Predator or prey? - Effects of fast-growing farms on their neighborhood

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Abstract:

This paper aims to examine how path-breaking farms which dramatically increase their farm-size influence other farms in an agricultural region by using agent-based participatory experiments. Our experiments are based on the FarmAgriPoliS business management game, in which a human participant manages a farm in AgriPoliS, an agent-based model of structural change in agriculture. With these experiments we can show that the impact on other farms in the model region differs depending on the performance of the human participant. In general, economically successful fast-growing participants (path-breakers) increase regional added value. Although path-breakers have a negative effect on the average income of other farms in the region some other farms may even benefit. Whether a single farm in the region can benefit from a path-breaker depends on the distance. Moreover, even more smaller farms may survive. Although the influence decreases overall with growing distance, the functional correlation is neither linear nor exponential, but wave-like.

Acknowledgment: This work was supported by the German Research Foundation (DFG): The research was conducted within the Subproject 5 of the research unit “Structural change in Agriculture (SiAg)”.

JEL Codes: Q15, D9
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1 Abstract
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2 Introduction
The FarmAgriPoliS business management game allows a human participant to manage a farm in AgriPoliS (Happe et al. 2006) which can be described as an agent-based model of structural change in agriculture. Experiments with FarmAgriPoliS show significant differences in the behaviour of human protagonists and myopically rational computer agents (i.e., the automated agents as they are used in AgriPoliS) in coping with the challenges of managing a farm in a complex competitive environment. Though human participants showed on average not to be substantially more successful than standard computer agents in AgriPoliS, human participants tend to be more skilled at avoiding losses than in achieving gains.

Cluster analyses of existing experiments (in total 143 based on 49 persons and 9 different scenarios with different output prices, initial farm sizes and production cost levels) revealed a substantial heterogeneity in the behaviour and success amongst the participants. We identified four distinct experimental outcome clusters. These output clusters can be described as: Cluster 1 – “The negligent gamblers”, Cluster 2 – “Missed opportunities”, Cluster 3 – “The solid farm managers”, and Cluster 4 – “The successful path-breakers”. The first tree clusters that included some 88% of the experiments corresponded with prospect theory (cf. Kahnemann 1979) – that is, the participants were more successful in avoiding losses than in exploiting opportunities. However, approximately 12% of the participants succeeded in leaving predetermined development paths (Cluster 4). These experiments can be characterized as rather difficult scenarios with challenging price developments (fluctuating or even declining) and the farms cost structures. In these experiments, the
participants managed strong growth and performed substantially more successful than computer agents and other participants. These very successful path-breakers do not fit into prospect theory, and characterise specific entrepreneurs which developed specific strategies.

This paper provides insights in the regional effects of the different behavioral Clusters. In particular, it is analyzed how a) successful path-breakers (Cluster 4) and b) poorly performing participants (Cluster 1) affect farms in their neighborhood. Moreover, we analyze whether these effects of "winner" or "looser" farms are distributed uniformly over the entire neighborhood or whether these effects also dependent on the distance and therefore on the spatial distribution of farms?

3 Background

3.1 Path dependence and path breaking

The agricultural structure of a region can be described in terms of farm sizes and numbers, tenure patterns, legal organisation (sole proprietorship, partnership or corporation), production capacities, technologies and activities (Tweeten 1984). Farm structures can be very heterogeneous even within and between regions with similar agricultural conditions (climatic, soil, infrastructural, economic, social). To some degree, the size distributions of farms follow the Pareto principle (see Sombart 1967): Often, a relatively small number of large farms hold a major share in agricultural production.

Balmann (1995) argues that agricultural structures are path-dependent, which means that feedback mechanisms lead to a lock-in at a stable or quasi-stable state that may be inefficient and prevent the system from transitioning towards a more efficient state. In the agricultural sector, these feedback mechanisms may result from sunk costs of assets or frictions on the land market. The concept of path dependency (cf. Arthur 1989, David 1985 North 1990, Cowan and Gunby 1996, Pierson 2000, Schreyögg et al. 2003) attempts to explain why similar systems may develop very differently due to historical events. That is, today’s agricultural structures are shaped by history, and will also affect future structures. Path dependence not only emerges on the aggregate level of agricultural structures, but also on the individual level. In this regard, Balmann (1995) and Balmann et al. (1996) particularly refer to the role of sunk costs of assets and human capital. Sydow et al. (2005) provide an overview and classification of different reasons as to why path dependencies emerge. These reasons include economies of scale and scope, direct and indirect network externalities, learning, expectations, expectations of expectations, and coordination and complementary effects. The first two reasons may be classified as technological reasons, whereas the remaining may be classified as institutional (Sydow et al. 2005). A further category of reasons that may be particularly relevant in path dependence in agriculture may be found in mental models of the protagonists, which especially captures issues related to learning and expectations. In general, a mental model may be understood as a simplified, internal
representation of reality of an individual or a group that may serve the perception and solution of problems in complex decision situations (Bach, 2010).

In certain cases, a farmer may overcome the specific frictions resulting from path dependence on the farm level as well as the sectoral. Overcoming path dependence may be understood as a kind of mindful deviation from the previous or usually expected development path (Garud and Karnoe 2001, Garud et al. 2010) and may be considere as either path creation or path-breaking. In such cases, a farm manager is able to manage unusually strong and also profitable growth. In simulation experiments with AgriPoliS, Ostermeyer (2015) found for the same study region that approximately some 2% of the participants successfully succeeded in leaving predetermined development paths ending up with a size that is some 20 to 30 times the average farm size of the other farms in the region.

3.2 Economic experiments
Laboratory experiments have become popular in agricultural economics (Colen et al., 2016; Viceisza, 2015). There is an ongoing academic debate as to the best methods for investigating specific field contexts as “it is not the case that abstract, context-free experiments provide more general findings if the context itself is relevant to the performance of subjects” (Harrison and List, 2004: 1022). A wide spectrum of experimental tools ranging from simple and abstract (e.g. Hellerstein et al., 2013; Torres-Guevara and Schlüter, 2016) to complex decision environments have been adapted to specific field settings (e.g. Fiore et al., 2009; Reutemann et al., 2016). On the one hand, somewhat abstract laboratory experiments yield clean data at relatively low cost. The external validity of experimental results is, however, limited. On the other hand, empirical data from field studies has greater external validity, but identifying causal effects is often difficult. Framed field experiments using context-specific software environments may bridge this gap (Harrison and List, 2004; Fiore et al., 2009; Reutemann et al., 2016). Agent-based models may also provide such a context-specific environment, where the participant becomes part of the agent-based simulation. Guyot and Honiden (2006) describe this type of experimental setting as an agent-based participatory experiment.

3.3 The FarmAgriPoliS model
FarmAgriPoliS may be understood as a business management game providing participants a software-based environment for farm managers in a simulated agricultural region. Within FarmAgriPoliS, participants are assumed to manage a farm and to compete with computer-simulated farms (agents) that derive their decisions from mixed-integer short-term profit maximization. FarmAgriPoliS is based on AgriPoliS (Agricultural Policy Simulator; Happe, 2004; Happe et al. 2006; Kellermann et al. 2008), a spatially explicit and dynamic agent-based model that simulates structural change in an agricultural region in response to policy scenarios. Both models offer a software environment for the simulation of farms, regional farm populations and structures, markets, agricultural production, and so on. Sahrbacher et al. (2014) provides detailed documentation of AgriPoliS following the ODD standard protocol
AgriPoliS has been used extensively for analyzing structural, income, land market and environmental effects of agricultural policies (e.g. Happe et al. 2008, Brady et al. 2009, Piorr et al. 2009, Uthes et al. 2011, Brady et al. 2012, Sahrbacher et al. 2012, Balmann and Sahrbacher 2014, Appel et al. 2016, and Brady et al. 2017). FarmAgriPoliS uses identical specifications for regions and specified farms as AgriPoliS does. So if FarmAgriPoliS is used for behavioural experiments, one can assume that participants face a comparable salient context that induces decisions similar to those faced by actual farm managers (cf. Guyot and Honiden, 2006) as can be assumed for the use of AgriPoliS.

In FarmAgriPoliS, every participant controls a specific agent (or farm) located in the center of a modelled region. The farm is equipped with a certain amount of machinery, buildings, owned and rented land, labour, and financial resources. A typical experiment lasts twenty rounds (equivalent to twenty simulated years), in which participants must decide on farm exit or continuation, bidding strategies for land, and investments in durable and capital-intensive assets such as buildings and machinery. These are the more strategic decisions that drive a farm’s performance in the long run. Short-term optimizations such as the planning of the annual production are made for the participants based on his or her price expectations using mixed-integer optimisation. The participants compete with other farms controlled by the computer, which also make their decisions on investments, exits and land rentals by means of mixed-integer but short-term optimization. Participants may access information on how a computer agent would decide, which provides a default for rental bids and investments from which participants can deviate. Appel et al. (2018) gives a more detailed description of FarmAgriPoliS.

In AgriPoliS, and thus also in FarmAgriPoliS, the farms influence each other primarily through the land rental market. The farms in the model region compete for available land (i.e. land that is currently not rented) via a repeated auction. Within the auction, every farm first selects the available plot that is most valuable for the farm and then calculates a bid for this plot. Every farm’s bid equals a specific proportion (e.g. 80%) of the marginal gross margin of this additional plot. The bid considers transportation costs that are assumed to be proportional to the distance between plot and farm. The farm with the highest bid receives the plot and is able to use it for a specific contract length (cf. Kellermann et al., 2008, p. 28 ff.). Afterwards, all farms can again submit bids that are compared again. This procedure continues as long as land is available.

3.3.1 Region
We defined an economic environment adapted to the characteristics of the Altmark region for the experiments. The Altmark is located in the German Federal State of Saxony-Anhalt, and captures important features of the large-scale agricultural structures of East German agriculture. The Altmark has a comparatively high proportion of grassland at nearly 27%. The soil quality is rather poor, and the yield levels in arable farming are rather low. By far the most of the land is cultivated by farms with more than 200 ha. Farm sizes are
heterogeneous. In terms of numbers of farms, individual full and part-time farms as well as partnerships predominate the Altmark. Although legal persons (mainly limited companies and producer cooperatives) only account for some 10% of the farms, they use almost 45% of the agricultural land. The farms have a high share of loan capital and rented land, and therefore a relatively low capital base. In addition, large stocks dominate the livestock production. Fattening pigs are mainly kept in herds of more than a thousand animals and dairy cows in herds of a hundred to more than five hundred. Around 40% of the dairy cows and 53% of the specialised dairy farms in Saxony-Anhalt are located in the Altmark although the region covers only 23% of the agricultural acreage of Saxony-Anhalt (in 2007, StaLa, 2008 and StaLa, 2014), emphasising the relative importance of livestock production. Ostermeyer (2015) gives a detailed description on how the Altmark region is implemented in AgriPoliS.

For the experiments, a portion (approx. one fifth) of the Altmark is simulated to shorten the computation time and to avoid longer waiting times for the participants during the experiments. The region is, however, large enough to represent the specific characteristics of the region and relevant neighborhood effects.

3.4 Design of behavioural experiments and subject pool

Varied scenarios were developed for the behavioural experiments in order to study the decision-making of the participants in a competitive agricultural context. We defined three specific farm types with different sizes and individual production cost levels. One experiment lasted for twenty rounds considered equivalent to a time horizon of twenty years. We also defined three specific milk price developments (see Figure 1) in three different scenarios to study how participants respond to changing prices. Both factors were combined into a full factorial design. The scenarios are presented in Table 1.

### Table 1 Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Milk price (trend)</th>
<th>Farm</th>
<th>Production cost factor*</th>
<th>Size</th>
<th>Number of experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Constant</td>
<td>Farm 1</td>
<td>Good (0.9)</td>
<td>Medium (665 ha)</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Price 1 (fluctuating rising)</td>
<td>Farm 1</td>
<td>Good (0.9)</td>
<td>Medium (665 ha)</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Price 2 (failed expectation)</td>
<td>Farm 1</td>
<td>Good (0.9)</td>
<td>Medium (665 ha)</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Constant</td>
<td>Farm 2</td>
<td>Normal (1)</td>
<td>Large (1,480 ha)</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Price 1 (fluctuating rising)</td>
<td>Farm 2</td>
<td>Normal (1)</td>
<td>Large (1,480 ha)</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Price 2 (failed expectation)</td>
<td>Farm 2</td>
<td>Normal (1)</td>
<td>Large (1,480 ha)</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Constant</td>
<td>Farm 3</td>
<td>Poor (1.15)</td>
<td>Medium (665 ha)</td>
<td>31</td>
</tr>
<tr>
<td>8</td>
<td>Price 1 (fluctuating rising)</td>
<td>Farm 3</td>
<td>Poor (1.15)</td>
<td>Medium (665 ha)</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>Price 2 (failed expectation)</td>
<td>Farm 3</td>
<td>Poor (1.15)</td>
<td>Medium (665 ha)</td>
<td>13</td>
</tr>
</tbody>
</table>

Note: * factor multiplied with the variable costs of the farm for each production activity
Participants for our experiments were recruited mainly among students from three German universities in 2014 and 2015. A total of 49 students participated. Participants were mainly students of Agriculture and related subjects (80%) from Humboldt University Berlin (20%), Martin Luther University Halle-Wittenberg (53%), and the University of Göttingen (27%). Participants were on average 25.1 years old (SD = 3.45), 35% were female, 63% had a Bachelor’s degree, and 63% had some practical experience with agriculture and farming.

Participants were randomly assigned to scenarios, and each participant was able to perform up to three scenarios (drawing from an urn without replacement). In total, data sets of 144 experiments are available for analysis. Every scenario was also simulated by replacing the participants with identical initialisation in which a computer agent managed the farm identically to all of the other agents within the simulation. These runs provide benchmarks for participant behaviour comparison. The participants were introduced to FarmAgriPolIS and requested to maximise their farm’s equity capital after twenty rounds. They were also told that they would receive payments contingent on their performance in the experiment. In addition to a fixed show-up fee of 20 euros, subjects received a euro for every two-percent increase in equity relative to the computer benchmark; the equity bonus was limited to up to a maximum of 30 euros per experiment. The reference for payment calculation was replaced by a simulation run with an informed human putting just enough effort in to ensure the survival of the farm in scenarios where the computer farm went bankrupt; this was only for payment calculation. The computer agent served as the benchmark in every scenario for analysis. Detailed instructions of the software followed to ensure sufficient comprehension. Participants also had the opportunity for a test run, which was widely used. The participants were supervised by a researcher, who also assisted them with the software, throughout the experiment.

4 Hypothesis
As land is locally a scarce resource, a farm is only able to increase its landbank if other farms reduce their landbank or exit from agriculture. Due to this competitive interdependence it

![Figure 1 Index of milk price developments used for the experiments (Period 0 = 100)](image)
can be assumed that a particularly successful farm has a rather negative effect on the surrounding farms. This leads to Hypothesis 1:

- A successful path breaking participant in the region has a negative impact on the neighboring farms.

This can be shown, in particular, in lower incomes of farms, smaller farm sizes, a higher number of farm closures and higher rental prices.

Vice versa this competitive interdependence on the land market can lead to a beneficial situation when the participants' performance is lower. This leads to Hypothesis 2:

- Neighboring farms benefit from a poorly performing participant.

AgriPoliS and FarmAgriPoliS consider transportation costs between the location of the farms and their fields. For the land market the farms thus have to account for the distance between farmstead and plot (cf. Kellermann et al., 2008, p. 28 ff.). The chance of being able to rent land, however does not only depend on the farms' marginal cross margin and the farms' distance (transportation costs) to a specific plot, but also on the distance of other competing farms to this plot and their marginal gross margins. Therefore, the regional interdependences between farms - whether positive or negative - can be assumed to be stronger in the direct neighborhood. This leads to Hypothesis 3:

- The impact of the participants' behavior (resp. Cluster) on other farms diminishes with increasing distance to these farms.

As worse performing farms have lower marginal gross margins, their bids are lower. Therefore poorly performing participants are less competitive on the land market. This leads to Hypothesis 4:

- The closer a farm is to a poorly performing participant the more it can benefit.

5 Results

5.1 Structural change/Regional results

5.1.1 Farms and Farm Sizes

To get a first impression of the impact of the different clusters of behavior on the whole region, we analyze the development of the number of active farms in the model region. Active farms are those farms which are active in agriculture and have not quit farming due to a voluntary (too high opportunity cost) or forced (illiquidity) exit.

Table 2 shows the development of the number of active farms in relation to the benchmark; the number of active farms in the respective benchmark situation corresponds to 100%.
<table>
<thead>
<tr>
<th>Periode</th>
<th>Indicator</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>„negligent gamblers“ relative to Benchmark</td>
<td>„missed opportunities“ relative to Benchmark</td>
<td>„solid farm managers“ relative to Benchmark</td>
<td>„successful path-breakers“ relative to Benchmark</td>
</tr>
<tr>
<td></td>
<td></td>
<td>absolut (%)</td>
<td>absolut (%)</td>
<td>absolut (%)</td>
<td>absolut (%)</td>
</tr>
<tr>
<td>0</td>
<td>Number of Farms</td>
<td>63.00</td>
<td>100.00</td>
<td>63.00</td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>av. Farm size (ha)</td>
<td>257.38</td>
<td>100.00</td>
<td>257.38</td>
<td>100.00</td>
</tr>
<tr>
<td>9</td>
<td>Number of Farms</td>
<td>53.70</td>
<td>99.44</td>
<td>53.62</td>
<td>100.44</td>
</tr>
<tr>
<td></td>
<td>av. Farm size (ha)</td>
<td>301.96</td>
<td>100.56</td>
<td>302.42</td>
<td>99.56</td>
</tr>
<tr>
<td>19</td>
<td>Number of Farms</td>
<td>20.30</td>
<td>99.51</td>
<td>25.84</td>
<td>102.16</td>
</tr>
<tr>
<td></td>
<td>av. Farm size (ha)</td>
<td>798.77</td>
<td>100.49</td>
<td>627.60</td>
<td>97.89</td>
</tr>
</tbody>
</table>

Note: : significance level: *p < 0.05; **p < 0.01; ***p < 0.001
In the first periods not much happens: the number of active farms is quite close to the benchmark. However, especially in Cluster 4 significantly more farms stay active in agriculture than in the benchmark simulations, in the longer run. These farms are accordingly smaller on average. The amount of farms and farm sizes in other Clusters, on the other hand, remains fairly close to the benchmark - especially in Cluster 1. Here, participants quickly exit farming and thus lose their influence on regional development. For Clusters 2 and 3, the deviation from the benchmark is less than five percent over time. In Cluster 3 there are slightly less, but larger farms, while in Cluster 2 it is the other way around. Anyway, only the number of farms in Cluster 3 at the end of the experiment is slightly significant.

5.1.2 Regional income and added value

As the number of active farms and their average size only provide limited insights about the farming sector of a specific region, we also focus on the financial situation, e.g. the development of farm incomes and profits and the added value of the region. The farm incomes and profits also consider farms that already left agriculture. In this case, they will continue to receive incomes for the production factors owned by the former farm. This means that they receive the rent paid by the leaseholder for their owned land, wages for off-farm working family members in case of family farms, and interest for their liquid capital. On the other hand, the closed farms are affected by depreciations and interest costs for existing debts (cf. Kellermann et al. 2008, p. 44). In order to minimize the scenario effects, we consider the deviation of the aggregated farm household incomes from the benchmark.

![Figure 2 Development of aggregated farm income and profits in the region relative to the Benchmark; excluding the participant](image)

At the beginning of the simulation, the aggregated regional income of all other farms (excluding the farm managed by the participant) dropped partly distinctly compared to the benchmark (see Figure 2). Particularly, Cluster 1 has a negative effect. The participants of this Cluster have the strongest ambitions (strongest maximizing tendency) and – due to high
prices for their products – they are very successful in the beginning. However, these participants finally end up with huge losses after prices lower again (detailed description in Appel and Balmann 2018). This initial negative effect of Cluster 1 is diminished over time: As the participants’ farms become illiquid, the participants also lose their influence on the region. The impact on the aggregated farm household income even turns from negative to positive and, in the end, is well above the level of the benchmark. Similar results, but with a lower impact can be observed for Cluster 2. The development in Cluster 3 is almost identical to the benchmark situation. In Cluster 4, the aggregated farm household income becomes increasingly lower than in the benchmark.

Figure 3 Development of aggregated farm household income in the region relative to the Benchmark including the participant

But this only holds as long as the participant’s farm income is excluded from the aggregated regional income. If the participants are included (see Figure 3), Cluster 4 has in the longer run a clear positive effect while Cluster 1 has a smaller positive effect and Cluster 2 and 3 almost no effect. This means that the Cluster participants account for a major share of regional farm incomes (including negative incomes in Cluster 1).
To estimate the effect on the regional added value, we cumulate the aggregated economic land rents of all farms in the region (Figure 4). Again, we consider for each experiment the deviation from the benchmark situation to minimize the scenario effect. For all clusters the economic land rents are lower than the benchmark in the beginning. While all other clusters stay below the benchmark level, the cumulated economic land rents of cluster 4 the difference to the benchmark turns and become positive in the end. Therefore one could assume a gain for the value added in the region which would also positively affect other stakeholders like land owners (e.g. former farmers that receive rental payments for their own land).

- In contradiction to Hypothesis 1, more farms stay active in Cluster 4 than in the respective benchmark situation. Although these farms are smaller on average, we can assume a gain in the regional added value as the cumulated economic land rents are higher compared to the benchmark situation.
- In contradiction to Hypothesis 2, in Cluster 1 the other farms of the model region cannot benefit from the worse performing participant. No significant effect on the regional level is detected regarding farm sizes and numbers of active farms. The cumulated economic land rents in that cluster show the most negative deviation from the benchmark situation. Therefore, we can assume that the region does not benefit from a poorly performing participant.

5.2 Spatial Analysis
So far, the region has been considered as a whole. However, it can be assumed that the influence of the participants is not equally distributed over the entire region. In the following section, we analyze the influence of the participants on other farms in the region depending on their distance to the participants' farm. In FarmAgriPoliS the coordinates of the farmstead
are recorded for each farm. This can then be used to determine the distance to the participant's farmstead.

5.2.1 Equity Capital
To analyze the development of the farms' equity (see Figure 5), we use for every farm in the region the relative difference in equity capital from the respective farm in the benchmark situation (see Equation 0. This accounts for different initializations and scenarios.

![Figure 5 Spatial distribution of equity capital at the end of experiment (relative to the Benchmark; excluding the participant)](image)

1) \( \text{Equity}_{\text{relative}} = \frac{(\text{Equity}_{\text{Experiment}} - \text{Equity}_{\text{Benchmark}})}{\text{Equity}_{\text{Period=0}}} \)

Different clusters have a different impact on the level of relative equity capital of neighboring farms. For Cluster 2, the curve is flattest, i.e. participants of this Cluster have the least impact. The reason can be seen in the fact that these farms are very similar to the benchmark. The poorly performing farms in Clusters 1 and 3, obviously have a positive effect on farms in their direct neighborhood. In Cluster 4, the peak of this positive effect occurs at a slightly greater distance, but overall it is much lower.

Overall, the spatial influence seems to be rather wave-like across all Clusters: What has a positive influence on the direct neighbor can be negative again for the second and vice versa. These waves shallow with increasing distance, i.e. the influence of the participants decrease.
5.2.2 Farm Size

Figure 6 Spatial distribution of farm sizes at the end of experiment (relative to Benchmark; excluding the participant)

This wave-like shape can also be observed in the relative farm sizes (Figure 6). However, in particular Cluster 4 is remarkable: The direct neighbors have a significantly lower relative farms size compared to other clusters. The peaks of the "wave" are significantly larger. So the next farms behind the direct neighbors (about a distance of 3.5 kilometers) are even bigger than in other Clusters.

5.2.3 Rental prices

Figure 7 Spatial distribution of rental prices for arable land at the end of experiment (relative to Benchmark; excluding the participant)

The successful participants of Cluster 4, have a strong effect on the level of rental prices in their neighborhood. However, this effect diminishes significantly with the distance to the
Participant’s farm, as Figure 7 shows. Here, too, this effect seems to be wave-like: Due to the
direct competition with a successful participant, rental prices of direct neighbors are much
higher (only by high biddings these farms have a chance on the land market). Higher rental
payments or direct competition will limit or even reduce competitiveness. This, in turn,
strengthens neighbors’ neighbors, etc.

5.2.4 Reflections on functional form

Since all considered variables of the spatial analysis show the same wave-shaped pattern,
this section provides a brief discussion of the functional form. We used the spatial
distribution of the equity capital (see Figure 5) to calculate Fourier coefficients. Since we are
primarily interested in the influence of the distance, the Cluster effect is ignored in that
calculation. In order to determine the influence, values were determined on the basis of a
kernel density estimation (Epanechnikov 1969), for which a functional shape is estimated by
means of a Fourier transformation. Since it makes little sense to carry out this
transformation in such detail that the values are exactly traced, the frequencies were
selected that influence 80 % of the curve and thus also explain the influence of the distance
on the farms’ equity to 80 %. The result is shown graphically in Figure 8.

Note: single circles: generated from Kernel-weighted local polynomial smoothing (Epanechnikov) of
the four Clusters (cf. Figure 5)

**Figure 8 Fourier transformation of spatial distribution of equity capital at the end of
experiment (relative to Benchmark; excluding the participant)**

The resulting function can be expressed as Equation 2) with the coefficients given in Table 3.

\[
2) \quad x' = \frac{2\pi}{32} \cdot x
\]

\[
y = \sum_{j=-2}^{2} a_j \cdot \cos(j \cdot x') + b_j \cdot \sin(j \cdot x')
\]
Table 3 Fourier transformation - coefficients

<table>
<thead>
<tr>
<th>j</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>-0.0255</td>
<td>0.0110</td>
</tr>
<tr>
<td>-1</td>
<td>-0.0167</td>
<td>-0.0321</td>
</tr>
<tr>
<td>0</td>
<td>0.0279</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-0.0167</td>
<td>0.0321</td>
</tr>
<tr>
<td>2</td>
<td>-0.0255</td>
<td>-0.0110</td>
</tr>
</tbody>
</table>

As Figure 8 shows, the curves flatten with increasing distance. Thus it can be concluded that the participants' influence on other model farms in the region decreases with increasing distance.

- In consistence with Hypothesis 3 the impact of the participants' behavior (resp. Cluster) on other farms diminishes with increasing distance to these farms.

However, it cannot be determined due to the wave-shape whether this influence on the other farms is in general positive or negative.

5.3 Structural equation modeling

Figure 9 Structural equation model of the neighborhood effects on farms' equity capital (relative to Benchmark)

Additionally to the graphical results of the previous sections, the influence of the different Clusters needs to be captured more precisely and statistically substantiated. The previous (graphical) analyzes have shown that the participants have a different influence on the region, depending on the Cluster. It was also shown that the distance of a model farm to the participants' farm has an impact. So far, no distinction between the influence of the regional situation and the influence of the Cluster was made. The present complex multilayer panel structure of the experimental data is a challenge for econometric analysis. To meet this
challenge and to grasp the multi-layered structure of the data, the analysis in this section is based on Structural Equation Modeling (SEM).

In general, a graphic structure of the (assumed) relationships and influencing factors is set up first (see Figure 9) by using the SEM Builder from STATA. Subsequently, the calculation of the established model structure is carried out using the maximum likelihood method. We incorporate into this method what we have so far gained about the success determinants of the participants. For example, the scenarios (i.e., the operation and the price scenario) influence the success and also the agent’s behavior (Cluster membership). Also the spatial distribution of the farms and thus the distance to the participant depends on the scenario: The distribution of farms in the region differs from the other scenarios only in scenarios 4 to 6. This is exactly the case where the participants manage "Farm 2". Furthermore, we account for the participants' equity capital as a success factor. We use relative measures to diminish the scenario effect. Regarding the spatial influence, logarithmic form of distance, is used because the effect of the participants' behavior on the neighboring farm is larger, the closer this farm is to the participants' farm (cf. Figure 8). This is also consistent with Gravity models.

As Table 4 shows, the relative equity capital of the participants has a significant negative impact on the size and equity capital of the neighboring farms. On the other hand, the level of relative rental prices for arable land and grassland has a significantly positive effect. Thus, the higher the equity of the participants (and thus the more successful the participant), the smaller are the neighboring farms (regarding equity capital and farm size in hectares) and the higher are rental prices in the region.

Also, the distance to the participants’ farm has a significant influence on all considered measures. The fact that the coefficient is sometimes positive, sometimes negative originates from the wavelike distribution of the spatial effect (cf. Figure 8).

The equity capital of the participant has a positive effect on the level of the rental prices: That means, the more successful the participant, the higher the rental prices in the region. The distance, on the other hand, has a negative impact on the level of rental prices. The further away from the participants’ farm, the lower the rental prices. This effect can also be seen very well in Figure 7. The effect is, as already described, undulating. What positively influences the direct neighbor can be negative again for neighbors’ neighbors and vice versa. In this case: Due to the direct competition with a successful participant, the rental prices of the direct neighbor are initially much higher (only by bidding high prices they have a chance on the land market). Higher rental prices or direct competition will however limit or even reduce competitiveness. This, in turn, strengthens the neighbors’ neighbors.

In addition to the already described influence of the participants' equity, also their assignment to a certain Cluster has a partially significant influence: Both, Cluster 1 and Cluster 4, have a rather negative effect on farm size and the equity capital. Only Cluster 3, the solid managers, have a positive effect.
In addition, Cluster 4 has a significant negative impact on the level of rental prices for arable land. However, with the generally smaller farm sizes (see 5.1.1 Farms and Farm Sizes), it should be mentioned that this effect may also be due to the fact that other farms in the vicinity of a Cluster 4 participant are not able to get involved in the land market at all (not able to bid high enough to receive new rental contracts for land).

- In consistence with Hypothesis 4 farms can benefit from a poorly performing participant nearby.

Table 4 SEM results for estimated measures

<table>
<thead>
<tr>
<th></th>
<th>Coef.</th>
<th>Robust Std. Err.</th>
</tr>
</thead>
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<tr>
<td>Equity capital a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity capital participant a)</td>
<td>-0.005***</td>
<td>0.002</td>
</tr>
<tr>
<td>In Distance</td>
<td>-0.020***</td>
<td>0.003</td>
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<td>-0.010</td>
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<tr>
<td>CLUSTER3</td>
<td>0.007*</td>
<td>0.003</td>
</tr>
<tr>
<td>CLUSTER4</td>
<td>-0.014**</td>
<td>0.004</td>
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<tr>
<td>Period</td>
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<td>0.000</td>
</tr>
<tr>
<td>Const.</td>
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<td>0.009</td>
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<tr>
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<tr>
<td>Farm size a)</td>
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<tr>
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</tr>
<tr>
<td>In Distance</td>
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</tr>
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</tr>
<tr>
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<td>0.016</td>
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<tr>
<td>In Distance</td>
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</tr>
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<tr>
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<td>0.060</td>
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<tr>
<td>var(e. Rental price grassland a)</td>
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</table>

Note: Standard error adjusted for 49 clusters
significance level: * p < 0.05; ** p < 0.01; *** p < 0.001
a) relative to Benchmark
6 Conclusion

Our analysis confirmed the thesis that farms in a region are not independent regarding their development, but are mutually dependent. As presumed first, path-breakers have a negative effect on the income of other farms in the region. The SEM analysis also confirms the negative impact of cluster 4 on the equity capital of other farms in the region. -However, more, albeit on average, smaller farms remain active. So there are distributional effects: The more farms, the smaller their piece of cake.

Also the path-breakers are part of the region. If they are included in the analysis, in total there is a positive effect on efficiency in general and the accumulated economic land rents as well as on regional added value.

Whether a single farm in the region can benefit from a path-breaker depends on the distance. Although the influence decreases overall with growing distance, the functional correlation is neither linear nor exponential, but wave-like. Thus, a path breaking farm may have substantially negative effects on immediate neighbors which lose land and can be considered as prey of the path breakers. On the other hand, path-breakers may be beneficial to certain farms in a region which are not in their immediate vicinity.

In case of poorly performing participants, farms may benefit. This may be especially true for direct neighbors that can rent additional land if these farm become illiquid. In such cases, the participants in the experiments may be considered as "prey". Our analysis suggests that poorly performing participants deteriorate added value for the entire region. In some cases, a poorly performing farm may be unfavorable for neighboring farms in the region, especially if they are not the direct neighbors.

To sum up: The farm performance and distance determine who is "predator" and who is "prey".
References


Happe, K., 2004. Agricultural policies and farm structures - agent-based modelling and application to EU-policy reform. Studies on the Agricultural and Food Sector in Central and Eastern Europe. IAMO.


