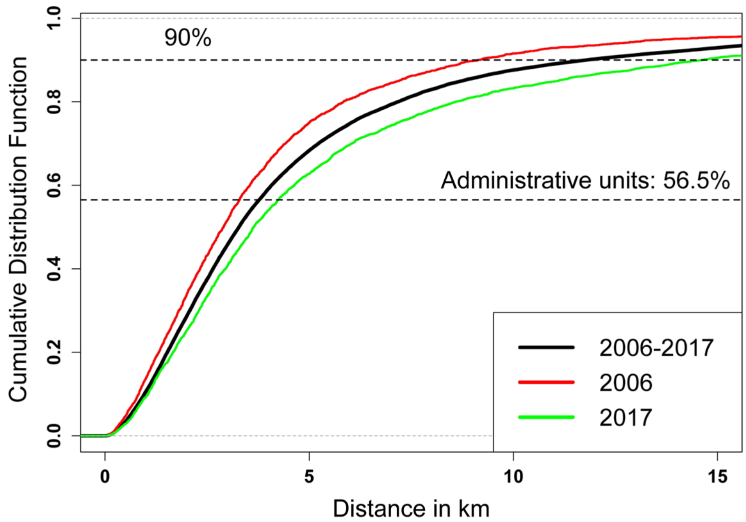
Source: own calculations based on the IACS dataset

Choosing municipalities as underlying regions to assess land market concentration is a pragmatic and commonly applied approach (e.g., Piet et al. 2012, Saint-Cyr et al. 2019), but poses problems. It is prone to inaccuracies that arise, for example, when farms are located close to a municipality border and the farm's main region of interest for expansion is located in the neighboring municipality. Assessing land market concentration hence requires a more precise definition of regions in which farmers are potentially interested in land. This would provide a more reliable identification of neighboring farms as potential competitors.

An alternative to fixed administrative units is provided by Cotteleer et al. (2008), who empirically derive distances between farmsteads and transacted plots for the Dutch land market. These distances define the radius serving as a base to define regions in which concentration is measured. They identify this radius by the 90th percentile of the distances, which corresponds to 6.7 km. This means that for 90% of the sales transactions in the Dutch land market, the transacted plot has a maximum distance of 6.7 km to the farmstead.

To identify farm-specific regions for our dataset similar to Cotteleer et al. (2008), we consider all land plots that were newly acquired (by rental or sale contracts) by existing farms and measure the distance between the farmstead and the centroid of the newly acquired land plot. Since the exact location of the farmstead is not provided in the dataset, we calculate it as the center of the plots operated by the farm in the previous year. This means that the center rather reflects the center of the farming activities than the actual farmstead. The distance corresponding to the 90th percentile is 11.8 km, which is larger than that in the Dutch land market (Figure 2). We are, however, not able to identify whether this results from different farming structures in both land markets or from the fact that Cotteleer et al. (2008) only consider sale transactions, while we also include rent transactions. To consider temporal development, Figure 2 also displays the empirical cumulative distribution functions of the distance for transactions between 2005 and 2006 and 2016 and 2017 separately. The distributions reveal that the farmer's willingness to accept longer distances increased over the study period, which is in line with the increase in average farm size reported in Table 1.

Figure 2: Cumulative distribution function of the distances in km between farms and the acquired land plots in Brandenburg



To compare the two approaches for the whole study period, we also calculate the percentage of transactions in which the farm and the acquired land plots lie within the same municipality (Figure 2). In 56.5% of the transactions, the plot and the farm center are located within the same municipality. This implies that in nearly half of the transactions, farms expand beyond the borders of administrative units. Temesgen (2014) reports that for the land market in Brittany, France, 75% of all sale transactions are within the same municipality. One potential source of the divergence is different farming structures in both study regions.

One problem that all approaches have in common and that cannot be solved with the available dataset is that the underlying database includes only actually transacted plots. Hence, information about whether farms unsuccessfully tried to expand beyond the considered region is not available in the dataset. This, however, is also an argument to account for larger regions than municipalities.

Figure 3 depicts the number of competitors, the Gini coefficient, and the Lorenz asymmetry coefficient for the land market in Brandenburg for 2005 (upper panel) and 2017 (lower panel). The Gini coefficient is a measure of the degree of inequality between farm sizes on each farm's relevant land market. Higher inequalities have a value closer to one. The Lorenz asymmetry coefficient (LAC) measures the asymmetry of the Lorenz curve and hence supports the interpretation of the Gini coefficient. If inequality arises from many small farms, it takes values below one whereas values above one indicate that the source of inequality is a few large farms. All indicators are computed by means of the farm-specific approach that considers a radius of 11.8 km around the farm's center. It is calculated for all farms (2005: 5,695, 2017: 5,248) and interpolated for Brandenburg using inverse distance weighing.[2]

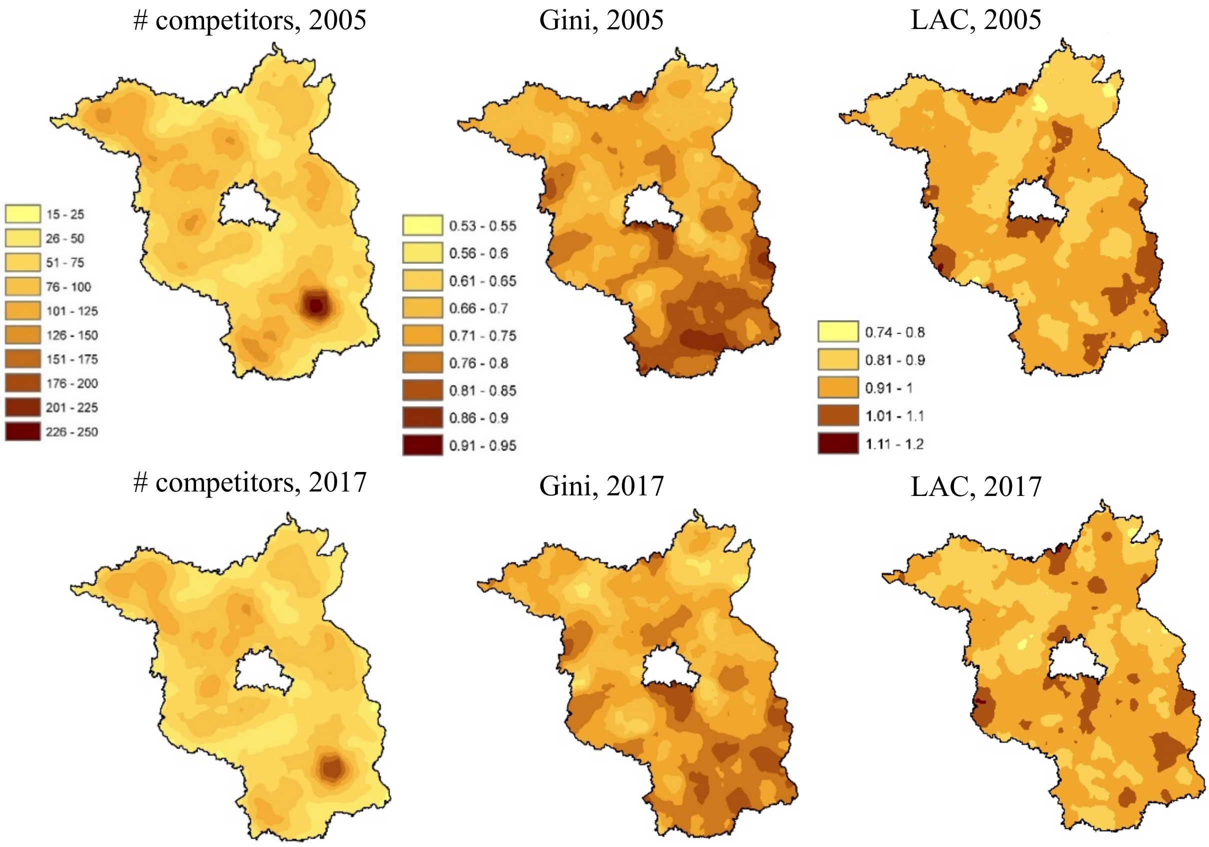
[2] Values close to the border of Brandenburg have to be interpreted with care since the farm's relevant market may not be fully considered.

The number of competitors varies between 15 and 250 in Brandenburg and decreased from a mean of 88 in 2005 to a mean of 79 in 2017. The maximum is located in southeastern Brandenburg, a region characterized by a large share of olericulture and horticulture. This implies smaller farm sizes and hence more competitors. The heterogeneity within Brandenburg is also reflected in the Gini coefficients, which range from 0.53 to 0.95 and have a mean of 0.73 in 2005 and 0.71 in 2017.[3] While in northern Brandenburg, land is more equally distributed among farms, we observe stronger differences in farm sizes in the southern part of the state. In most regions in Brandenburg, the LAC is below one. This implies that the Lorenz curve is relatively flat in the beginning.

All three indicators together allow us to characterize structural change in the farmland market in Brandenburg. The decrease in the number of competitors, which took place rather uniformly across all regions, led to an increase in average farm size (cf. Table 1). A decreasing Gini coefficient implies that the remaining farms face a more evenly distributed farmland market. The LAC remains below one in most regions, which suggests that larger farms still operate a large amount of land in 2017. Whether smaller farms are restricted in their expansion possibilities, however, cannot be determined and thus needs further investigation in the econometric analysis.

[3] Note that a direct comparison of Gini coefficients in 2005 and 2017 is difficult because the number of farms changes over time.

Figure 3: Number of competitors, Gini coefficient, and Lorenz asymmetry coefficient in Brandenburg, 2005 and 2017



Source: own calculations based on the IACS dataset

5 Econometric Analysis of Farm Growth and Concentration in Brandenburg

In the econometric analysis, we want to assess the impact of concentrated agricultural land markets on changes in farm structures. The analysis will reveal whether farms in Brandenburg are constrained by concentration and size inequality in agricultural land markets when expanding. We show how the probability and level of expansion depend on farm characteristics, as well as proxies for competition in agricultural land markets. Specifically, we apply the following two-stage Heckman (1979) model:

$$\begin{aligned} &\text{Stage I: } \Pr(y_i > 0|\boldsymbol{X}_i) = \boldsymbol{\Phi}(\boldsymbol{X}_i\boldsymbol{\beta}' + \epsilon_i) \\ &\text{Stage II: } y_i = \boldsymbol{Z}_i\boldsymbol{\beta}' + \gamma\text{IMR}_i + u_i \qquad \text{if } \boldsymbol{X}_i\boldsymbol{\beta}' + \epsilon_i > 0. \end{aligned} \tag{1}$$

Here, $y_i > 0$ denotes a positive change in the size of farm i. $\boldsymbol{X}_i$ is a vector of exogenous variables explaining the decision to expand and $\boldsymbol{Z}_i$ is a vector of exogenous variables influencing the level of expansion. According to the exclusion restriction, $\boldsymbol{Z}_i$ has to be a strict subset of $\boldsymbol{X}_i$, i.e., at least one variable from the first stage has to be excluded in the second stage. To account for a selection bias introduced by restricting the analysis to expanding farms only, the inverse Mills ratio IMR_i is included in the second stage.

In the empirical application, we analyze how the probability of expansion and absolute change in agricultural area (in ha) from 2005 to 2017 depend on farm characteristics as well as proxies for land market competition. We estimate two two-stage models, which differ in the definition of the relevant land market when computing the concentration indicators. In the first model, we use a radius of 11.8 km, which is derived from the 90$^{\text{th}}$ percentile of transaction distances (farm-specific approach, cf. Figure 2). In the second model, we define the relevant market by means of municipalities (municipality-based approach). The study object are farms that remain in the database over the whole study period. For the econometric analysis, we exclude all farms with extreme expansion behavior (the lower and upper 0.5%) to reduce the influence of outliers.

Moreover, we exclude all farms operating less than one ha to account for potential inaccuracies in the dataset. This restricts the number of farms to 3,099 in the first stage estimation. Yet, the farms excluded from the analysis still remain present as neighboring farms, meaning that they are still included in the computation of the concentration indicators. In the second-stage estimation, we exclude all farms that either shrink or stagnate over the study period, which reduces the number of farms to 1,699.

5.1 Explanatory Variables

A descriptive overview of the included variables is provided in Table 2 (first stage) and Table 3 (second stage). Both include internal farm characteristics that are hypothesized to affect farm growth, as well as proxies for land market competition. All variables are derived from the IACS dataset.

With respect to Hypothesis 1 on the effect of farm size on the probability and amount of expansion, we include farm size in terms of total utilized agricultural area (UAA) (farmsize_i). Together, farm size and squared farm size (farmsize_i^2) can identify the existence of non-linear effects of farm size on the probability and amount of expansion. In light of the discussion about optimal farm size, we would expect a positive effect of the linear term and a negative effect of the squared term on the probability and amount of expansion. Farm size has a mean of 320.86 ha in the first stage and 247.89 ha in the second stage. Hence, the share of smaller farms increased in the subsample of expanding farms. While this might seem puzzling at first, the reason lies in the restriction of the dataset to those farms that survived over the study period. Moreover, this might be a specific phenomenon that applies to the study region due to Brandenburg's dual agricultural structure.

Regarding the second hypothesis that addresses whether farms expand if expansion helps consolidate land plots, we include two fragmentation indicators similar to Latruffe and Piet (2014). The first one measures the farm's extension by means of the maximum distance between the center of the farming activity and the center of the most distant plot (extent_i), which is 4.98 km on average in Brandenburg in the first stage estimation and 4.34 km in the second stage estimation. In addition to the farm size, the maximum distance between the farm and the operated plots can provide further information about spatial extension. The second fragmentation-related indicator measures via a dummy variable if the farm were able to reduce its fragmentation over the study period. Here, farm-specific fragmentation is measured as the minimum distance between a plot and the nearest plot of the same farm, averaged over all plots of the farm. If this measure decreases over the study period, this means that the farm succeeded in putting its plots closer together and hence the farm consolidated and dummy variable $D_i^{\mathrm{defragmentation}}$ equals one. More than half of the farms consolidated (54%). Fragmented farms consolidating over the study period could do so by expanding near their own plots (expansion) or by giving isolated plots away (shrinkage), so that the expected effect in the first-stage estimation is unclear. In the second stage, we exclude the variable $D_i^{\mathrm{defragmentation}}$ following the exclusion restriction. We hypothesize that defragmentation increases the probability of expansion as it might help increase the farm's productivity, but that it should have no effect on the amount of extension as it cannot provide any information about the relative market position of the farm.

In addition to own farm characteristics, we include proxies for competition between farms in the close neighborhood to test Hypothesis 3, which relates to the Gini coefficient and number of competitors in the relevant region. The Gini coefficient (gini_i) of farm size in farm i's region measures the degree of inequality of farm size distribution and changes only slightly between both stages of the estimation (70.56 % and 70,53 % in the first and second stage, respectively). We hypothesize that surviving farms in unequally distributed markets are more likely to expand than those in equally distributed markets. As effects should differ between small and large farms, we include an interaction term between the Gini coefficient and a dummy variable D_i^{large}

to indicate whether a farm is larger than the median farm ($\text{gini}_i \cdot D_i^{\text{large}}$). We expect a positive influence on the farm's probability of expansion as well as on the extent of expansion since the interaction term can indicate whether the farm has a predominant position in the local land market. A further indicator influencing the expansion possibility is the number of competitors (num_comp_i). With a lower number of competitors, farms may act as oligopsonists and are more likely to acquire new land plots. Effects on the level of expansion are expected to be negative as a higher number of competitors could furthermore imply smaller plots in a region, which could lower the level of expansion. We exclude the CR and LAC as concentration indicators since they are highly correlated with other included variables and could thus lead to multicollinearity in the analysis.

Table 2. Definition and descriptive statistics of variables included in the 1st stage, $N = 3,099$

Variable	Code	Mean	St.dev.	Lower 5%	Upper 5%
Internal farm characteristics					
Change in utilized agricultural area (UAA) (dummy)	$D_i^{\Delta \text{farm\_size}>0}$	0.52	0.50	0	1
UAA in ha	farmsize_i	320.86	528.41	2.51	1426.96
Maximum extent in km	extent_i	4.98	8.19	0	15.44
Defragmentation (dummy)	$D_i^{\text{defragmentation}}$	0.54	0.49	0	1
Competition proxies *(farm-specific)*					
Gini in %	gini_i	70.56	4.64	62.97	77.70
Interaction term: Gini and large farm dummy	$\text{gini}_i \cdot D_i^{\text{large}}$	36.96	35.41	0	76.34
Number of competitors	num_comp_i	86.57	35	40	133
Competition proxies *(municipalities)*					
Gini in%	gini_i	72.71	11.37	55.31	90.39
Interaction term: Gini and large farm dummy	$\text{gini}_i \cdot D_i^{\text{large}}$	37.29	36.52	0	84.10
Number of competitors	num_comp_i	28.41	19.16	5	64

Table 3. Definition and descriptive statistics of variables included in the 2nd stage, $N = 1,699$

Variable	**Code**	Mean	St.dev.	Lower 5%	Upper 5%
Internal farm characteristics					
Change in utilized agricultural area (UAA) (dummy)	$\Delta\text{farm\_size}_i{}^{+}$	105.33	158.68	0.76	453.31
UAA in ha	farmsize_i	247.89	439.24	1.991	1169.63
Maximum extent in km	extent_i	4.34	7.14	0	13.44
Competition proxies *(farm-specific)*					
Gini in %	gini_i	70.53	4.60	63.11	77.81
Interaction term: Gini and large farm dummy	$\text{gini}_i \cdot D_i^{\text{large}}$	31.4	0.35	0	76.13
Number of competitors	num_comp_i	87.12	35.13	41	133
Competition proxies *(municipalities)*					
Gini in %	gini_i	73.14	11.08	55.68	89.66
Interaction term: Gini and large farm dummy	$\text{gini}_i \cdot D_i^{\text{large}}$	31.66	36.14	0	82.23
Number of competitors	num_comp_i	29.21	19.24	5	64

5.2 Results and Discussion

In Table 4, we present the results from both two-stage models. To correct for heteroscedasticity, we apply robust standard errors in both models. The (Pseudo-) R^2 is rather low (5% in the first stage and 24% in the second stage), which is not surprising given the lack of socioeconomic and financial information of farms in our dataset.

The results from the two-stage model with the farm-specific approach defining the relevant market are not in line with our expectations from Hypothesis 1. In the first stage, we observe a statistically significant negative effect of farm size on the probability of expansion and a non-significant positive effect of the squared farm size. The marginal effect of farm size is non-constant, negative for the range of farm sizes in our sample, and rather small. For example, an increase in farm size from 300 to 400 ha reduces the expansion probability from 53.2% to 52.1%, assuming that all other variables are held constant at their sample means. These results relate to the discussion about structural change in agriculture as they show that among surviving farms, smaller farms are not disadvantaged in terms of their expansion possibilities. This could reveal that for smaller farms to survive, expansion in terms of farm size is necessary. In the second-stage estimation, the signs of the coefficients change and the effect of farm size stays statistically significant and becomes positive. This indicates that among the expanding farms, larger farms expand more. Squared farm size is not statistically significant, but it has a positive sign which shows that larger farms grow disproportionately stronger. When interpreting these results, one should recall that the analysis includes surviving farms only.

Regarding our second hypothesis, we observe a negative effect of the farm's extension on the probability to expand. Our data, however, cannot reject the null hypothesis of no influence of the farm's extension in the first stage. The defragmentation dummy variable shows a statistically significant negative coefficient in the first stage: The probability of expansion decreases by three percent for consolidating farms. That means that consolidation takes place by shrinking or substituting remote plots with nearer plots rather than by expanding. Despite the exclusion of the defragmentation dummy variable and the inclusion of the inverse Mills ratio in the second stage, it remains unclear whether our analysis would be subject to a sample selection bias since our data cannot reject the null hypothesis of no influence of the inverse Mills ratio in the second stage.

The main focus of this paper is how land market competition affects the expansion behavior of farms (Hypothesis 3). In the first and second stage, we find statistically non-significant influences of the Gini coefficient for smaller farms. The significant interaction term between the Gini coefficient and farm size, however, demonstrates different reactions between the groups of large and small farms. In the second stage, we find that increased inequality leads to stronger expansion for larger farms: An increase in the Gini coefficient by 10 percentage points leads to an increase in expansion by 9.8 ha. Distinct effects for the groups of small and large farms could point at the existence of market power. However, the dimension of the coefficients and their statistical significance render this a vague finding. A further indicator of the market power potential is the number of competitors. The negative sign of the coefficient in the second stage is in line with our initial hypothesis. Our data, however, cannot reject the null hypothesis of no influence of the number of competitors in both stages.

The results of the municipality-based approach are similar to those of the farm-specific approach, but differ for some variables. One important difference are the coefficients for both Gini variables. In the municipality-based approach, we observe that increasing inequality brings lower expansion for both large and small farms. This contradicts both the farm-specific approach and our initial hypothesis. One reason is that compared to small farms, large farms are more likely to act beyond administrative borders, which would imply that the municipality-based approach affects large farms more.

Table 4. Estimation results

	Farm-specific approach				Municipality-based approach			
	Stage I		Stage II		Stage I		Stage II	
Variable	Coef.	St.err.	Coef.	St.err.	Coef.	St.err.	Coef.	St.err.
intercept	0.0903	0.3496	44.233	99.452	-0.0664	0.1414	98.146	101.25
Hypothesis 1								
farmsize_i	-0.0003**	0.0001	0.0903*	0.0466	-0.0003**	0.0001	0.0922**	0.0453
farmsize_i^2	2.2e-08	3.7e-08	5.7e-06	2.0e-05	2.2e-08	3.7e-08	4.0e-06	2.0e-05
Hypothesis 2								
extent_i	-0.0062	0.0028	0.0011*	0.0006	-0.0062	0.0029	0.0010*	0.0006
$D_i^{\text{defragmentation}}$	-0.1033**	0.0462	-	-	-0.1077**	0.0463	-	-
Hypothesis 3								
gini_i	0.0044	0.0049	-0.0992	0.6986	0.0059***	0.0021	-1.1467**	0.5214
$\text{gini}_i \cdot D_i^{\text{large}}$	-0.0041***	0.0009	1.0782***	0.3387	-0.0040***	0.0009	0.9879***	0.3106
num_comp_i	7.9e-05	0.0007	-0.0736	0.0753	0.0024*	0.0013	0.2255	0.2356
IMR_i	-	-	15.750	117.061	-	-	29.111	111.561
(Pseudo-)R^2	0.045		0.238		0.050		0.234	

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively.

6 Conclusion

This paper investigates the interplay of size changes of individual farms when competing for land. The main research question was to analyze whether regional farm structures impact future growth decisions of farms. Using geo-referenced plot-level data for the German federal state of

Brandenburg, we determine the concentration of operated farmland by means of various concentration measures. Together with fragmentation indices, these measures are used to describe regional structures in the agricultural land market. We calculate and compare these indices for administrative units (municipalities), as well as for farm-specific boundaries. In doing so, we address the problem of defining the relevant geographical land market. In the subsequent econometric analysis, we apply a Heckman two-stage model to investigate how land market concentration affects the probability and level of farm expansion.

Our study offers four notable results. First, regarding the relevant size of the land market, we find that about half of the land transactions occur beyond municipality borders. This underlines the importance of carefully defining the neighborhood when computing concentration measures. These differences translate into small divergences in the results of the econometric analysis. Secondly, the descriptive analysis shows that the temporal and spatial development of farming structures in Brandenburg is heterogeneous. On a state-level average, concentration rates of farms decreased slightly between 2005 and 2017. For single municipalities, however, we observe both increasing and decreasing concentration rates. The Gini coefficient decreases between 2005 and 2017, indicating lower inequality among the farms being active in 2017 compared to those being active in 2005. Third, results of the econometric analysis show that for farms that remained active between 2005 and 2017, farms that defragment are less likely to expand. Finally, we find that higher inequality of land distribution leads to distinct expansion effects for large and small farms. Even though the reported effects are rather small, it is tempting to interpret this finding as evidence for the existence of market power effects on land markets. At this point, one should recall the ambiguity of concentration measures mentioned in the theoretical background. The policy implications of the two interpretations of increasing concentration rates are diametrical: Concentration that enables market power and thus deviations from a socially optimal resource allocation calls for competition policy and market regulation, whereas concentration as a result of structural change and sectoral adjustment processes does not. Consequently, it is not sufficient to solely inspect concentration measures as indicators of market power.

Our results feed into the current debate on land market regulations in the EU. In 2017, the European Commission issued guidelines confirming that EU member states are allowed to take measures against excessive speculation and concentration on agricultural land markets. Though sound ownership distribution and fair access of all farms to this production factor is an important objective of agricultural policy, little empirical knowledge exists about the spatio-temporal diffusion of farm sizes. Our paper provides an example how existing administrative data can be used for this purpose. The applicability of our findings to other regions is difficult due to the specific (dual) farm structure in Brandenburg, which still reflects the legacy of the socialistic era. Further caveats result from the informational content of our IACS dataset. While its high spatial resolution is a strength, missing information about the economic and financial situation renders the explanation of farms' growth and exit decisions difficult. Furthermore, the identification of informal holding structures, which play a role in agricultural land markets, at least in Eastern Germany, is not possible. Merging IACS data with land ownership information from cadaster or financial data from agricultural census data would be a promising effort for further empirical analyses on structural change and land market competition.

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