Between path dependence and path creation: The impact of farmers' behavior on structural change in agriculture

Dissertation
zur Erlangung des
Doktorgrades der Agrarwissenschaften (Dr. agr.)

der

Naturwissenschaftlichen Fakultät III
Agrar- und Ernährungswissenschaften,
Geowissenschaften und Informatik
der Martin-Luther-Universität Halle-Wittenberg

vorgelegt von

Frau Franziska Appel
geb. am 21.01.1986 in Herzberg (Elster)

1. Gutachter: Prof. Dr. Alfons Balmann
(Martin-Luther-Universität Halle-Wittenberg)

2. Gutachter: Prof. Dr. Uwe Latacz-Lohmann
(Christian-Albrechts-Universität zu Kiel)

Datum der Verteidigung: 26. November 2018

Zusammenfassung

Landwirtschaftliche Strukturen als komplexe adaptive Systeme umfassen regelmäßige Interaktionen zwischen landwirtschaftlichen Unternehmen und den dort involvierten Personen (LandwirtInnen) sowie ihrer Umgebung. Diese Systeme unterliegen einem permanenten, aber oft langsamen pfadabhängigen Wandel. LandwirtInnen spielen nicht nur eine wesentliche Rolle in landwirtschaftlichen Strukturen, sondern sind selbst ein Teil dieser Strukturen. Die Rolle, die sie in diesem komplexen Prozess spielen, hängt von den Merkmalen des Unternehmens, den Managementfähigkeiten der BetriebsleiterInnen sowie vom lokalen Wettbewerb und den allgemeinen wirtschaftlichen und ökologischen Rahmenbedingungen ab.

Traditionell basieren empirische sowie normative Modelle in der Agrarökonomie auf der Annahme, dass sich LandtwirtInnen gemäß dem Konzept rationaler PreisnehmerInnen verhalten. Die verhaltenswissenschaftliche Forschung zeigt jedoch, dass Menschen am ehesten als begrenzt rational beschrieben werden können und zahlreichen kognitiven Verzerrungen unterliegen. Sie ignorieren oft einen Großteil der verfügbaren Informationen und verwenden eher Heuristiken als strikte Maximierung, wenn sie Entscheidungen treffen. Um das Verständnis für das Verhalten von LandwirtInnen zu verbessern, scheint eine stärkere empirische Fokussierung auf die Entscheidungszusammenhänge und das Entscheidungsverhalten von LandwirtInnen sinnvoll.

Ziel der vorliegenden Arbeit ist es, Möglichkeiten zur Analyse verhaltensbasierter Aspekte des Agrarstrukturwandels zu entwickeln und zu evaluieren. Grundlage ist FarmAgriPoliS, ein agentenbasiertes Planspiel, mit dem das Entscheidungsverhalten und der wirtschaftliche Erfolg realer Menschen in einem Labor experimentell untersucht werden kann. FarmAgriPoliS basiert auf AgriPoliS, einem agentenbasierten Modell zur Analyse des Agrarstrukturwandels, und bietet den TeilnehmerInnen Rahmenbedingungen, die Entscheidungen in Situationen erfordern, mit der BetriebsleiterInnen auch in der Realität konfroniert sind.

Die Experimente mit FarmAgriPoliS erlauben Einsichten, wie menschliche

Akteure strategische Entscheidungen als landwirtschaftliche BetriebsleiterInnen treffen und wie sie sich dabei in ihrem Verhalten unterscheiden. Dabei können vier unterschiedliche Verhaltenscluster identifiziert werden: Cluster 1 - "Fahrlässige SpielerInnen", Cluster 2 - "Verpasste Chancen", Cluster 3 - "Solide BetriebsleiterInnen" und Cluster 4 - "Erfolgreiche PfadbrecherInnen". Die ersten drei Cluster, die sich in etwa 88% der Experimente finden, entsprechen der Prospect Theory - das heißt, die TeilnehmerInnen waren erfolgreicher bei der Vermeidung von Verlusten als bei der Generierung von Gewinnen. Etwa 12% der TeilnehmerInnen konnten jedoch vorgegebene Entwicklungspfade erfolgreich verlassen (Cluster 4). Diese letztgenannte Gruppe spielte eher schwierige Szenarien mit herausfordernden Preisentwicklungen (schwankend oder sogar rückläufig) und ungünstigen Kostenstrukturen der Betriebe. In diesen Experimenten weisen die Betriebe der TeilnehmerInnen ein starkes Wachstum auf und sind wesentlich erfolgreicher als die Betriebe von Computeragenten und anderen TeilnehmerInnen mit identischen Voraussetzungen. Diese sehr erfolgreichen PfadbrecherInnen passen nicht in die Prospect Theory und charakterisieren UnternehmerInnen, die spezifische Strategien entwickelt haben und besondere Merkmale aufweisen. Da die Betriebe in einer Region hinsichtlich ihrer Entwicklung nicht voneinander unabhängig sind, werden zudem die Implikationen dieses pfadbrechenden Verhaltens für andere Betriebe in der Nachbarschaft analysiert. Die Ergebnisse zeigen, dass PfadbrecherInnen negative Auswirkungen auf das Einkommen anderer landwirtschaftlicher Betriebe in der Region haben. Allerdings bleiben mehr andere, wenn auch im Durchschnitt kleinere Betriebe aktiv. Wird die gesamte Region (einschließlich der PfadbrecherInnen) an Stelle von Einzelbetrieben analysiert, so findet sich eine allgemeine Steigerung der Effizienz, der kumulierten Grundrenten sowie der regionalen Wertschöpfung. Ob ein einzelner Betrieb in der Region von einem/einer PfadbrecherIn profitieren kann, hängt auch von der Entfernung ab.

Highlights der Dissertation

- Verwendung eines agentenbasierten Modells als kontextspezifische Umgebung für Verhaltensexperimente.
- Im Vergleich zu Computeragenten zeigen menschliche TeilnehmerInnen ein resilienteres Verhalten.
- Drei Arten von resilienten Strategien identifiziert: Überleben des Betriebes, geplanter Ausstieg, Pfadbrechung.
- Teilnehmer neigen dazu, erfolgreicher bei der Vermeidung von Verlusten als bei der Realisierung von Gewinnen zu sein.
- Einige TeilnehmerInnen übertreffen Computer-Agenten in anspruchsvollen Situationen deutlich.
- Verlustvermeidung durch geplante statt erzwungene Betriebsaufgabe und intelligentere Anpassung.
- Pfadbrecher können die regionale Wohlfahrt erhöhen.

Summary

Agricultural structures may be described as complex adaptive systems of regular interactions between farming enterprises including the involved persons (farmers) and their environment and are underlying permanent but often slow, path-dependent change. Farmers not only play an essential role in agricultural structures, but are also embedded in these structures. The role they take within this complex process depends on the farm's characteristics, the characteristics of the farmer as a manager, and also local competition and general economic and environmental conditions.

The traditional agricultural economic assumption in empirical as well as normative models of farmer behavior is based on the concept of rational price-takers. However, research in behavioral economics reveals that humans are best described as boundedly rational, and they are subject to numerous cognitive biases. They often ignore much of the available information and use heuristics rather than strict maximization when making decisions. To improve our understanding of farmers' behavior, a stronger empirical focus on the decision context of farmers seems useful.

The objective of this thesis is to develop and evaluate possibilities of analyzing behaviorally based path dependence of structural change in agriculture. Starting point is FarmAgriPoliS, an agent-based business game, that enables researchers to experimentally study the decision behavior and the economic success of real persons in a laboratory. FarmAgriPoliS is based on AgriPoliS, an agent-based model of structural change in agriculture, and provides the participants with a salient context which requires decisions close to those situations faced by actual farm managers.

The experiments based on FarmAgriPoliS analyze how human participants act in a strategic farm management context and how they differ in their behavior. Four distinct outcome clusters are identified which can be described as: Cluster 1 - "Negligent gamblers", Cluster 2 - "Missed opportunities", Cluster 3 - "Solid farm managers", and Cluster 4 - "Successful path-breakers". The first three clusters that included some 88% of the experiments corresponded with prospect theory - that is, the participants in

these games 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 latter experiments can be characterized as rather challenging scenarios with unfavorable price developments (fluctuating or even declining) and farms' cost structures. In these experiments, the participants managed strong growth and performed substantially more successful than computer agents and other participants playing identical games. These very successful path-breakers do not fit into prospect theory and characterize entrepreneurs which developed specific strategies and have specific characteristics.
As farms in a region are not independent regarding their development, the implications of such path-breaking behavior for other farms in the neighborhood are further analyzed. The results reveal that path-breakers have a negative effect on the income of other farms in the region. However, more, albeit on average, smaller farms remain active. If the whole region (including the path-breakers) are analyzed instead of single farms, an increase of the efficiency in general, in the accumulated economic land rents as well as in the regional added value is detected. Whether a single farm in the region can benefit from a path-breaker depends on the distance.

Highlights of the thesis

- Using an existing agent-based model as context specific environment for behavioral experiments.
- Compared to computer agents, human participants exhibit a more resilient behavior.
- Three types of resilient strategies identified: successful survival, planned exits, path-breaking.
- Participants tend to be better in avoiding losses than in realizing gains.
- Some participants strongly outperform computer agents under challenging situations.

- Loss avoidance through planned instead of forced farm exits and smarter adjustment.
- Path-breakers may increase the regional welfare.

Abbreviations

%	percent
AEE	Agentur für Erneuerbare Energien e.V.
AgriPoliS	Agricultural Policy Simulator
ANOVA	Analysis-Of-Variance
BMG	business management game
BMJ	Bundesministerium der Justiz
Coef.	Coefficient
Const.	constant
ct	Cent
DIW	Deutsches Institut für Wirtschaftsforschung
ESU	european size unit
FADN	farm accountancy data network
FarmAgriPoliS	Farmers' Agricultural Policy Simulator
fig.	Figure
FAQ	Frequently asked questions
FTE	full time equivalent
GDSM	General Decision-Making Styles
GUI	graphical user interface
GWh	gigawatt hour
ha	hectare
HLL	Holt and Laury Lottery
Ife	Institut für Ernährungswirtschaft
kg	kilograms
KLU	Kommission Landwirtschaft am Umweltbundesamt
km	kilometer
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft
kW	kilowatt
LFL	Bayerische Landesanstalt für Landwirtschaft
MW	megawatt
Obs.	Observations
ODD	Overview, Design concepts, and Details

OLS	Ordinary least squares
PC	Personal Computer
REA	Renewable Energy Sources Act
REF	reference scenario
resp.	respectively
Scen.	Scenario
SD	standard deviation
SEM	Structural equation modeling
SGM	standard gross margin
SO	standard output
Std. dev.	standard deviation
Std. err.	standard error
UAA	utilized agricultural area
UML	Unified Modeling Language
vTI	von Thünen Institute

Contents

List of Figures

List of Tables

1 Introduction[1]

Agricultural structures may be understood as complex adaptive systems of regular interactions between humans (farmers) and their environment underlying permanent but often slow path-dependent change (Balmann, 1995). Farmers not only play an essential role in agricultural structures, but are also embedded in these structures. Farmers usually face rather fierce competition on output and input markets within this environment, particularly on the land market. The technological treadmill concept in agriculture (Cochrane, 1958) suggests that farmers either have to innovate, adapt or exit business under such conditions. The role they take within this complex process depends on the farm's characteristics, the characteristics of the farmer as a manager, and also local competition and general economic and environmental conditions.

The traditional agricultural economic assumption in empirical as well as normative models of farmer behavior is based on the concept of rational price-takers. Not only general and partial equilibrium models (e.g. Balkhausen et al. (2006)), but also several agent-based models of the agricultural sector are based on this principle; examples include AgriPoliS (cf. Happe et al. (2006)), MP-MAS (cf. Berger and Schreinemachers (2006), Schreinemachers and Berger (2011)) and SWISSLand (Möhring et al., 2016).

These assumptions have been questioned by research in behavioral economics (Ariely (2010), Kahnemann (2011), Thaler (2012)). Humans are best described as boundedly rational, and they are subject to numerous cognitive biases. They often ignore much of the available information and use heuristics rather than maximization when making decisions. In the agricultural sector, still relatively little is known about the actual behavior of farmers. First empirical findings based on behavioral experiments suggest that farmers do not behave rationally under all circumstances (e.g. Schwarze et al. (2014)). To improve our understanding of their behavior, a stronger empirical focus on the decision context of farmers seems to be useful.

[1] This section condenses and extents the introductions Appel et al. (2016), Appel et al. (2018), Appel and Balmann (2018).

This thesis presents FarmAgriPoliS, an agent-based business management game, that enables researchers to experimentally study the decision behavior and the economic success of real persons in a laboratory. FarmAgriPoliS is based on AgriPoliS, an agent-based model of structural change in agriculture (Happe et al., 2006) and provides the participants with a software-based environment that involves multiple relatively realistic decisions in a simulated agricultural region. Therefore, FarmAgriPoliS is an opportunity for behavioral and participatory experiments in which human subjects are assumed to manage a farm in competition with computer-simulated farms (agents) that use mixed-integer short-term profit maximization. It allows to compare the observed experimental behavior and economic results with those of computer agents in identical situations.

1.1 Objective

The overall objective of this thesis is to develop and evaluate possibilities of analyzing the impact of farmers' behavior on structural change in agriculture. This can be further divided in methodological and thematic objectives. On the methodological side there is a dilemma when empirically investigating farmers' behavior: On the one hand, laboratory experiments allow for the identification of causal effects and data can be obtained 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 it is often difficult to identify causal effects. 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 this 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. The methodological purpose of this thesis is to document the process of developing FarmAgriPoliS as a platform for agent-based participatory experiments and address details of its use.

The thematic objective is to improve the understanding as to how human participants act in a strategic farm management context, how they differ in their behavior, and how these differences affect the performance of the participant's farm, as well as regional structures. Particularly, it is examined whether path-breaking behavior can be detected and further, what are the implications of such path-breaking behavior for other farms in the neighborhood.

1.2 Structure of the thesis

Section 2 provides the basic theoretical and methodological background of this thesis. The theoretical part focuses on selected system-theoretical and economic concepts related to structural change, and clarifies their importance for agricultural structures. On the methodological side a general introduction to agent-based modeling is provided.

This is followed by Section 3 based on Appel et al. (2016) as an example of how agent-based models can contribute to analyses of structural change in agriculture.

Section 4 motivates the experimental approach and illustrates FarmAgriPoliS in more detail. The model description is based on Appel et al. (2018) and documents the process of developing FarmAgriPoliS and addresses details of its use. It provides a systematical classification of FarmAgriPoliS into the framework of business management games with agricultural backgrounds. Furthermore, FarmAgriPoliS is evaluated based on participants' experiences and performance in behavioral experiments. Finally, the suitability of FarmAgriPoliS (i) for didactic purposes, (ii) as an experimental platform, and (iii) for entertainment is discussed.

Based on Appel and Balmann (2018) the experimental findings are elaborated in Section 5. In the theoretical part of this paper the concept of resilience is defined as it applies to farmer behavior within the process of structural change. The methodological part in Section 5.3 motivates the use of experimental approach to examine the hypotheses developed in Section

5.2.2 and provides the description of the experimental design and subject pool (Section 5.4). Subsequently, the experimental findings are elaborated. In addition to a descriptive analysis in Section 5.7.1 where the performance of the participants is compared to that of computer agents, Section 5.7.3 provides a cluster analysis to systematize the differences between the participants. How path-breaking farms which dramatically increase their farm-size influence other farms in an agricultural region is examined in more detail in Section 6.
Finally, Section 7 summarizes and discusses the results of the papers presented in this thesis and draws conclusions.

2 Theoretical and Methodological Background[2]

2.1 Structural change in Agriculture

The agricultural structure of a region can be described in terms of farm sizes and numbers, tenure patterns, legal organization (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, farm size distributions follow the Pareto principle (see Sombart, 1967): Often, a relatively small number of large farms hold a major share in agricultural production.
Agricultural structures may be described as complex adaptive systems of regular interactions between farming enterprises including the involved persons (farmers) and their environment. Farmers not only play an essential role in agricultural structures, but are also embedded in these structures. Farms usually face rather fierce competition on output and input markets, particularly on the land market. The technological treadmill concept in agriculture (Cochrane, 1958) suggests that farms either have to innovate,

[2]This section condenses and extents the theoretical and methodological backgrounds of Appel et al. (2016), Appel et al. (2018), Appel and Balmann (2018)

adapt or exit business under such conditions. The role they take within this complex process depends on the farm's characteristics, the characteristics of the farmer as a manager, and also local competition and general economic and environmental conditions.
Structural change may not be seen as a societal goal itself, but farm structures may still play an important role from a societal perspective as structures change slowly with long-term effects on economic, social and environmental outcomes. Structural goals may be justified by considering a certain farm structure as a kind of intangible asset. This may also be the reason why structural changes often raise public concerns (Balmann and Valentinov, 2016; Chatalova et al., 2016). A distinction may be drawn between two core concerns regarding structural change. These concerns relate firstly to potential winners and losers, as structural change only leads to Pareto superior results in exceptional cases. This issue has been addressed by the technological treadmill concept in particular as it applies to structural change in agriculture (Cochrane, 1958). The underlying fundamental phenomenon has already been addressed more generally by the Schumpeterian notion of creative destruction (Schumpeter, 1942). Secondly, concerns regarding structural change may be related to the complexity of structural change itself, which may ultimately provoke an "ongoing discourse between the so-called industrial and agrarian philosophies of agriculture" (Chatalova et al. 2016, referring to Thompson 2010).

2.1.1 Path dependence in agriculture

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. A general definition of path dependency is that historical events affect the future development of a system, i.e. that history matters. A path dependent dynamic system has multiple absorbing states with self-reinforcing mechanisms to which it can lock-in. This means that there are multiple equilibria and persistent disequilibria. Path-dependency implies a non-predictability of the future evolution of the system at some points in time while at other points in time the system will display hardly any change at all (Arthur, 1989).

Balmann (1995) argues that also 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, frictions on the land market and policies supporting current farm standards. 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 a general overview and classification of different reasons 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. According to Jones et al. (2011), *"(m)ental models are personal, internal representations of external reality that people use to interact with the world around them. They are constructed by individuals based on their unique life experiences, perceptions, and understandings of the world. Mental models are used to reason and make decisions and can be the basis of individual behaviors. They provide the mechanism through which new information is filtered and stored."* Recent applications in organizational theory, recognize the role of cognitive processes and social-emotional aspects in the concept of path dependency. Accordingly, mental models have to be seen as cause of self-reinforcements of existing states of a social system. Nevertheless, these aspects received relatively little attention in research yet. While the neoclassical economics' literature ignores cognition and mental models largely, the concept of path dependence can give a more prominent position to these issues. But so far, there is no universal understanding of mental models in the various scientific disciplines. Rather, there are various discrete concepts, based on Johnson-Laird (1983) and related works (Bach, 2010). In general, a mental model can be understood as a simplified, subject internal representation of reality, which serves the perception and solution of problems in complex decision situations (Bach, 2010). Mental models include, among others values, beliefs, knowledge, skills and capabilities of information processing. Often it is assumed that each individual has different mental models for individual objects instead of one single mental model of reality (Johnson-Laired (1983); Bach (2010)). Through new experiences mental models can be changed (Bach, 2010). However, such changes take time, since individuals tend to primarily accept what fits to their ideas, and to miss others (Able et al., 1998). Insofar mental models can obviously be subject to self-reinforcment. Only an "activating event" (Craton, 2002, p. 66) may result in a change of or within a mental model (Eckert and Bell, 2006); by itself, mental models do not change. Thus mental models themselves can be described as - at least temporarily - path dependent. They are as long self-reinforcing until (e.g. by own experience) the mental model is obviously no longer true. Also group dynamics can have a significant role in changing or maintaining mental models: mental models within a group may also be self-reinforcing. According to Ackermann (2001) it is even possible that mental models within society converge and establish collective mental models. Particularly relevant for the convergence of mental models, according to Denzau and North (1994), are interaction and communication between individuals and groups. This allows not only individual mental models themselves but also interdependencies of mental models of different individuals and groups to act self-reinforcing and thus lead to path dependencies. A deviation from existing - as Ackermann calls it - "social paradigms" results often in negative sanctions (Ackermann, 2001, p. 158f). This can lead to a situation where reforms are rejected due to the normative implication of common models - regardless of any detectable dysfunctionality (Ackermann, 2001, p. 206). Especially in agriculture the ignorance of innovations and deadlocked ways of thinking can be reasons for permanent path dependency. Thus mental models of farmers can strongly influence their actions. Ostermeyer (2015) gives the example of a farmer's mental model from the East Allgäu (Germany). The farmer was asked about his future vision for his farm. He wished that he can manage his farm in the current form for the next 20 years and generate income from agricultural production without any mayor change in the farm structure (e.g. growth). Thus it can be assumed that he will invest little time and money in the search for development opportunities. Eckert and Bell (2005) discover that farmers reject advices and feedback from experts if these were not in accordance with their mental models about agriculture, or they asked for further information that were congruent with their mental models. The consequence is that some innovations are not even contemplated and simultaneously mental models are repeatedly confirmed. Only by an activating event, such as becoming aware of the dangers of pesticide use for the applier, the mental model is changed fundamentally: e.g. switching to organic farming as described in the example by Eckert and Bell (2006). In general, farmers can have various mental models, even if they work under similar conditions in the same region (cf. Ostermeyer (2015)). The reason is that mental models are developed for specific purposes. Because interests of individuals could deviate, mental models can vary, too. Moreover, several mental models can overlap. In the example described by Eckert and Bell (2006) the mental models of some of the questioned farmers overlap in case of family and agriculture.

2.1.2 Path breaking and path creation

Starting from the assumption that path dependencies are potentially inefficient, the question arises whether and under which circumstances a change towards a more efficient path is possible. It should be possible to leave an inefficient current path if the actors become aware of this inefficiency.

Especially the fact that that mental models and learning could establish path dependencies provides opportunities to deviate from existing paths by changing mental models. A further starting point is to emphasize the entrepreneurship of the actors. Garud and Karnøe (2001) argue that the traditional concept of path dependence ignores that agents may be active in finding ways to overcome path dependence. In contrast, Garud and Karnøe (2001, p. 2) describe entrepreneurs as reflective and self-determined actors: *"In our view, entrepreneurs meaningfully navigate a flow of events even as they constitute them. Rather than exist as passive observers within a stream of events, entrepreneurs are knowledgeable agents with a capacity to reflect and act in ways other than those prescribed by existing social rules and taken-for-granted technological artefacts."*

Summing up, two starting points for overcoming path dependencies can be identified: Garud and Karnøe (2001) develop a concepts of "path creation" and "path breaking". If, on the one hand, path dependence is an unintended macro-result of intended micro-behaviors, path-breaking as a kind of mindful deviation may be an option to overcome a path dependence (Schreyögg et al. (2003), Stack and Gartland (2003), Meyer and Schubert (2005)). On the other hand path creation emphasizes the role of entrepreneurs and how they can intentionally create desirable new paths.

Sydow et al. (2005) separate between four "anchors", each having a different focus for applying path-breaking concepts. Interestingly, these "anchors" all refer to some kind of "mental path dependence" and thus support the importance of such a category: i) Cognitive (reflection traps: "we don't see what we don't see"): Path-breaking may be achieved through an organizational discourse, possibly supplemented by information from external consultants (new knowledge and perspectives), ii) Emotional (commitment or identity trap: "this commitment is our identity - the more we are committed the stronger is our identity"): Path-breaking may be achieved with the help of behavioral interventions, iii) Social (normative or cultural trap: "what we are doing is right because we are doing it"): Systematic interventions by irritating the social system in order to break systematic routines and patterns could overcome path dependence, and iv) Resource (sunk costs trap:

"if we gave up this investment it would be wasted"). Path-breaking may be achieved through reallocation of resources that incorporates prevailing cognitive and normative rules.

Though Theuvsen (2004) recognizes a significant potential, the concepts of path creation and path breaking have not yet been transferred to many agricultural economics problems. With regard to the issues of structural change, one may ask: How and under which (policy) circumstances can path dependence of suboptimal structures in agriculture (e.g., too small farms) be overcome? The search for answers to this question can start at the microlevel perspective of a farm or a supply chain as well as from a sector or policy perspective. Particularly with regard to supply chains, several authors recently referred to seismic and rapid changes over the past several decades. The enormous rise of supermarkets within developing and transition countries is emphasized by, e.g., Reardon and Berdegué (2002), Reardon and Swinnen (2004) and Dries et al. (2004). Also, Boehlje (1999) finds that new dimensions of structural change emerge with a particular role of value chains and agricultural production becoming a kind of biological manufacturing. Balmann and Schaft (2008) refer to enormous changes in the U.S. pork industry in which the ten largest producers control about 40% of all sows; they contend that there is a changing nature of structural change. Based on these developments, one may consider that at least in some parts of the agricultural food chains a kind of path-breaking or path-creation exists; however, it seems that these processes occur particularly in those areas of the agribusiness which are less land dependent, less regulated and less subsidized. Accordingly, one may ask whether and under which circumstances significant changes may be expected in more regulated sectors. In the case of the agricultural sector, creation of new paths may arise through changes in the policy environment. A deviation from the current policy is associated with high costs (Kay, 2005). Reforms within the European agricultural policy took place during the MacSharry reform in 1992 and more recently the Agenda 2000, the 2005 Mid Term Review and the 2008 Health Check. All these reforms followed a certain path towards a decoupling of agricultural support from production by requiring farmers to become more market oriented and to assume a more entrepreneurial role. With regard to farm development and structural change, Ostermeyer (2015) argues that path-breaking may be considered as relatively trivial in the case of a farm exit. This may be too simplified for practical purposes if a planned and ordered exit is considered as a strategic and entrepreneurial challenge. A planned farm exit may also require mindful deviation in terms of overcoming a personal mental model as well as the mental models prevalent in the social environment. Nevertheless, more challenging and far less trivial is surely the case where a farm manager is able to manage unusually strong and also profitable growth. Ostermeyer (2015) found that a small fraction of some 2% of farms may be able to show such behavior allowing them to gain substantial shares in total regional production in simulations of structural change with the agent-based model AgriPoliS. This small fraction of farms may partly be explained by, for example, the limits on the amount of land in a region such that farms can only increase their shares in production if other farms decline or exit. On the other hand, the small share of path-breaking farms found by Ostermeyer (2015) may also result from limitations to agent strategies in AgriPoliS.

2.2 Agent-based modeling

In addition to the more conventional theoretical and empirical approaches, simulation models such as recursive programming models and agent-based models (hereafter referred to as ABM) can be used for analyzing complex dynamic systems (Day, 1963; Axelrod, 1997). The idea of ABM is to map real or conceptual systems and to simulate their development. A distinguishing feature compared to other modeling approaches lies in the fact that ABM considers many individual agents (Railsback and Grimm, 2011). These agents may be individuals, groups, institutions or any other entities that pursues a specific objective (e.g. Railsback and Grimm, 2011; Tesfatsion, 2012). They have different initial situations, such as for example age and size, and have the ability to make decisions. ABM further allows consideration of local interactions between the individual agents. Agents can react to changes in their environment, and thus to the behavior of other agents in their close environment (Railsback and Grimm (2011)). The results are therefore not easily predictable from the start, even in the case of simplistic underlying assumption(Axelrod, 1997). This phenomenon is referred to as emergence (Axelrod and Tesfatsion, 2006), 2006). Overviews of the capabilities and requirements of ABM in agricultural economics are provided, for example, in Nolan et al. (2009) and Berger (2001).

The methodological starting point of this thesis is AgriPoliS. This spatially explicit and dynamic agent-based model enables ex post and ex ante analyses of agricultural structural change, particularly regarding the impact of alternative policies and assumptions on agriculture by comparing actual policies with counterfactual assumptions. Effects of alternative scenarios can be analyzed on several levels. These include individual behavior (e.g., regarding investments) and the overall performance (e.g., profits, liquidity, size) of individual farms but also those of a specific group of farms as well as farm size, number of farms, cultivation patterns, and the land market of entire agricultural regions. There are manifold examples of applications. For example, Happe et al. (2008) analyze how the initial structure of two agricultural regions in Germany influence farm structures after a policy reform. Another study on a wider European context is provided by Uthes et al. (2011), who analyzed the impact of direct payments on agricultural structures. Appel et al. (2016) analyze the effects of Germany's biogas policies (see Section 3).

The traditional agricultural economic assumption in empirical as well as normative models of farmer behavior is based on the concept of rational price-takers. Not only general and partial equilibrium models (e.g. Balkhausen et al. (2006)), but also several agent-based models of the agricultural sector are based on this principle; examples include AgriPoliS (cf. Happe et al. (2006)), MP-MAS (cf. Berger and Schreinemachers (2006), Schreinemachers and Berger (2011)) and SWISSLand (Möhring et al., 2016).

Frequent application of this assumption in agent-based models of the agricultural sector may be attributed to its high compatibility with linear, recursive and positive mathematical programming farm models in the tradition of Earl O. Heady (1983), Richard H. Day (1963), Richard E. Howitt (1995) and others that dominated farm-level modeling in agricultural economics for many decades. On the one hand, the specific strengths of each of these approaches have to be seen in their compatibility with farm-planning databases and the (usually unique) solutions they develop for any decision problem. On the other hand, these approaches to model farmer behavior show several common weaknesses, all of which are related to decisions in complex situations. These weaknesses include sensitivity of optimization model results to uncertain expectations, ignorance of strategic issues, and the assumption of perfect rationality amongst agents.

Agent-based models are quite flexible with regard to modeling agent behavior Examples of behavioral approaches range from simple rules to computational intelligence, including learning. These concepts and the modeling process are applied partly on the basis of participatory approaches such as the companion modeling approach (Antona et al., 2003). An extreme case can even be found in role-playing games where humans directly play the role of an agent and the games themselves serve as the models (Barreteau et al., 2003). A further option of modeling agent behavior may be found in behavioral experiments in a laboratory. Behavioral laboratory experiments in particular are used to study human behavior in controlled environments, which have shown that humans do not necessarily behave according to fully selfish and rational profit maximization, and that context does matter (Harrison and List, 2004, e.g.). These insights also apply to farmer behavior (e.g. Schwarze et al., 2014; Howley, 2015; Rommel et al., 2017).

3 Effects of the German Renewable Energy Act on structural change in Agriculture – The case of biogas [3]

Franziska Appel, Arlette Ostermeyer-Wiethaup and Alfons Balmann

Abstract

The strong political support for biogas production in Germany over the past decade has greatly affected agricultural production, farms and land markets. This paper analyzes the effects of Germany's biogas policies on agricultural development by using the agent-based simulation model AgriPoliS. Particular focus is placed on the effects of the previous German Renewable Energy Act (REA, German "EEG") of 2012, as well as the latest amendments, which were added in 2014. Our results show that under the previous REA and its predecessors, biogas production provided an attractive investment opportunity, especially for large farms, which led to a boost in biogas production. However, this policy also caused distortions within the agricultural sector, including increasing land rental prices. These effects particularly threatened farms that were not able to invest in biogas, as well as smaller biogas farms. On average, biogas farms could not increase their profitability. The main reason for this effect can be seen in the fact that a significant share of the value added is transferred via increased rental prices to land owners. The amendment of the REA in 2014, which reduced support levels substantially, partly attenuates some of these effects, though the previous policy will cast a long shadow.

JEL codes:

Q15; Q18; Q42; C69

[3]This chapter is based on Appel et al. (2016). Alfons Balmann contributed to the analysis and discussion of the results. Arlette Ostermeyer-Wiethaup provided the regional settings and input data. The model was jointly adapted and further developed to biogas investments by Arlette Ostermeyer-Wiethaup and Franziska Appel.

Keywords:

Biogas production; Agent-based modelling; Renewable energy act

3.1 Introduction and background

Biogas production can be considered one of the most influential innovations in German agriculture in recent decades. Farms' adoption of biogas production jumped after the Renewable Energy Sources Act (REA)[4] was introduced in 2004. Guaranteed feed-in tariffs (which mean a guaranteed price for the delivered electricity) for a period of 20 years and priority access to the electricity grid provided strong incentives for farmers to invest in biogas plants (AEE). Prior to 2004, biogas played only a minor role in German agriculture, but after the REA was established, both the number of biogas plants and the average plant capacity increased. Particularly between 2006 and 2011, the total number of plants doubled and the total capacity increased by more than 150%. In 2013, more than 7850 biogas plants with a total capacity of 3543 MW produced renewable energy in Germany (Fachverband Biogas, 2014); this has implications on the structure of German agriculture. About 85% of these plants are operated by farmers, and most feedstuff used in biogas plants is based on agricultural produce (Fachverband Biogas, 2015).

In general, agricultural structural change involves multiple and interlinked drivers that affect farm sizes, production patterns and farm capacities, as well as the economic and social situation of farms (cf. Goddard et al., 1993; Balmann et al., 2006). The renewable energy policies on the national level in Germany, i.e. the guaranteed feed-in tariffs for biogas production, also have strong implications for farms and farm structures. Several empirical studies found that the higher the biogas production in a region, the stronger was the increase in land purchase and rental prices (Braun et al., 2009; Kilian et al., 2008; Habermann and Breustedt, 2011; Hüttel et al., 2012). This is because biogas producers need substrates to feed their biogas

[4] REA: Renewable Energy Act; in German: Erneuerbare-Energien-Gesetz (EEG).

plants; key feed stuffs are silage from maize, other cereals and grasses. To produce the necessary amount of biomass, an appropriate amount of land is required either by the farms or by farms in the region that provide the feedstuff. Although biogas plants are usually planned and built according to the available feedstock, the lifetime of the plants exceeds the duration of rental contracts. Therefore, farms with biogas plants have to ensure access to land rental contracts via high bids. In addition to the effects on the land market, biogas production also affects the composition of regional production. Fodder production for livestock and food production is argued to be increasingly displaced by renewable energy crops such as maize and ley (cf. Agrarheute, 2012; KLU, 2013). On the other hand, livestock production on biogas farms partly benefits from biogas investments because since 2009 the use of manure as a complementary co-substrate has been highly subsidized (BMJ – Bundesministerium der Justiz, 2008).

Concerns regarding their future development perspectives exist on the side of farms that are either not willing or not able to invest in biogas production. These farms fear for their (future) competitiveness, particularly on the land market (cf. Müller-Frank, 2013; Schröder, 2010) . On the other hand, biogas farmers are concerned about the stability of political decisions (cf. Hemmerling, 2013; Maurin, 2015). Furthermore, electricity prices for private households and smaller firms increased significantly (cf. Editorial, this issue). The Renewable Energy Act was amended several times since 2000 (see Editorial, same issue). The latest change introduced in 2014, resulted in a substantial reduction of the guaranteed feed-in tariffs.

While the impacts of biogas production on land markets and land prices have been analyzed in the past, other aspects of structural change such as impacts on farm performance and cultivation patterns have hardly been analyzed. The present paper seeks to fill this gap by studying the long-term impacts of renewable energy policy and subsequently biogas production on two German regions, namely the Altmark in Eastern Germany and the Ostallgäu (East Allgäu) in Southern Germany, which have very different farm structures. Nevertheless, both regions have an agricultural sector with a high proportion of specialized dairy farms and grassland, and therefore have sources of biomass from several sectors, including manure.

As we focus on the farm level as well as on the regional level, we concentrate on the following aspects: the investment behavior of farms regarding biogas production; the effects of biogas production on structural change; regional cultivation patterns; the land market; and on the overall performance of farms. Contrary to previous studies focusing on empirical land market data, we use an agent-based simulation model, namely AgriPoliS. This spatially explicit and dynamic agent-based model enables ex post and ex ante analyses of agricultural structural change, particularly regarding the impact of alternative policies and assumptions on agriculture by comparing actual policies with counterfactual assumptions. Policy impacts that can be analyzed include shares of different crops, profits of biogas and non-biogas farms, rental prices for arable and grazing land, as well as farm size developments. As far as possible, simulation results are validated by comparing them with empirical observations. As the majority of biogas plants are operated by farmers (Fachverband Biogas, 2015), biogas production of non-agricultural investors is not considered in the model simulations, though these investments also affect agricultural production and land markets.

The paper proceeds as follows. The next section introduces the agent-based model AgriPoliS, together with the case study regions Altmark and East Allgäu. In section 3.3.1, simulation results for a time period of 12 years are analyzed, while section 3.4 provides discussion and conclusions.

3.2 Methodological approach and case study region

To analyze the impact of biogas production, we use the agent-based model AgriPoliS (Agricultural Policy Simulator, e.g. Happe et al. (2006)). In this chapter we describe the model's features and the study regions.

3.2.1 The agent-based model AgriPoliS

AgriPoliS is an agent-based spatial model that enables one to simulate the development of regional agricultural structures over time in response to alternative scenarios such as specific policies (see Happe, 2004; Happe et al., 2008; Balmann, 1997). A detailed documentation of the current version can be found in Kellermann et al. (2008). A protocol following the ODD standard (Overview, Design concepts and Details) is available in Sahrbacher et al. (2012).

In AgriPoliS, a number of individual agents represent farms that interact in a synthetic landscape that maps agriculturally related regional and structural characteristics. AgriPolis is adapted to selected regions by specifying farm types that are typical for that region and which are weighted to match regional characteristics. Apart from the farms' initial factor endowment and size, the different farm types are differentiated in a stratification process during the initialization of a model run. According to the weight of the farm types, a proportional number of farm agents are randomly distributed in the spatial grid of land plots and initialized with individual management skills (i.e. different variable production costs) and ages of the farmer and farm assets.

The farms are assumed to maximize profits or household income by use of a mixed-integer programming model that is linked to the selected farm agents' data on factor endowments (facilities, labor, capital, land, management quality, etc.), as well as the various production and investment alternatives from which the farms can choose to maximize their profit. The provided investment and production activities can be considered as typical for the region and are calibrated such that in the beginning of each simulation, the derived farm agents choose the same or similar production activities as the real farms they represent.

Besides deciding on products and investments, farms can also extend their capacities by renting additional agricultural land and employing workers. Furthermore, capital can be borrowed on a short- and long-term basis. In contrast, capacities can be reduced, e.g., land rental contracts can expire, quotas can be rented out, hired labor can be dismissed and family workers can be employed outside of the farm. Furthermore, liquid assets may be invested outside the farm. In case of renting land, farms compete for available land (i.e. land that is currently not rented) via a repeated auction. Within the auction, every farmer first selects the available plot that is most valuable to 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. Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

3.2.2 Case study regions

The first case study region is the Altmark, which is located in the north of the German Federal State of Saxony-Anhalt, approx. 50-150 km west of Berlin, and comprises the two districts Stendal and Altmarkkreis Salzwedel. Being characterized by large arable farms, as well as large mixed farms with livestock, the Altmark captures important features of East German agriculture (see Table 2). The relative importance of livestock production is emphasized by the fact that as of 2007, some 40% of the dairy cows and 53% of the specialized dairy farms in Saxony-Anhalt were located in the Altmark, though the region covers only 23% of the state's utilizable agricultural area (UAA) (StaLa, 2008a, 2014). Farms are predominantly organized as legal entities, full- and part-time family farms, as well as partnerships. Although legal entities that are usually either limited liabilities or production cooperatives only account for some 10% of the farms, they use almost 45% of the UAA.

Table 2: Characteristic indicators of the study regions.

	Altmark	**East Allgäu**
Number of farms	957	1057
Average farm size in ha UAA/farm[a)]	278	26
Number of dairy cows/dairy farm	178	30
Share of grassland in %	27	>90

a) UAA: utilizable agricultural area.
Source: StaLa (2008a, 2014); BLF

The other study region is located in the district of Ostallgäu (East Allgäu) in the south of Bavaria. The landscape structure of mainly pre-Alpine terrain is bounded on the south by the Allgäu Alps. This region is also relatively homogeneous in terms of geographic and climatic conditions. With a high share of grassland (almost no arable land), this region is particularly suitable for dairy production. The East Allgäu is predominated by small and more homogeneous family farms with less than 30 ha. Overall in 2007, the 27,117 ha UAA in the selected municipalities were maintained by 1,057 farms; 844 of them hold a total of 25,499 dairy cows (BLF). Beef cattle and suckler cows are less common, and there is hardly any other livestock in the study area.

Both study regions are suitable for biogas production. Since 2009, the Altmark has been assigned as one of 25 so-called bioenergy regions (Bardt et al., 2012) in Germany because it offers a huge potential of biomass from several sectors. In the long run, one aim of the bioenergy regions initiative is to generate regional value added by extending bioenergy production to support the sustainable development of rural areas (Regionale Planungsgemeinschaft Altmark, 2012). With a high proportion of specialized dairy farms and grass land, agriculture provides biomass for energy production, e.g. biogas. Many farms have invested in biogas production in recent years: in 2012, a total of 107 biogas plants produced 364 GWh electrical energy (Landtag von Sachsen-Anhalt, 2014).

As a region focused on grassland and livestock, East Allgäu is also suitable for biogas production. The distribution of biogas plants in Bavaria (Röhling and Keymer, 2006) shows a significant investment concentration in the cattle-growing regions of Swabia and Allgäu, Bavaria Central Franconia and the Southeast. Currently, 74 biogas plants are operating in East Allgäu (LFL, 2014).

3.2.3 Modelling the regions in AgriPoliS[5]

To adapt AgriPoliS to the regional agricultural structure of the Altmark and East Allgäu, available statistics on regional agricultural characteristics (e.g. number of farms, livestock, farm size classes etc.) and FADN data of regional farms are used (cf. Balmann et al., 2010). Because of data availability and calibration purposes, the model was initialized for 2006 and simulations start in 2006. The adaptation procedure resulted in 33 typical farms for the Altmark, which are stratified according to their weights to 968 model farms. For the East Allgäu, 16 typical farms represent 962 model farms.

The model farms are able to produce cash crops and fodder from arable land (only in the Altmark), and feedstuff from grass and livestock. The assumptions for the different production processes are derived from publicly available data bases for crops (Richter, 2009), as well as feed and livestock (Hanff et al., 2008; Röhling and Keymer, 2006; LFL, 2014). For the initialization, i.e. the starting year of 2006, no model farm is assumed to be invested in biogas production. The reason is that statistical data about existing biogas plants for both regions in 2006 were not available. With

[5] This section is based on Ostermeyer (2015) which contains a more detailed description of the implementation of the two model regions.

regard to biogas production, starting in 2006, the model farms can invest in biogas plants of different sizes. For biogas production they can choose between different substrate mixtures. Table 3 shows the assumptions on the biogas plants regarding their revenues from feed-in tariffs, the investment and calculated substrate costs, as well as the working time required to operate the plant. The guaranteed feed-in remuneration, consisting of a basic payment and bonuses, are derived from the REA 2009 and 2012 (BMJ – Bundesministerium der Justiz, 2008, 2010, 2011). Overall, three plant sizes for each region (150, 450, 800 kW for Altmark and 70, 125, 200 kW for East Allgäu), and three mixtures with different shares of maize and grass silage, liquid cattle manure, and rye grain are offered. The plant sizes between which the farms can choose are adapted to the regional characteristics and are derived from data provided from KTBL (2010) and Grundmann et al. (2006). The investment costs per kW are assumed to decrease with increasing plant size, but are also regionally adjusted and calibrated in relation to other costs in the region so that the simulation results are assessed as realistic by stakeholders (Ostermeyer, 2015). Model farms can neither choose intermediate plant sizes, e.g. between 150 and 450 kW, nor cooperate and share facilities. In the East Allgäu region, farms have no access to arable land. The farms are, however, allowed to buy maize silage from outside the region. We assume fixed exogenous prices for maize silage, which probably underestimates that these substrate costs also rise because of substantial biogas investments. In the Altmark region, model farms do not have the opportunity to buy substrates from other farms. Local experts and farmers reported during stakeholder workshops in the Altmark that in general only non-agricultural investors buy their substrates from other farmers. The biogas-producing farmers in the Altmark are assumed to have either sufficient arable land or can rent additional land to produce the required substrates by themselves (see Ostermeyer, 2015). As the activities of non-agricultural biogas producers are not considered, our analysis underestimates the indirect land market effects of biogas support.

According to the REA 2012 and its previous forms, the basic guaranteed feed-in tariff for new bioenergy plants declines over time. For simplifica-

Table 3: Assumptions on biogas production from 2013 to 2025.

	Altmark			East Allgäu		
	150 kW	**450 kW**	**800 kW**	**70 kW**	**125 kW**	**200 kW**
Feed-in tariff in 1,000 Euro/year (dep. on mix)	208-213	544-579	935-992	93-118	168-173	295-303
Feed-in tariff in 1,000 Euro/year (REA 2014)	129[a)]	401[a)]	720[a)]	55-111[a)]	99[a)]	161[a)]
Investment costs in 1,000 Euro	850	1,825	2,650	420	625	800
Investment costs in Euro/kW	5667	4056	3,313	6,000	5,000	4,000
Calculated substrate costs in 1000 Euro/year (w/o costs for manure)	66-99	198-277	351-476	35-50	59-85	93-131
Working hours (dep. on mix)	894-1,064	1,344-1,581	1,839-2,227	623-642	709-738	819-862

a) From 2014 in the REA 2014 scenario.
Source: Own assumptions according to BMJ – Bundesministerium der Justiz (2011), KTBL (2010).

tion, we did not consider this dynamic degression of feed-in tariffs. This is to some extent balanced by ignoring the likely decrease in investment and production costs over time because of technological progress (cf. Hobohm and Mellahn, 2010). Therefore, we assume constant remunerations (Table 3) during the 2013 to 2025 period according to the REA. Furthermore, we have not implemented the requirement that biogas operations require a minimum use of heat because there is no data available regarding the extent to which these could be used in the respective regions.

The REA has been reformed several times. These reforms are considered in a simplified way. For 2006 to 2011, the regulations of the REA 2009 (BMJ – Bundesministerium der Justiz, 2010) are assumed to be valid. Starting in 2012, assumptions shown in Tables 2 and 3 are considered. The main difference between the REA 2012 and the REA 2009 affects the allowed shares of different substrate types. In 2012 a maximum limit of 60% of maize silage, corncob mix and grain kernel was introduced in the REA. This limitation is also used in the model (Table 4). Accordingly, from 2012 on, farms can choose between three mixtures to produce biogas. With Mix 3 it is possible to operate a biogas plant without cattle manure. More common in reality is the use of manure and maize silage (see Mix 1 and Mix 2). For validation of both model regions, as well as for the simulation of biogas production we used a participatory approach that included stakeholders (for more details see Ostermeyer, 2015, p. 96 ff).

Table 4: Assumptions on substrate mixtures from 2013 to 2025.

	Altmark			**East Allgäu**		
	Mix 1	**Mix 2**	**Mix 3**	**Mix 1**	**Mix 2**	**Mix 3**
Cattle manure	60%	30%	–	80%	50%	45%
Maize silage	20%	60%	20%	10%	50%	20%
Grass silage	20%	10%	20%	10%	–	35%
Whole-crop-silage	–	–	40%	–	–	–
Rye grain	–	–	20%	–	–	–

Source:Ostermeyer (2015)

In our study, we compare two biogas scenarios with a reference scenario (REF). In the REF scenario, farms cannot invest in biogas plants at any time. This counterfactual scenario enables us to analyze how the model regions would have developed without the influence of the REA and biogas production; it thus serves as a benchmark to analyze the effects of biogas production. Biogas production is implemented in two scenarios, where model farmers can choose biogas production as an activity. In the REA 2014 scenario, the feed-in tariffs and conditions follow the REA 2012 from 2006 until 2013 for new investments. From 2014 onwards, the conditions of REA 2014 apply according to the latest amendment of the renewable energy act in 2014 (cf. Table 5). Other regulations such as the capping of the guaranteed payments for plants larger than 100 kW were not considered. The REA 2012 scenario contains a hypothetical continuation of the REA 2012 after 2014. Apart from these differences regarding biogas production, farms have the same conditions in all three scenarios.

Table 5: Comparison of scenarios and basis payments $^{a)}$ in ct/kWh.

			REF	REA 2012	REA 2014
Possibility to invest in biogas plants?			No	Yes	Yes
		plant size			
2013-2014	Basis Payment in ct/kWh	75 kW	–	25.00*	25.00*
		150 kW	–	14.30	14.30
		500 kW	–	12.30	12.30
		5 MW	–	11.00	11.00
		20 MW	–	6.00	6.00
2014-2025	Basis Payment in ct/kWh	75 kW	–	25.00*	23.73*
		150 kW	–	14.30	13.66
		500 kW	–	12.30	11.78
		5 MW	–	11.00	10.55
		20 MW	–	6.00	5.85

* Minimum share of manure in the substrate mixture is 80% (manure bonus)
a) Bonus payments e.g. for Feedstock class I and II, and manure were not considered in the simulation
Source: Juris – Bundesministerium der Justiz und für Verbraucherschutz (2014).

3.3 Results

The analysis of biogas policy impacts focuses on the following aspects: Investments in biogas plants, structural change, changes in cultivation patterns, effects on land markets, and farm performance. To minimize random effects resulting from the initialization of AgriPoliS, each scenario is simulated 100 times. Simulations start for calendar year 2006, and our analyses consider the period 2013 as the last year before the reform of 2025.

For the analysis, we differentiate between "biogas farms" and "non-biogas farms". Those farms that invest in biogas plants in the REA 2012 scenario are labeled "biogas farms" irrespective of their behavior in the other scenarios. Farms that do not invest in biogas plants in the REA 2012 scenario are labeled as "non-biogas farms". These labels are applied for the same farms in the REF and REA 2014 scenario, irrespective of whether the farms invest in a biogas plant in these scenarios. In doing so we are able to analyze how biogas producers in the scenario REA 2012 would have developed without the opportunity to invest in biogas or under another political setting.

3.3.1 Investment in biogas

Only a fraction of the farms is able and willing to invest in a biogas plant. A certain farm size and sufficient financial resources are prerequisites for investments. Table 6 shows that biogas farms are on average substantially larger than non-biogas farms. In terms of European size units (ESU), biogas farms are nearly 1.8 times as large as other farms in the Altmark region. In the East Allgäu region they are even 2.5 times larger. In terms of farm size in ha, they are around 4 times (6 times in East Allgäu) larger, have a higher share of rented land, keep many more dairy cows, and have a higher equity capital.

In the "REA 2012" scenario, in 2013, 89 of the 709 model farms (i.e. 12.6%) in the Altmark region own a total of 184 biogas plants, with a total capacity of around 36 MW. Accordingly, biogas-producing farms have, on average, an installed capacity of around 405 kW. In the East Allgäu region there are far fewer biogas farms. Only 5 of the 917 model farms (0.5%) invest until 2013 in biogas plants, with a total capacity of 744 kW. The lower level of biogas production in the East Allgäu region is mainly due to the fact that the farms have only grassland and no arable land, and thus can neither cultivate maize as feed for their cattle, nor use it as a substrate for their biogas plants; they have to purchase maize silage.

Compared to reality, model farms invest in more but smaller biogas plants. This is because model farms can neither choose intermediate sizes, e.g., between 150 and 450 kW, nor cooperate and share facilities. Furthermore, model farms do not have the opportunity to buy substrates from other farms (except for maize silage in the East Allgäu region). Therefore, most model farms are too small to invest in biogas plants. In 2013, the smallest farm that invests in a biogas plant in the Altmark manages 315 ha and 240 dairy cows, and in the East Allgäu 103 ha and 135 dairy cows.

Table 6: Characteristics of biogas and non-biogas farms in the REA 2012 scenario 2013 (model results).

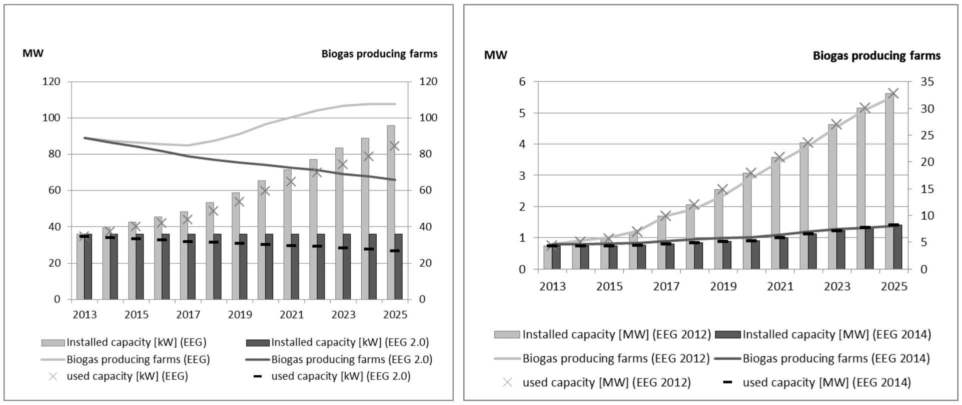
Characteristics	**Altmark**		**East Allgäu**	
	Biogas farms	**Non-biogas farms**	**Biogas farms**	**Non-biogas farms**
Number of farms	89	620	5	925
Average farm size in ha	1,182	282	170	28
Average farm size in ESU[a)]	655	76	355	31
Share of rented land (%)	93	82	76	29
Number of dairy cows	1,048	48	488	92
Equity capital in EUR	1,268,139	272,679	1,097,237	361,940
Equity capital in EUR/ha	1,073	967	6,454	12,926

a) ESU means European size units; one ESU equals 1,200 Euro standard gross margins (SGM).

As a consequence, the simulation results underestimate the real investments systematically. For example in 2012, the installed capacity of the Altmark region was around 48 MW (Landtag von Sachsen-Anhalt, 2014), while in the model, in 2013 the plants have a total installed capacity of 36 MW.

For the period since the latest amendment of the renewable energy act in 2014, simulation results support expectations that biogas production would continue to increase if there would be no policy reform. A continuation of bioenergy support according to the REA 2012 would have offered substantial potentials for biogas farms to invest in more and even larger plants: in the Altmark, the number of some 90 biogas-producing farms remains stable, while the installed capacity increases. This indicates rising plant sizes. From 2013 with an average installed capacity of 405 kW, biogas farms increase their capacities to 892 kW per farm in 2025. In the East Allgäu region, the average installed capacity increases from 161 kW to 174 kW per farm, and the number of biogas-producing farms increases by almost a factor of 6 between 2013 and 2025 (Fig. 1). This means that farms need to reach a critical size first before they are able to invest in biogas.

According to our simulations, the REA 2014 stops the rapid expansion of biogas production in both study regions (cf. Fig. 1). In the Altmark, the number of biogas plants even declines slightly as some biogas farms exit in the REA 2014 scenario and no new investments in biogas plants are realized after 2013. The installed capacity for the whole region remains constant for several years due to the operational lifetime of the existing biogas plants. In the East Allgäu, the capacity increases after the reform slightly further due to a few additional investments. The reason is that in the East Allgäu there are still some investments in small plants that benefit from a specific manure bonus (cf. Table 5). Until 2025, the installed capacity only reaches 1.4 MW in the East Allgäu and even declines to 26.9 MW in the Altmark.



(a) Altmark (b) East Allgäu

Figure 1: Number of biogas-producing farms and their installed and used capacity in megawatts in the REA 2012 and REA 2014 scenarios, 2013-2025 (model results).

3.3.2 Structural change

Tables 6 and 7 show that in the Altmark, especially farms with more than 1000 ha invest in biogas production. Also in the East Allgäu, only larger farms have resources to invest in biogas plants. Once invested, biogas farms have the potential to grow faster than other farms because some of them generate additional profits with biogas production and offer higher rental prices on the land market.

The model results (Table 7) show that in the Altmark, farms with biogas production would grow in the REA 2012 scenario between 2013 and 2025 by some 38%, to 1,636 ha, on average, while their number would increase by some 21% during the period 2013 and 2015. In contrast, non-biogas farms decline faster in total number as well as in average size compared to the REF scenario.

In the East Allgäu region, the biogas farms are also larger with an average farm size of about 170 ha in the REA scenarios, compared to non-biogas farms with 28 ha on average. Until 2025, the number of biogas farms would

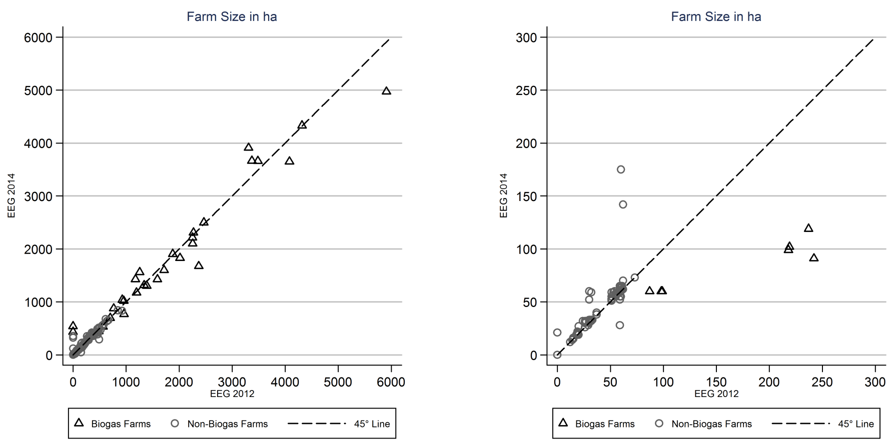
Table 7: Number of farms and farm sizes in the model regions, REF, REA 2012 and REA 2014 scenario (model results).

		Altmark				**East Allgäu**			
		non-bio. farms		biogas farms		non-bio. farms		biogas farms	
		farms	size[a)]	farms	size[a)]	farms	size [a)]	farms	size[a)]
2013	REF	627	273	87	1,252	913	28	5	99
	EEG 2012	620	282	89	1,182	912	28	5	170
	EEG 2014	620	282	89	1,182	912	28	5	170
2025	REF	452	274	101	1,545	543	43	32	84
	EEG 2012	424	245	108	1,636	519	38	32	194
	EEG 2014	428	249	107	1,624	533	41	32	140

Note: Biogas farms are those farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario); Non-Bio. Farms are those farms that do not invest in biogas plants in the REA 2012 scenario.
a) Farm size in hectare UAA.

increase by 540%, while the average acreage of these biogas farms increases by only 14% to an average farm size of 194 ha in the REA 2012 scenario. Despite this growth in numbers and size, the overall share of biogas farms is much lower than in the Altmark. Accordingly, competition between the non-biogas farms is not as heavy as in the Altmark. In the REA 2012 scenario, 40% of the farms in the East Allgäu quit farming until 2025. In the REF scenario, the number of exits is slightly lower. Thus, in both regions, structural change is fostered by the biogas subsidies.

In both regions, the REA 2014 amendments affect structural change in terms of farm sizes and farm exits. While some farms that invested in biogas production before the introduction of the REA 2014 would grow less fast in the future, others may even grow faster (cf. Fig. 2). These farms benefit from the fact that after 2013, hardly any farm invests in biogas production, while they still receive the guaranteed high feed-in tariffs. In the East Allgäu region, a few larger biogas farms that would grow substantially in the REA 2012 scenario would not do so in the REA 2014. Vice versa, a few non-biogas farms may benefit in the REA 2014 because of higher relative competitiveness.



(a) Altmark (b) East Allgäu

Note: Farm size in hectares of single farms in 2025. Farms that are on the 45° degree line are equally sized in both scenarios. Farms underneath the 45° line are larger in the REA 2012 scenario, while farms above the 45° line farm more hectares in the REA 2014 scenario. Biogas farms are farms that produce biogas in the REA 2012 scenario.

Figure 2: Farm size of biogas and non-biogas farms in 2025, in the REA 2012 and REA 2014 scenarios (model results).

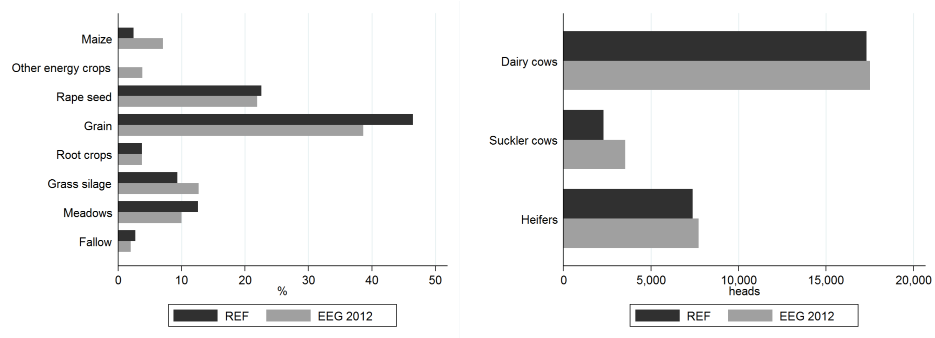
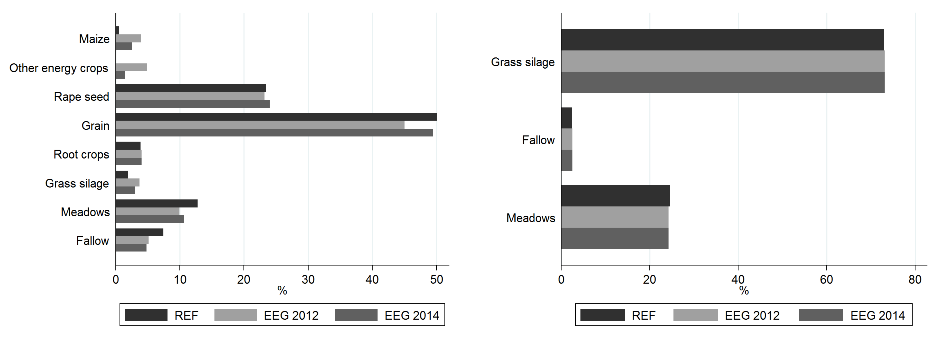


Figure 3: Shares of different crop types; and number of cows and heifers in the Altmark in the REF and REA 2012 scenario, 2013 (model results).

3.3.3 Cultivation

Due to biogas production, the farms' overall production structure changes. The amount of fallow land decreases and the cultivation of maize and other energy crops increases (cf. Fig. 3). Furthermore, the use of grassland is intensified as the usage changes from meadows to grass silage. Due to the lack of arable land in the East Allgäu region, there is only a minor intensification in the use of grassland, while the purchase of maize silage increases substantially. In 2013 this rate is doubled compared to the REF scenario. In total, the amount of purchased maize silage is rather small; its production requires arable land in an amount of only 0.4% of total UAA in the East Allgäu. Therefore, a significant impact of this demand for maize silage should not to be expected on the regional market and thus also not on the price.

Livestock production in the Altmark is positively affected in the REA 2012 scenario. Due to synergy effects of liquid manure for bioenergy production, more cows and cattle are kept in the biogas scenario. This means that the REA policy indirectly supports livestock production. Accordingly, the demand for grass and maize as feed for cattle increases in parallel. In East Allgäu there is no significant effect on regional production, neither in crop nor livestock production, until 2013. This is mainly due to the low level of



(a) Altmark (b) East Allgäu

Figure 4: Shares of different crop types in the model regions Altmark and East Allgäu in the REA 2012 and REA 2014 scenario, 2025 (model results).

biogas production in that region (only 0.5% of the farms in 2013).

The cultivation patterns are also affected by the REA reform in 2014 (Fig. 4). However, there is no straight adjustment towards the results of the REF situation. In the Altmark, the biogas investments before 2014 have a long-lasting effect because the assumed operational lifetime of biogas plants is 20 years and feed-in tariffs are fixed. Nevertheless, there are some adjustments. Fig. 4 shows that in the REA 2014 scenario, farms produce more cash crops while the area for maize, grass silage and other energy crops decreases. More land becomes fallow, and the stock of cattle declines. This is different for the East Allgäu because investments in biogas plants continue even under the REA 2014 conditions. The production structure in the REA 2014 very strongly resembles the REF situation. The only observable difference in the land use is a slight drop in meadows in favor of grass silage production. Accordingly, the 2014 amendments of the REA cause a partial re-adjustment towards the situation without the previous strong support of the REA 2012, though there remains a long-term effect.

3.3.4 Land market

AgriPoliS allows one to keep track of the rents paid by single farms or specific groups of farms. Table 8 shows that in general, biogas support causes higher and increasing rental prices. There are only a few exceptions for 2013 that may be seen as outliers. Moreover, Table 8 shows that biogas farms pay substantially higher land rental prices than non-biogas farms. Obviously, biogas farms are also more competitive if they cannot invest in biogas. The reasons for this can be seen in economies of size, as well as in a superior management coefficient, i.e. producing at lower variable costs than the average. Vice versa, the relatively low level of rents paid by non-biogas farms is mainly because these farms are less competitive in the land auction and rarely get new rental contracts.

Table 8: Average rental prices for new rented land in 2013 and 2025 in Euro per hectare of biogas and non-biogas farms in the model regions, REF, REA 2012 and REA 2014 scenario (model results).

		Altmark				East Allgäu	
		non-bio. farms (87%)[a)]		biogas farms (13%)[a)]		non-bio. farms (99%)[a)]	biogas farms (1%)[a)]
		arable land	grassland	arable land	grassland	grassland	grassland
2013	REF	112.06	26.99	206.21	109.35	130.57	351.81
	EEG 2012	117.03	24.62	191.95	112.87	129.09	590.16
	EEG 2014	117.03	24.62	191.95	112.87	129.09	590.16
2025	REF	176.18	33.78	299.59	120.59	108.71	187.11
	EEG 2012	177.77	43.94	332.87	158.33	154.64	237.67
	EEG 2014	181.91	42.19	316.76	150.08	127.92	220.78

Note: Biogas farms are farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario); Non-biogas farms are farms that do not invest in biogas plants in the REA 2012 scenario.
a) Share of farms in 2013

In the East Allgäu region, rental prices are substantially higher than in the Altmark. Several reasons are responsible: Farms in the East Allgäu often have overcapacities of family labor and a high equity capital compared to their farm size. Thus, the competition for land is very intensive in the East Allgäu, as land is the most scarce production factor. Moreover, the extremely high prices for newly rented land in 2013 were caused by the fact that in the beginning, only few farms invest in biogas. This can be seen as a specific outlier effect: These few farms are exceptionally profitable compared to the average farm and therefore have a very high marginal gross margin for additional land. The average rental price of biogas farms decrease as more and more other farms also invest in biogas production, because then also more farms with lower profitability belongs to the group of biogas farmers In the Altmark, competition for land is much lower. Compared to the profitability level, the relatively large farms in Eastern Germany pay relatively low rental prices (Balmann, 2015). Eventually, they benefit from a certain market power.

The rental price effects of biogas production decline after the introduction of the REA 2014 (Table 8). Due to the reduced guaranteed feed-in tariffs, biogas farms no longer invest and rent additional land for biogas production. Nevertheless, in both regions the rental price for biogas farms remains substantially higher than in the reference scenario, and may even continue to increase, particularly in the Altmark. The main reason is the fact that in the Altmark, rental prices are still low compared to the profitability of farming, irrespective of biogas support. In the East Allgäu region, the rental prices in the REA 2014 scenario start to decrease after the reform.

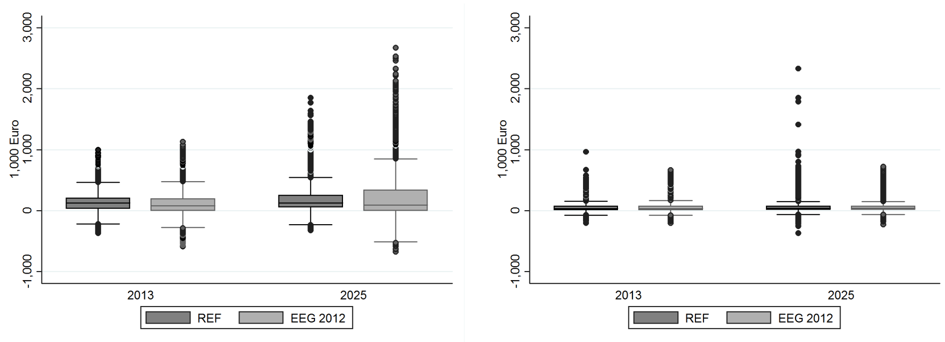
3.3.5 Farm performance

Rental prices for land affect the farms' profits. The higher the share of the value-added that is transferred to the land owners as a result of increased rental prices, the less remains as farm income. Fig. 5 shows for the Altmark that some biogas-producing farms have higher profits in the scenario REA 2012 compared to the REF scenario. The variance of profits is, however, also larger under conditions of the REA 2012. The average profit of biogas farms is even slightly lower in the REA 2012 scenario. Comparing 2025 and 2013 shows that the variance in profits increases over time for both scenarios, but particularly under conditions of the REA 2012. While some biogas farms can increase their profits substantially until 2025, other biogas farms even achieve high losses. After investing in a biogas plant, biogas farms are highly dependent on land to produce substrates for their biogas plant. Even if they are not profitable, they need to rent land if rental contracts expire. Then these farms are competing with profitable biogas farms that may even bid high rental prices for further growth. Because of the increasing competition for land, several biogas farms lose their initial advantage from biogas production. The beneficiaries are land owners who receive higher prices for their land. Only those farms with a real competitive advantage in biogas production benefit in the longer run; others even lose. The benefiting farms are larger and have a better management coefficient. In the long run, these effects accumulate. While some biogas farms benefit even more, others lose even more. On average, the non-biogas farms do not lose a lot. However, some non-biogas producers are not able to grow under the conditions of the REA 2012, while they would prosper in the REF scenario. For the East Allgäu region, these effects play a minor role, as there are only a few farms investing in biogas and these are rather large and have higher managerial skills. Furthermore, for plant sizes less than 75 kW, these farms have the opportunity to receive an extra manure bonus. Therefore, biogas production is slightly more profitable in the East Allgäu, at least for those farms that have the required size to run a biogas plant.

The amendments of the REA 2014 cause several biogas farms that are very successful under conditions of the REA 2012 to lose (Fig. 6). On the other hand, a few biogas farms, and particularly a number of non-biogas farms in the East Allgäu benefit from the reduced competition on the land market. These farms benefit from higher profit per ha (Fig. 6).

3.4 Discussion and conclusions

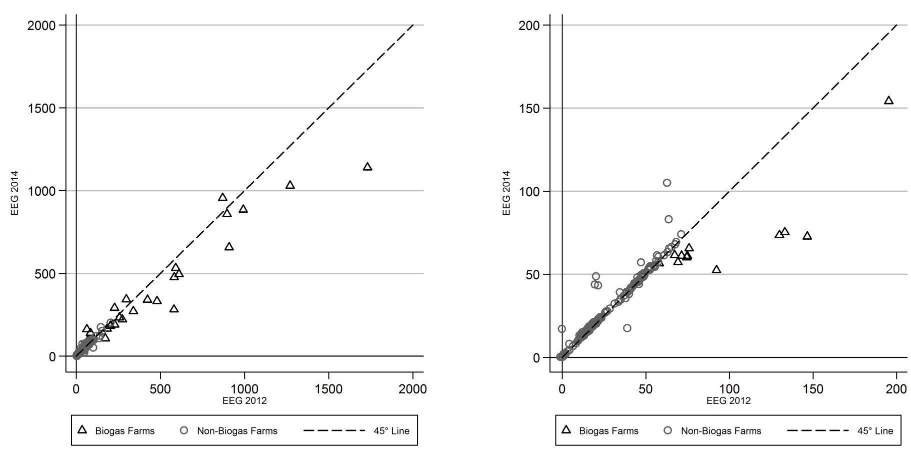
Our analyses show that only farms with a sufficient farm size and sufficient financial resources are able to invest in biogas plants and thus benefit from the related subsidies. The reason is that a minimum size is needed to be able



(a) Biogas farms (b) Non-biogas farms

Note: Biogas farms are those farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario). Non-biogas farms are those farms that do not invest in biogas plants in the REA 2012 scenario.

Figure 5: Distribution of profits per biogas and non-biogas farms in 1,000 Euro in 2013 and 2025 in the Altmark, REF and REA 2012 scenario (model results).



(a) Altmark (b) East Allgäu

Note: The scatterplot shows profits per farm of single biogas and non-biogas farms. Farms that are on the 45° line perform equally well in both scenarios. Farms underneath the 45° line benefit in the REA 2012 scenario, while farms above the 45° line benefit in the REA 2014 scenario.

Figure 6: Profit per farm of surviving farms in 2025 in the REA 2012 and REA 2014 scenario (model results).

to feed a large biogas plant. If there is specific and sufficiently high support for smaller biogas plants like in the REA, such smaller plants can be attractive for farms that have less land. In any case, biogas production requires substantial amounts of substrate. According to Brendel (2011), some 200 ha of arable land are needed to operate a plant with a capacity of 500 kW – depending on the substrate sources and annual operating hours. Furthermore, the cultivation of energy maize comes at the expense of grassland as well as fallow and abandoned land (cf. Lupp et al., 2014); the simulation results support this finding.

Because of the complementarity between biogas production and cattle production in the case of attractive opportunities for using manure as a substrate, biogas support offers indirect subsidies for cattle production while at the same time other production activities are substituted. Due to the fact that land is scarce and biogas plants as well as cattle have to be fed constantly with maize and/or grass silage, biogas farmers have to reorient their production to the crops that deliver more biomass per ha to avoid feedstock bottlenecks. Lupp et al. (2014) also mention this connection: because maize is an attractive feedstuff for livestock and biogas, the share of maize production increases. Furthermore, Grundmann and Klauss (2014) conclude that "Increasing the production of energy from agricultural biomass tends to exert pressure on food production, especially when the comparative advantage of food production is low." As our analyses do not account for biogas investments of non-farmers, the effects are supposed to be even stronger in reality (cf. Thünen-Atlas, 2015). On the other hand, we have not implemented the requirement of a minimum use of heat which probably could overestimate the investments of farmers in biogas production.

Because the total amount of land within a region is limited, biogas increases competition for land between farms. Thus, land prices tend to rise. This linkage between biogas and land can affect the whole farm structure of agricultural regions. As a consequence of biogas support, smaller and less competitive farms quit at a higher pace. Brendel (2011) also argues that the high remunerations may cause traditional farmers to lose rented land after rental contracts expire.

However, these effects are overlapped with other more general tendencies of structural change. Irrespective of biogas support, structural change continues and more competitive farms pay higher land prices while less competitive farms stagnate, shrink or exit. Moreover, our simulations show that at least for the Altmark, rental prices for newly rented land plots are at a very similar level for biogas farms in the scenarios with and without biogas production. The same applies for the non-biogas farms, though at a substantially lower level. Accordingly, it is not only the biogas investments that drive up land prices, but rather the fact that in general, those farms that tend to invest in biogas are in any scenario very competitive on the land market. Rental prices are determined by the most efficient (biogas) farms. The more such potentially investing farms exist in a region, the higher are land prices, even if the farms would not be allowed to invest in biogas.

Because biogas support nevertheless leads to higher and increasing land prices, not all biogas farms gain in the long-run. As some farms may overenthusiastically invest in biogas, the increasing land prices may hit back and may even lead to losses for underperforming biogas farms compared to a situation without biogas support. In the end, only those farms gain from biogas support that are producing biogas most efficiently. We find that on average, the group of biogas farms has even a lower profitability than without the support of biogas.

According to our results, the reform of the REA in 2014 only partly attenuates some of the above mentioned effects. Key structural implications of the previous REA regulations can only be reduced slowly, while others are persistent. The 2014 reform has created both winners and losers. Even some biogas farms that previously invested in biogas plants benefit in the future from less competition on the land market because other farms will no longer heavily invest in further biogas plants.

To sum up, our results show that biogas policies influence individual farms as well as the development of agricultural regions. Because different direct and indirect effects overlap, the impacts are of a complex nature. The complementarity of biogas and livestock production causes an additional intensification of land use and more investments in livestock production. Furthermore, the higher competition on the land market leads to increasing land prices. Those facts add up to changes in the agricultural structure of the analyzed regions. On average, biogas farms may not even achieve higher profitability because a significant share of the value added is transferred via increased rental prices to the land owners. In the end, every support for a specific type of investment has to be seen as a tax for competing production alternatives. Moreover, every subsidy for a specific type of farm creates disadvantages for competing farms. These indirect effects do not only affect farms investing in biogas, but rather the whole sector. Further reforms of the REA should therefore better consider the implications of limited land resources in agriculture.

Even though the last amendments of the REA in 2014 more or less stopped investments, the previously high level of support has long-term implications. This is mainly due to the long, useful duration of the bioenergy plants, as well as the guaranteed feed-in tariffs for 20 years. Therefore, the formerly high support level granted by the pre-2014 REA rules casts a long shadow of the past.

Most of the results of the simulations can be assumed to be true for other regions. Key drivers of the results such as differing farm sizes within each region and different management capabilities of farmers can be found everywhere. These heterogeneities are responsible for specific effects such as the differing ability of farms to invest in biogas plants and the differing profitability of farming in general, and biogas production in particular.

In principle, the heterogeneous ability of farms to invest in biogas plants could be partly addressed by policies that ease investments for smaller and less competitive farms by providing additional subsidies for smaller plants. It is, however, questionable why such investments should be more beneficial than support measures for biogas in general. Smaller investments would require guaranteed support at an even higher level per unit of bioenergy, which in the end has to be paid by someone. Moreover, such support would also cause side effects like higher land prices, and as a consequence unprofitable investments by farmers who are less competitive.

Acknowledgments

This research was conducted within the Subproject 5 of the German Research Foundation (DFG) research unit "Structural change in Agriculture (SiAg)". We gratefully acknowledge financial support from the DFG (FOR 986/2). The authors would like to thank two anonymous reviewers for their valuable comments and suggestions to improve the quality of the paper.

4 FarmAgriPoliS – An Agricultural Business Management Game for Behavioral Experiments, Teaching, and Gaming [6]

Franziska Appel, Alfons Balmann, Changxing Dong, Jens Rommel

Abstract

Business management games have been used for decades, primarily for educational purposes, training, and entertainment. More recently, the use of such games has expanded to experimental research platforms. Usually business management games are designed and developed from the scratch for one or more of these purposes. This paper discusses another possibility: the development of a business management game based on an existing agent-based model. We motivate this use and describe the extension of the agent-based model AgriPoliS, which has been widely used to analyze structural change in agriculture. We document the resulting software FarmAgriPoliS and provide a systematic classification of FarmAgriPoliS into the framework of business management games with agricultural background. Furthermore, we evaluate the suitability of FarmAgriPoliS for teaching, experimental use, and online gaming.

Keywords:

Business Management Game, Agent-Based Model, Behavioral Experiments, Agriculture, Teaching

4.1 Introduction

Business management games have a long history. Typically, a "management game is designed to create an exercise in business management," and it "is

[6] This chapter is based on Appel et al. (2018). Alfons Balmann was involved in the conceptualization of the idea and contributed to the discussion of the results. Jens Rommel was involved in preparing and carrying out the experiments and contributed to the theoretical background. Changxing Dong was responsible for the programming of FarmAgriPoliS.

based upon a more or less realistic model of a business situation which is used to simulate the outcomes of management decisions made by the participants in the exercise" (Longworth, 1969, p. 58). In a business management game, participants make entrepreneurial decisions, constrained by a set of systematic rules. These decisions lead to an outcome which defines success or failure. For instance, the objective may be to maximize the value of final assets in a given game. In some games, players have to solve a problem or play against nature, whereas in other games, success also depends on the interaction among players. In the latter case, a player's decision must include the consideration of the potential competitors' strategies and actions.

Business management games can serve a number of purposes. They might be used (i) for didactic reasons in education and training, (ii) as a tool for obtaining data from behavioral experiments, or (iii) for entertainment. They may even be used for a combination of those purposes.

This paper introduces the business management game FarmAgriPolis. It was developed as an extension of the agent-based model AgriPoliS (Agricultural Policy Simulator), which was developed to endogenously simulate the structural change in a selected region with specific agricultural characteristics (Balmann, 1997; Happe et al., 2006). Within AgriPoliS, a number of farms compete within a spatially explicit region for land. These farms can invest in assets and can use assets, land, and labor for production purposes. The decisions are based on myopic expectations and follow the goal of income or profit maximization, and therefore, AgriPoliS can be used to study the implications of specific agricultural policies (e.g. Happe et al., 2008; Uthes et al., 2011; Appel et al., 2016). In FarmAgriPoliS, a real person takes over the role of the manager of one of the farms within the model. This person competes with other farms (agents) which base their decisions, as in AgriPoliS, on mixed integer optimization, but with short-term horizon. The types of decisions a player has to make in FarmAgriPoliS include farm exit or continuation, bidding strategies for land, and investments in durable and capital-intensive assets such as buildings and machinery. Short-term plans, such as the optimization of production, are made automatically based on the expectations of the player.

Originally, FarmAgriPoliS was developed to enable researchers to experimentally study the decision behavior and the economic success of real persons in a laboratory and to compare the observed experimental behavior and economic results with those of computer agents in identical situations. The aim was to identify factors such as risk considerations, strategic behavior, and possibly social attitudes and mental models.

In addition, FarmAgriPoliS was made available to anyone interested to play via the website www.farmagripolis.de as a business management game. FarmAgriPoliS allows players to experience the complex interrelationships of individual farm development with surrounding farms and farm structures. Instead of just theoretically learning about structural change and the effects of various agricultural policy scenarios, FarmAgriPoliS allows players direct and intuitive access: The short- and long-term impact of their own decisions are experienced directly at their own model farm as well as in comparison to other farms in the region.

The purpose of this paper is to document the process of developing FarmAgriPoliS and address details of its use. We also systematically classify FarmAgriPoliS into the framework of business management games with agricultural backgrounds. Furthermore, we evaluate the game based on players' experiences and performance in behavioral experiments. Finally, we discuss the suitability of FarmAgriPoliS (i) for didactic purposes, (ii) as an experimental platform, and (iii) for entertainment.

4.2 History of Business Management Games

The first management games were created during the late 1950s and were derived from military situations (Wells, 1990). Since then, these often computer-based games have frequently been used in teaching to familiarize students with economic decision-making. Aldrich (2004) even describes them as "the first fundamental change to education since the textbook." Business management games also have been used in agricultural economics for several decades (Longworth, 1969). The first agricultural business management game was the "Farm Operations Simulator" at Purdue University (Eisgruber, 1990). A long tradition in this field also exists at the University of Göttingen (Brandes et al., 1990). The game "Puten und Perlhühner" (Turkeys and Guinea Fowls) was developed in the early 1980s and is still used for teaching purposes.

Over the years, business management games in agricultural economics have diversified. They were adapted to serve specific teaching needs, as documented by the variations of "Puten und Perlhühner" (e.g., "Wachsen oder Weichen" (Grow or Exit, Hinners-Tobrägel and Brandes, 1997) or "Spatz oder Taube" (Sparrow or Dove, Brandes, 2002)). "Wachsen oder Weichen" focuses on the decisions of farmers to leave the agricultural sector and to search for off-farm employment, whereas "Spatz oder Taube" focuses on agricultural markets. At the same time, business management games have grown in complexity and developed into commercial simulation games like the Farming Simulator (GIANTS Software, 2015). The purpose of "Farming Simulator" is entertainment rather than learning. Recent years have seen a trend that combines teaching and research on the basis of business management games For instance, Mußhoff et al. (2011) show in a carefully designed experiment that suitable research data can be obtained under controlled conditions at relatively low cost as a by-product of simulations for teaching purposes. Consequently, the combination of teaching and research may become relatively wide-spread.

4.3 Objective, Design and Description

4.3.1 Objective and Background

In this section we describe how the model AgriPoliS was adapted to the business management game FarmAgriPoliS. We start with an overview of particularities, specific characteristics, and related challenges.

1. Utilization of FarmAgriPoliS as an experimental platform
   As opposed to business management games developed purely for teaching purposes, FarmAgriPoliS was initially designed for analyzing the behavior of human agents in strategic farm management (farmers, students) and to compare their decisions and performance with those of computer agents. Regarding real behavior of farmers, empirical findings based on behavioral experiments suggest that farmers do not behave perfectly rational under all circumstances (e.g. Schwarze et al., 2014). A stronger empirical focus on the decision context of farmers seems useful to improve the understanding of their behavior. There is a methodological dilemma when empirically investigating farmers' behavior: On the one hand, laboratory experiments allow for the identification of causal effects and data can be obtained 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 it is often difficult to identify causal effects. Framed field experiments that use context-specific software environments aim to bridge this gap (Harrison and List, 2004; Fiore et al., 2009; Reutemann et al., 2016) "because 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, p. 1022).

2. AgriPoliS
   AgriPoliS (Agricultural Policy Simulator; Happe (2004); Happe et al. (2006); Kellermann et al. (2008)) is a spatially explicit and dynamic model to simulate structural change within an agricultural region in re-

sponse to policy environments (Happe et al., 2006). It offers a software environment for the simulation of farms, regional farm populations and structures, markets, agricultural production, etc.. FarmAgriPoliS uses the AgripoliS platform. Moreover, like in AgriPoliS, the regions and specified farms used in FarmAgriPoliS are derived from real agricultural regions and farms for which AgriPoliS has been adapted. Therefore, the situational settings to which agents, respectively players, are confronted are the same in AgriPoliS and FarmAgriPoliS. If one assumes that agents in AgriPoliS have to make decisions that are framed in a way which is realistic, then this can also be assumed for agents in FarmAgriPoliS. Thus, a basic assumption for using for behavioral experiments as well as for training is that participants face a salient context which requires decisions close to those situations faced by actual farm managers (Guyot and Honiden, 2006). Compared to AgriPoliS, one fundamental difference remains for the analysis of a player's behavior: AgriPoliS is usually used to analyze the outcome of a large number of heterogeneous interacting farms, whereas in FarmAgriPoliS the studied subject is the playing agent representing an individual farm. Accordingly, one cannot rely on the law of large numbers, unless a large number of experiments is carried out. Usually, the restrictions of a case study apply.

3. Complexity
   Although a realistic setting is important and AgriPoliS is quite complex, game situations in FarmAgriPoliS should still be kept sufficiently simple to allow for an easy and quick introduction to the game situation. This allows players of FarmAgriPolis to concentrate on the strategic decisions which influence farms' performance in a longer perspective. These types of decisions include farm exit, land rental, and investments in stables and machinery. Short-term decisions, such as optimized annual production, are made automatically based on the player's expectations. Moreover, players can see how a computer agent would decide by observing default decisions for rental bids and invest-

ments. These defaults, however, are just suggestions to reduce the time a player would need for decision making and possibly necessary calculations. The players are free to deviate from these suggestions.

4. Time
   Despite the decision support, playing FarmAgriPoliS still takes some time (approximately one hour per run). Nevertheless, players should not lose motivation during the game. Besides the intrinsic fun of, satisfycing curiosity, solving puzzles, or learning, this usually can be achieved by introducing competitive elements into the game. In FarmAgriPoliS, players are encouraged to outperform the computer agents, which is achieved for instance by increasing the equity capital of the farm compared to that of other players. In the case of the behavioral experiments, players also receive a payment contingent on their economic performance in the game.

5. Interaction
   Interaction is another feature that sets FarmAgriPoliS apart from other business management games. FarmAgriPoliS includes (spatial) interaction effects because the focus of the behavioral experiments was on strategic decisions and served as a comparative analysis between human behavior and the behavior of computer agents. In FarmAgriPoliS the interaction effects result from the interaction of the player with the decisions of the (simulated) computer agents.

4.3.2 AgriPoliS and its applications

AgriPoliS was developed to model structural change in agriculture and analyze effects of various policies. A detailed documentation following the Overview, Design concepts and Details (ODD) standard protocol is provided by Sahrbacher et al. (2012, 2014).

To adapt AgriPoliS to a specific agricultural region, a synthetic landscape (a special grid of land plots) is created according to regional and structural characteristics. Farm types which are representative for this region are identified and stratified according to certain weights to match selected regional characteristics on the aggregate level. Based on these weights, a proportional number of individual farm agents is created and spatially distributed within the synthetic landscape. Each farm agent is randomly initialized with individual management skills (i.e., different variable production costs), age of the farmer, and farm assets. Neighboring land plots are assigned to these farm agents according their type of farm. A detailed description on parameterization and calibration of AgriPoliS is given by Sahrbacher et al. (2014).

In AgriPoliS, the farm agents' behavior is based on a mixed-integer programming model: The objective is to utilize the farms' factor endowments (facilities, labor, capital, land, management quality, etc.) to maximize the expected profit or household income of the next year dependent on whether it is a corporate or family farm. Various production and investment alternatives which are typical for the respective agricultural region are used to determine this. Furthermore, the farm agents can borrow short- and long-term capital or invest liquid assets outside the farm. Farm agents can hire or dismiss workers, and family labor force can be employed outside the farm. Additional agricultural land can be rented; land rental contracts expire after a certain number of years. The allocation of available land for rental is based on a repeated auction (see Kellermann et al., 2008, , p.28). A sales market for land is not yet included in AgriPoliS. Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

So far, AgriPoliS has been adapted to some 22 different agricultural regions across the EU. These regional adaptations have been used for a wide range of political scenarios. The exogenously defined political and economic environment mainly affects prices and payments for production activities as well as restrictions for production activities.

Structural change results from the individual decisions of all farms. The development of any farm can only be predicted to a certain extent based on the initialization. Any farm's development ultimately also depends on the behavior of neighboring farms.

Effects of alternative scenarios can be analyzed on several levels. These include individual behavior (e.g., regarding investments) and the overall performance (e.g., profits, liquidity, size) of individual farms but also those of a specific group of farms as well as farm size, number of farms, cultivation patterns, and the land market of entire agricultural regions. There are manifold examples of applications. For example, Happe et al. (2008) analyze how the initial structure of two agricultural regions in Germany influence farm structures after a policy reform. Another study on a wider European context is provided by Uthes et al. (2011), who analyzed the impact of direct payments on agricultural structures. Appel et al. (2016) analyze the effects of Germany's biogas policies (see Section 3).

4.4 FarmAgriPoliS – Details

AgriPoliS was basically supplemented by a graphical user interface (GUI) to enable FarmAgriPoliS players to manage an existing farm that is already equipped with a certain amount of machinery, buildings, owned and rented land, labor force, and financial resources. In addition, an intermediate level between the GUI and the actual AgriPoliS model has been established to manage the data preparation and calculations for the player's decision support. The player's decisions are returned to the AgriPoliS model (see Figure 7) to perform the routines with all interactions with other agents such as land rentals. All interactions between the player's farm and other farms are simulated according to the behavioral assumptions of AgriPoliS. The game is initialized in the same way as AgriPoliS by defining a specific regional adaptation, policy settings, and the specification of which farm in the region is supposed to be managed.

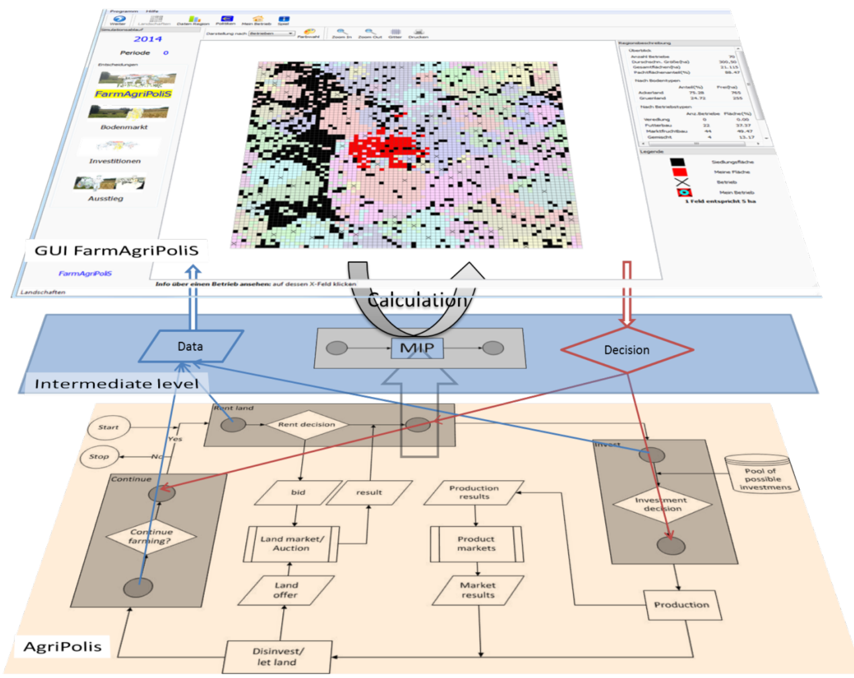


Figure 7: Interaction between AgriPoliS and FarmAgriPoliS

4.4.1 Structure and sequence of a game

A typical experiment lasts twenty rounds (equivalent to twenty simulated years). Figure 8 illustrates the course of actions per year and highlights the situations in which a player has to decide with the gray boxes. For a more technical illustration of one simulation period in FarmAgriPolis Figure A.1 provides a (reduced) sequence diagram.

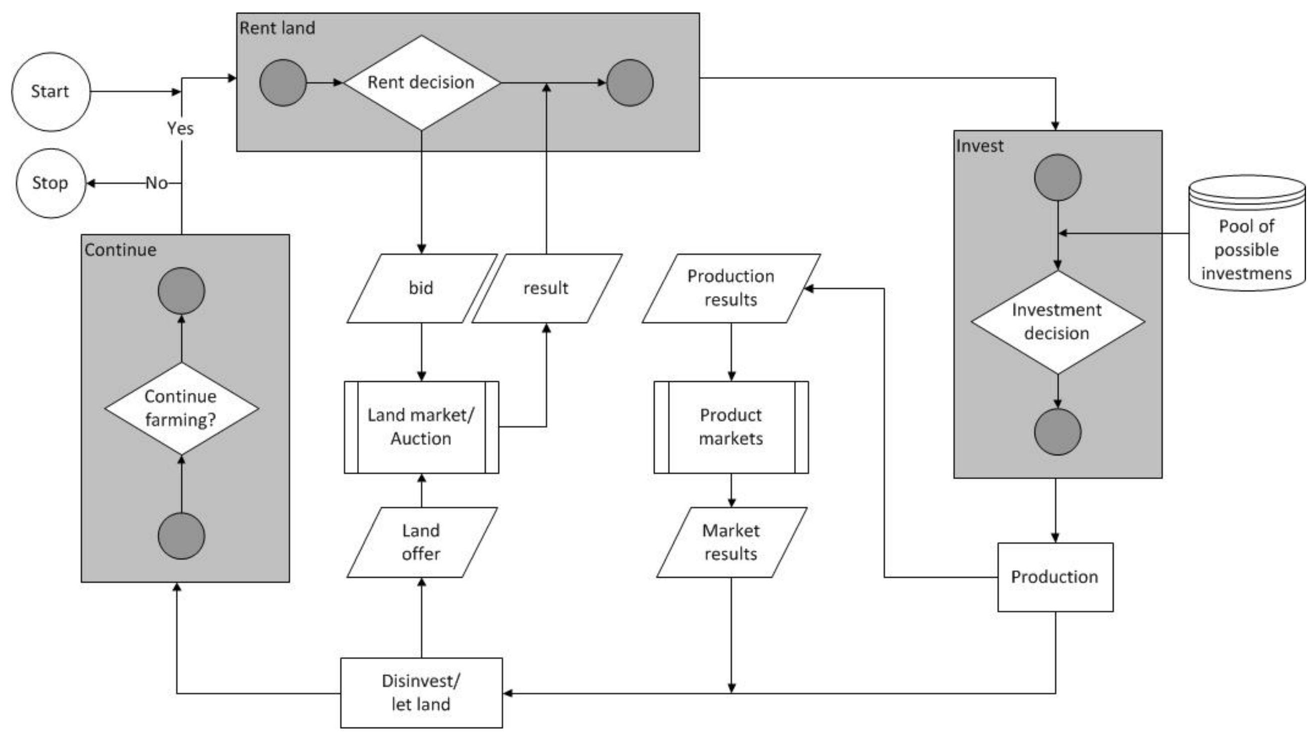
The players' decisions on farm exit or continuation, bidding strategies for land, and investments in durable and capital-intensive assets such as buildings and machinery can be considered strategic decisions that drive a farm's performance in the long run. Short-term optimizations such as planning of the annual production are considered as non-strategic. It is therefore assumed that these can be made by the computer program on the basis of the player's price expectations and using mixed-integer optimization. For the strategic decisions, players may access information on how a computer agent would decide, which provides a default for rental bids and investments from which players can, however, deviate.

Continuation or exit of farm

In any period, players must decide whether or not to stay in the farming business. The computer-controlled farms exit if opportunity costs of farm-owned production factors (land, labor, capital) are not covered by expected farm income. The players also receive information on the opportunity costs and can compare them with their expected farm income (cf. Figure A.4 for sequence diagram). If a player chooses to exit, income for the remaining periods is added to the farm's endowment. This means that the game continues without further interventions by the player. In contrast to self-determined farm exits, the game is always finished if the equity capital of a player's farm becomes negative. If only the liquidity is negative, short-term borrowed capital can be used to prevent insolvency.

Renting land

In case of renting land, both the computer-controlled farms and the player



Own figure based on Balmann (1995)

Figure 8: Flowchart of one iteration in AgriPoliS and FarmAgriPoliS

compete for available land (i.e., land that is currently not rented) via a repeated auction. Every computer-controlled farm agent as well as the farm managed by the player selects an available plot that is most valuable to the farm and then calculates a bid. Every farm agents' bid equals a specific proportion (e.g., 50%) 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 farm it for a specific contract length (see Kellermann et al., 2008, p. 28). Afterwards, all farms can again submit bids that are compared again. This procedure continues as long as land is available.

The player of FarmAgriPoliS is provided with information on how a computer agent would decide, which provides a default for rental bids from which the player can, however, deviate.
To avoid too extensive decisions, the land market proceeds sequentially with intermediate opportunities for the player to intervene. At the beginning of the land auctions, the player decides on bids for arable land and grassland. The player can adjust the bids after 50% of the available plots have been rented out. This option appears again after 90% of the land plots have been auctioned. A sequence diagram of the renting process is given by Figure A.2.

At the end of the land allocation process, the duration of rental contracts for each plot is determined randomly. In the current version, the contract length is determined by drawing randomly from a discrete uniform distribution ranging from 5 to 18 years.

Investments
Computer-controlled farms use short-term optimization (mixed integer linear programming) to determine their investments. Players also can access the results of such an optimization, but again are allowed to deviate from the suggestion. Players can create several investment plans for comparisons, and for every plan they can access information on the expected financial situation in the next period. Figure A.3 provides a sequence diagram of the

investment decision.

In principle, all investments are financed at 70% with debt capital. The remaining 30% have to be financed by cash or short-term borrowed capital (at higher interest rates). Further conditions may exist for some investments such as the availability of grassland for pasture. These constraints are automatically considered by the model, and any plan that violates constraints is rejected.

As Figure 8 shows, investment decisions are directly followed by production decisions. All farms, including those of players, optimize production subject to available production capacities (land, stables, capital, etc.) using mixed integer linear programming. FarmAgriPoliS does not allow players to deviate. Firstly, FarmAgriPoliS is focused on strategic decisions which influence the farms' performance in a longer perspective; secondly, the solution of the mixed-integer optimization is optimal and consider detailed and regional specific constraints.

4.4.2 Information available to players

Throughout the game players are provided with information on the economic situation of their farm, on factor endowments, and on the development of the region. Some key figures are also displayed graphically. Game instructions, help files, and histories of past decisions are also accessible at all stages of the game. In addition, players can see how a computer agent would decide as default decisions whenever the player is asked to decide.

- The entire region is plotted as a raster image in the Landscape Window, which is differentiated by farm and soil types. Plots available for rentals are highlighted graphically. During the land market phase players can observe how the available plots are gradually leased out. Players can retrieve data about other farms in the region by clicking on plots representing the location of their farmstead. This includes information on the farms' factor endowments, size, etc. Current prices of farm land and information about its owner are also accessible by clicking on a plot.

- The Regional Data Window provides certain indicators on the development of the agricultural region, which also can be retrieved by the player at any time. These key figures include income by farm type, profit by farm type, size by farm type, rents by soil type, number of animals and livestock density, classification of farms by equity capital, and product prices.

- In the policy window, players can access information about current and past policy and price changes.

- The My Farm Window provides various data to the player, including equity capital, profit/loss statement, rental balance, bank statement, rental contracts for used land, and liquidity.

4.4.3 Application – Regions

For the experiments, only the Altmark region is used for FarmAgriPoliS. In principle, all model regions used in AgriPoliS can be applied in FarmAgriPoliS with some minor modifications. A detailed description on how the Altmark region is implemented in AgriPoliS is provided by Ostermeyer (2015). 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. In addition to many small farms between 0 and 30 ha, many farms are found in the range of 200 to 500 ha. The majority of the land is, however, cultivated by companies with more than 200 ha. In terms of numbers, individual full and part-time farms as well as partnerships predominate the Altmark. Although legal persons account for only some 10%

of the farms, they use almost 45% of the agricultural acreage. Furthermore, farms with large stocks dominate the livestock production. Fattening pigs are mainly kept in herds of more than 1,000 animals and dairy cows in herds of 100 to 200 to more than 500 head. The relative importance of livestock production is emphasized by the fact that around 40% of the dairy cows and 53% of the specialized dairy farms in Saxony-Anhalt are located in Altmark, though the region covers only 23% of the agricultural acreage of Saxony-Anhalt (in 2007 StaLa, 2008b, 2014). In addition, the proportion of grassland is comparatively high (nearly 27%).

4.4.4 FarmAgriPoliS compared to other agricultural business management games

Table 9 gives examples of business management games with agricultural backgrounds. Commercial games such as the "Farming Simulator" (GIANTS Software, 2015) focus on operational tasks of the farm. The business management games developed at the University of Göttingen, such as "Puten und Perlhühner" (Turkeys and Guinea Fowls, Brandes et al., 1990) and "Spatz oder Taube" (Sparrow or Dove, Brandes, 2002) are less complex in terms of operational decisions players can make, and these games mainly focus on strategic decisions under competition. Outcomes critically depend on the game's own strategy in relation to the other players' strategies.

FarmAgriPoliS strives to be self-explanatory to a wide range of participants (e.g., farmers and students), although it requires a minimum threshold level of knowledge and experience with agriculture. A number of farm types and scenarios that differ in the level of difficulty have been developed. In addition, managerial skills (differences in the variable costs of production) can be easily varied to further adjust the level of difficulty. Several scenarios are currently provided to players, reflecting different political and economic environments. In some scenarios, players need to deal with fluctuations in milk prices, and in others the challenge is to develop successful growth strategies or decide for the best time to give up farming.

Table 9: Comparison with other agricultural business management games

BMG	Source	Participants	Interaction	Purpose
Puten und Perlhühner	Brandes et al. (1990)	Students	Yes	Teaching
Wachsen oder Weichen	Hinners-Tobrägel and Brandes (1997)	Students	Yes	Teaching
Spatz oder Taube	Brandes (2002); Mußhoff et al. (2011)	Students	Yes	Teaching; adaptation used for research
Farming Simulator	GIANTS Software (2015)	No limitation	No	Entertainment
FarmAgriPoliS	Appel et al. (2018)	Farmers, students, interested stakeholders	Yes (with computer agents)	Teaching, research, entertainment

4.5 Experiences from (previous) application

4.5.1 Experimental Usage

This section presents results from controlled experiments carried out with students in 2014 and 2015. Each of the 49 participants was asked to play up to three times with different game settings and initializations. These game scenarios include three different farm types (different size and managerial skills) and three milk price scenarios (stable, fluctuating with positive trend, fluctuating with negative trend). An overview of the scenarios is given in Table 10. In total, data sets of 144 games were available for the analysis.

4.5.2 Background of participants

Participants for the 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%

Table 10: Game scenarios

Scen.	**Milk price (trend)**	**Farm**	**Management skills***	**Size**
1	Stable	Farm 1	good (0.9)	medium (665 ha)
2	Price 1 (fluctuating rising)	Farm 1	good (0.9)	medium (665 ha)
3	Price 2 (failed expectations)	Farm 1	good (0.9)	medium (665 ha)
4	Stable	Farm 2	normal (1)	large (1,480 ha)
5	Price 1 (fluctuating rising)	Farm 2	normal (1)	large (1,480 ha)
6	Price 2 (failed expectations)	Farm 2	normal (1)	large (1,480 ha)
7	Stable	Farm 3	poor (1.15)	medium (665 ha)
8	Price 1 (fluctuating rising)	Farm 3	poor (1.15)	medium (665 ha)
9	Price 2 (failed expectations)	Farm 3	poor (1.15)	medium (665 ha)

Note: * factor multiplied with the variable costs of the farm for each production activity

had a Bachelor's degree, and 63% had some practical experience with agriculture and farming.

A post-experimental questionnaire was used to collect data on the personal background (age, gender, educational level, etc.), and included some questions on how they perceive and evaluate the game. Furthermore, two item batteries based on validated psychological scales were used to identify decision-making styles (GDSM; cf. Scott and Bruce, 1995; Mann et al., 1997) and to distinguish between satisficing and maximizing behavior (cf. Schwartz et al., 2002). Data on risk attitudes are gathered by means of a lottery (HLL; Holt and Laury, 2002).

In the post-game questionnaire, three items elicited participants' understanding of the game, perceived fun, and realism. As Table 11 shows, the objective of the game was clear to participants and most enjoyed playing FarmAgriPoliS. Although a majority of players indicated that the game was realistic, scoring 1 or 2 at the scale, a number of participants also disagreed with this statement. A possible explanation is that players could not freely select the scenario and farm they would like to play. Therefore, they might have had difficulties to identify themselves with the selected farm type. In particular, students from Western Germany might not have been used to the framing of managing a large corporate farm, as it is typical for the model region that is located in Eastern Germany. Table 12 shows that the share of students who perceived the game as not realistic is higher in Göttingen (Western Germany) than in Berlin or Halle.

Table 11: Game experience

Item	**Mean**	**Std. Dev.**	**N**
The objective of the game was clear to me. (clarity)	1.51	0.55	49
It was fun to play. (fun)	1.90	0.80	49
The game comes close to reality. (realism)	2.78	0.82	49

Note: 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree

Table 12: Evaluation on whether the game is perceived to be realistic by participants from different universities

	strongly agree	**agree**	**neither agree nor disagree**	**disagree**	**strongly disagree**
Berlin	0%	44%	52%	0%	4%
Göttingen	0%	31%	46%	23%	0%
Halle	0%	50%	35%	12%	4%

We also included some questions on background information on players' computer skills and use and their level of knowledge in agricultural management (Table 13). Most report that they have no problems using computers. Most participants consider working with a computer as fun, whereas computer games are generally not very popular. The knowledge in agricultural management is mediocre.

We have calculated the Spearman rank correlation coefficient to analyze how those experiences are related to players' evaluation of the game regarding clarity, fun, and realism (Table 14). It is noticeable that fun and realism are positively correlated: a game setting perceived as realistic increases the fun. In addition, there is a highly significant positive correlation between fun and the general fun of dealing with a computer. Therefore, a certain

Table 13: Participants' computer skills and agricultural knowledge

Variable	Mean	Std. Dev.	N
Dealing with the computer is easy for me. (Dealing PC)	1.65	0.75	49
Dealing with the computer is fun for me. (Fun PC)	2.08	1.06	49
I regularly play computer games. (PC games)	3.31	1.31	49
I have good knowledge in agricultural management. (Agricultural management)	2.77	1.06	35

Note: 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree

affinity for the use of computers can be considered as a prerequisite for enjoying FarmAgriPoliS. Furthermore, the skills in agricultural management are positively correlated with the perceived clarity and fun, even though this correlation is not significant. The game is therefore probably best suited for students at higher semesters/master level.

Table 14: Rank correlation coefficient (Spearman)

	clarity	fun	realism	Dealing PC	Fun PC	PC Games
clarity	1					
fun	-0.0519	1				
	(0.5991)					
realism	-0.0927	0.2040*	1			
	(0.3472)	(0.0369)				
Dealing PC	0.135	0.0717	-0.0855	1		
	(0.1698)	(0.4673)	(0.3857)			
Fun PC	0.2352*	0.3473***	0.1171	0.5554***	1	
	(0.0157)	(0.0003)	(0.2343)	(0.0000)		
PC Games	-0.0763	0.085	0.027	0.3943***	0.4350***	1
	(0.4389)	(0.3885)	(0.7842)	(0.0000)	(0.0000)	
Agricultural	0.1023	0.1326	0.05	0.0593	-0.0524	-0.1129
management	(0.2991)	(0.1774)	(0.6127)	(0.5480)	(0.5955)	(0.2514)

Note: significance level: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

4.5.3 Performance of players

Our analysis of players' performance focuses on financial outcome, namely equity capital at the final period for which players were asked and incentivized to maximize. Because scenarios differ quite strongly, players' performance may not be directly compared. The assessment must acknowledge characteristics of the scenario (cf. Table 10). For each scenario, a benchmark was calculated by running the scenario's farm by a simulated computer agent. In 47.92% of the data sets, human players outperform computer agents and achieve at the end of the game an equity capital higher than the benchmark. According to self-reported questionnaire data, only 35.42% of the human players mostly followed the default values that were set by the optimization routines. Both in terms of profit and equity, players show statistically significant differences from the computer benchmark: depending on the scenario, human players may either perform better or worse (Table 15). Human players tend to perform relatively poorly when the benchmark farm realizes a positive profit. In other words, computer agents perform better in scenarios with promising growth opportunities. In contrast, human players on average do better in scenarios with losses as the simulated benchmark (scenarios three, six, seven, eight, and nine). Generally speaking, human players are better at avoiding losses than realizing gains in our game, which is consistent with prospect theory (Kahnemann and Tversky, 1979).

We also analyzed how the players' socio-economic characteristics and character traits affects performance in the game using an OLS regression. In these regressions, the relative difference in equity capital from the computer benchmark was used as the dependent variable. The analysis was based on all rounds of all scenarios. We account for the panel data structure by clustering standard errors for players. We have also run random effects and fixed effects regression models that do not yield qualitatively different results.

We use two dummy variables for farm type and two dummy variables

Table 15: Student's T-test for selected financial indicators (at the end)

	Scen.	Obs.	Bench mark	Mean	Std. Err.	Std. Dev.	$(T < t)$	$(\|T\| > \|t\|)$	$(T > t)$
Equity capital (1,000 Euro)	1	15	2,843	1,733	270	1,045	0.0005***	0.0011**	0.9995
	2	20	2,484	1,430	293	1,312	0.0010**	0.0019**	0.999
	3	15	-1,099	-387	669	2,589	0.8476	0.3048	0.1524
	4	18	6,084	4,239	491	2,084	0.0008***	0.0016**	0.9992
	5	8	6,271	5,587	448	1,267	0.0852	0.1703	0.9148
	6	24	-2,723	1,053	887	4,343	0.9999	0.0003***	0.0001***
	7	20	-490	-533	117	523	0.3592	0.7184	0.6408
	8	11	-822	-303	114	378	0.9995	0.0010**	0.0005***
	9	13	-1,174	-714	222	801	0.9698	0.0605*	0.0302*
Profit (1,000 Euro)	1	15	842	214	146	566	0.0004***	0.0007***	0.9996
	2	20	359	111	90	403	0.0064**	0.0127*	0.9936
	3	15	-441	-104	149	577	1.0000	0.0000***	0.0000***
	4	18	1,915	1,142	233	987	0.0000***	0.0000***	1.0000
	5	8	1,719	1,350	213	602	0.0000***	0.0000***	1.0000
	6	24	-1,005	-84	216	1,056	1.0000	0.0000***	0.0000***
	7	20	-116	-138	9	38	1.0000	0.0000***	0.0000***
	8	11	-177	-143	12	39	1.0000	0.0000***	0.0000***
	9	13	-216	-192	20	73	1.0000	0.0000***	0.0000***

Note: significance level: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

for price movements to control for the two factors we manipulated in the scenario (cf. Table 10). Note that including eight dummy variables for all possible scenarios does not substantially improve the model fit. *Farm1* is a medium sized farm with the best managerial skills. *Farm2* is the largest farm with average managerial skills. *Price1* means fluctuating prices with an overall positive trend and *Price2* is as well fluctuating but with a positive trend in the first rounds followed by a strong decline. We also include a linear time trend variable *Round* for the progress of the game, i.e. game round (Table 16, Model 1), as well as demographic variables such as university location, gender, and age (Table 16, Model 2). We further use a psychological decision-making-style scale (GDSM; Scott and Bruce, 1995), a maximization tendency scale (Schwartz et al., 2002), and risk attitude (HLL; Holt and Laury, 2002) (Table 16, Model 3). Finally, we control for players' evaluation of the game (i.e., perceived clarity, fun, and realism) (Table 16, Model 4). The following regression table includes all variables.

Table 16: Regression of players' performance (equity capital relative to benchmark)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
Variable	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Farm1	0.1135225*	0.0550257	0.1090029	0.0586362	0.101775	0.0593575	0.0926298	0.0614796
Farm2	0.1609731*	0.0611642	0.1652611*	0.061756	0.168577**	0.0619598	0.1601302*	0.0632677
Price1	0.0186972	0.0295331	0.0269214	0.0298262	0.034615	0.0359003	0.0402323	0.0364208
Price2	-0.0157283	0.0518052	-0.009862	0.0523958	-0.0055855	0.0488928	0.0108002	0.0472806
Round	-0.0259040***	0.0039153	-0.0275013***	0.0038181	-0.0274979***	0.0038229	-0.0274999***	0.0038233
Berlin			0.0714816	0.0407883	0.0694965	0.054035	0.0623562	0.0545744
Göttingen			0.0087073	0.0548225	0.017974	0.0617969	0.0223689	0.0549898
Female			0.0109901	0.0445142	-0.0119145	0.0433486	-0.0244107	0.0450004
Age			0.008629	0.0064951	0.0112628	0.006696	0.015162**	0.0071202
rational					0.0418459	0.0470474	0.0642551	0.0506887
intuitiv					0.0425241	0.0329358	0.0528631	0.0340823
depend					-0.0321764	0.0315753	-0.0485076	0.0342183
avoid					0.0010794	0.0194976	0.0027778	0.0191708
spontan					-0.0134399	0.0264221	-0.0078807	0.0255481
max					-0.027897	0.0252787	-0.025035	0.0259282
HLL(save choices)					0.0272384**	0.0074911	0.0264844***	0.0076981
clarity							0.0236575	0.0294953
fun							0.0431003	0.0262217
realism							-0.0452178	0.0337718
Const.	0.9702225***	0.0446608	0.7171081***	0.174552	0.4637742	0.3459269	0.2687757	0.3856459

Note: significance level: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; standard errors clustered for players

The regression results show a statistically significant linear trend. The difference in equity capital between human players and the computer benchmark widens in favor of the computer over the course of the game. Farm2 has a significantly positive coefficient: It is the largest farm with average management skills and there are significantly more observations in the more challenging scenario six with negative price trend (Table 10), where human players on average do better than the computer agent. In addition to the game setting, the behavioral parameters of the players provide further implications. The risk attitude of the player shows a statistically significant influence on the performance. Participants who are more risk averse in the Holt and Laury Lottery, who choose a higher number of save choices, are more successful in the game. An overview of the results of the HLL is given in Table B.1. Older players also perform better (Table 16, Model 4).

Furthermore, there is some indication that players with a rational or intuitive decision-making style perform better compared to those with a dependent decision-making style (Scott and Bruce, 1995, p. 820), although these results are not statistically significant at conventional levels.

4.5.4 FarmAgriPoliS online

The website www.farmagripolis.de has been established for the gaming and educational version of FarmAgriPoliS. It contains extensive information about FarmAgriPoliS including short videos, a download area, and a list of high scores. These modifications follow the objective that users do not need direct support by a game instructor. In addition to the step-by-step video guide on the website, the support menu has also been comprehensively revised.
Different from the experimental version of FarmAgriPoliS, players can freely choose which farm type they want to manage within the model region. Certain price scenarios used for the experiments also can be freely selected. By varying the management factor of the selected farm, (i.e., alternative levels of variable productions costs), the players have alternative levels of difficulty.

At the end of each game, the players receive an overview of their game results and a score is calculated, which compares the players' performance with that of a computer agent playing the same scenario. The players have the opportunity to upload their score on the website and can compare themselves in a high score list with other players. Because these games are not played under controlled conditions and because of the huge variety of possible game settings, data from the online version of FarmAgriPoliS are currently not used for the research. By the end of 2016, the website of FarmAgriPoliS had already been accessed more than 1,000 times and more than 100 players had uploaded their results to participate in the high score list.

4.6 Discussion

To sum up, we discuss the results given the goal that FarmAgriPoliS should be suitable for (i) didactic purposes, (ii) behavioral experiments, and (iii) entertainment:

(i) Regarding the didactic suitability, the most important question is for whom the game is appropriate. Our analysis shows that older and more experienced students are able to make better decisions within FarmAgriPoliS. Accordingly, it can be assumed that FarmAgriPoliS is suitable for master students and perhaps experienced farmers. Another factor is the perceived realism of the game. If the game setting is perceived as realistic, the players may be better able to play the role of a farmer and eventually gain more experiences in farm management. As presented in the results section, the realism of FarmAgripoliS is perceived quite diversely. In particular, students from Western Germany evaluated the game as less realistic. Presumably, they are less used to the farming system (farm size, production patterns, etc.) that is typical for the East German model region in FarmAgriPoliS. Therefore, FarmAgriPoliS should be adjusted to alternative regional settings.

(ii) Regarding behavioral experiments, FarmAgriPoliS shows that the behavior between human actors and computer agents differs significantly. More specifically, the players tend to be better at avoiding losses and worse at achieving high profits and equity capital. By combining the experimental data with the questionnaire data, the experiments allow the linking of game results to some general behavioral patterns of the participants. Therefore, a broader analysis of success indicators is possible. In addition to the presented results, the collected data can be used for several further analyses (e.g., different behavioral patterns among the participants). In addition, these findings suggest the need to analyze whether farm agents within AgriPoliS are appropriately dealing with challenging economic environments and situations.

(iii) The participants of the experiments mainly agreed that FarmAgriPoliS is fun to play. Furthermore, the online version of FarmAgriPoliS is downloaded frequently and a sizeable number of the players contribute (repeatedly) to the online high score list. Even if we cannot directly analyze the motives of these players, they seem to be entertainment, curiosity, and fun, because there is no further (monetary) incentive.

Acknowledgments

This research was conducted within the Research Unit "Structural change in Agriculture (SiAg)" of the German Research Foundation (DFG) and within the project "FarmAgriPoliS 2.0 – Ein Unternehmensplanspiel zum Erleben des Agrarstrukturwandels" funded by the Landwirtschaftliche Rentenbank. We gratefully acknowledge the financial support.

5 Human behaviour versus optimising agents and the resilience of farms – Insights from agent-based participatory experiments with FarmAgriPoliS[7]

Franziska Appel and Alfons Balmann

Abstract

This paper aims to examine the extent to which human protagonists show higher resilience compared to computer agents in agent-based participatory experiments. We motivate and examine three types of resilient behaviour of farmers during a crisis or as response to competitive pressure: successful survival, loss-minimising farm exits, and path breaking respectively path creating growth strategies. Our experiments revealed that human decision makers recognized and exploited such resilient strategies in periods of crisis or under challenging circumstances in general better than myopic optimizing agents, although they did not perform better on average. The reason can be seen in a substantial heterogeneity of human decision makers, for which we identified four categories: negligent gamblers, actors missing opportunities, solid farm managers and successful path breakers.

Keywords

Resilience; Agriculture; Agent-based modelling; Behavioural experiments; Business management game; Agent-based participatory experiments

5.1 Introduction

Agricultural structures or farm populations may be described as complex adaptive systems of regular interactions between farms as well as between farms and their environment (Balmann et al., 2006). In general, structural

[7]This chapter is based on Appel and Balmann (2018). Alfons Balmann contributed to the analysis and discussion of the results.

changes occur in agriculture in a more gradual and path-dependent manner. Farms face fierce competition on both the input and output markets, especially on the land market. In particular, the concept of the technological treadmill (Cochrane, 1958) suggests that if new technologies emerge, farms either have to innovate, adapt, or exit the sector. The role that a farm takes within this complex process depends not only on the farm's characteristics, the characteristics of the farmer or farm manager, but also on local competition, available technologies as well as the economic, institutional and environmental conditions. For an adequate understanding of the underlying processes, it is important to capture not only the interactions amongst and between farms and their environment but also the farms' behaviour, i.e. their decision processes.

To capture these interactions, a large variety of economic modelling approaches has been developed. Examples include recursive programming models (Day, 1963), general and partial equilibrium models (for an overview c.f. Balkhausen et al., 2006) and, in recent decades, agent-based models (e.g. Happe et al., 2006; Berger and Schreinemachers, 2006; Freeman et al., 2009). The agent-based models explicitly focus on modelling the interactions among farms to study emergent properties on the system level.

Traditional agricultural economics assume that farm behaviour is based on the concept of profit- or utility-maximising price-takers; which are considered to be perfectly rational. These behavioural assumptions serve as the basis of general and partial equilibrium models. Additionally, several agent-based models of the agricultural sector are based on this principle. Examples include AgriPoliS (cf. Happe et al., 2006), MP-MAS (cf. Berger and Schreinemachers, 2006; Schreinemachers and Berger, 2011) and SWISS-Land (Möhring et al., 2016). The frequent application of maximisation concepts in agent-based models of the agricultural sector may be attributed to its high compatibility with linear, recursive, and positive mathematical programming farm models in the tradition of Earl O. Heady (1983), Richard H. Day (1963), Richard E. Howitt (1995) and others that inspired and dominated farm-level modelling in agricultural economics for many decades. The specific strengths of each of these approaches are related to their compatibility with farm-planning databases. At the same time, these approaches to modelling farm behaviour have several common weaknesses, all of which are related to decision-making in complex situations. These weaknesses include sensitivity of optimisation results to uncertain expectations, ignorance of strategic issues, and the assumption of perfect rationality amongst agents.

Agent-based models are, however, flexible with regard to modelling agent behaviour. Examples of behavioural approaches range from simple rules to computational intelligence, including learning. Some of these concepts and the modelling process itself are combined with participatory approaches such as companion modelling (Antona et al., 2003). An extreme case can be found in role-playing games where human participants play the role of an agent and the games themselves serve as the models (Barreteau et al., 2003). A further option of modelling agent behaviour may be found in behavioural experiments in a laboratory. Behavioural laboratory experiments are used to study human behaviour in controlled environments. Many behavioural experiments have shown that humans do not necessarily behave according to the fully selfish and rational profit maximisation, and that context matters (e.g. Harrison and List, 2004). These insights also apply to the behaviour of farmers (e.g. Schwarze et al., 2014; Howley, 2015; Rommel et al., 2017).

The objective of this paper is to analyse how different behavioural approaches perform under different conditions while considering the complexity of structural change in agriculture. In particular, we compare the behaviour and performance of human participants with that of optimising agents, which are used in AgriPoliS, an agent-based model of structural change (Happe et al., 2006).For this purpose, the business-management game FarmAgriPoliS (Appel et al., 2018) has been developed. FarmAgriPoliS allows a person to actively manage a farm within the agent-based framework of AgriPoliS. For the behavioural experiments students with a background in agricultural economics were selected. The experiments are then compared with simulations of the standard AgriPoliS model, where all farms are managed by optimising agents.

Of particular interest is the extent to which human participants show higher resilience in their behaviour compared to the optimising computer agents in the face of specific strategic challenges. Apart from that, we aim to improve our understanding of how human participants act in a strategic farm management context, how they differ in their behaviour, and how these differences affect a farm's performance. Finally, we aim to identify conditions under which the participants are more successful and more resilient than computer agents.

The theoretical part of this paper in Section 5.2 focuses on selected system-theoretic and economic concepts related to structural change in agriculture. Based on that, the concept of resilience is defined regarding its relation to farm behaviour within the process of structural change. The methodological part in Section 5.3 illustrates FarmAgriPoliS in more detail and motivates the experimental approach to examine the hypotheses developed in Section 5.2. The experimental findings are elaborated in 5.7. Section 5.8 discusses the results and conclusions drawn.

5.2 Theoretical background

5.2.1 Path dependence and resilience in agriculture

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 highly heterogeneous, even within and between regions with similar agricultural conditions (climatic, soil, infrastructural, economic, social). To some degree, farm size distributions correspond to the Pareto law (see Sombart, 1967): Often, a relatively small number of large farms are responsible for the majority of agricultural production.

Balmann (1995) argues that agricultural structures are path-dependent, meaning that feedback mechanisms lead to a lock-in at a certain state that may be inefficient and prevent the system from transitioning towards an efficient state. 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 et al. (1996, 2006) refer in particular to the role of sunk costs of assets and human capital as well as frictions on land markets. Sydow et al. (2005) provide a more general 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, coordination, and complementary effects.

A farm manager may have to overcome the specific frictions resulting from path dependence on the farm as well as the sectoral level in order to elicit change (voluntary exits and exploitations of new opportunities). Overcoming path dependence may be understood as either path creation or path breaking through a kind of mindful deviation from the previous or usually expected development path (Garud and Karnøe, 2001; Garud et al., 2001). With regard to farm development and structural change, Ostermeyer (2015) considers voluntary farm exits as a trivial kind of path breaking. Nevertheless, a voluntary farm exit may require mindful deviation in terms of overcoming a personal mental model as well as the mental models prevalent in the social environment. From a managerial point of view, more challenging and far less trivial is the case where a farm manager is able to manage unusually strong and profitable growth. From simulations with AgriPoliS, Ostermeyer (2015) found that a small fraction of some 2% of farms were able to show such behaviour, allowing them to gain substantial shares in total regional production. This small fraction of farms may partly be explained by the limits in the amount of land in the region, because farms can only increase their land bank if other farms decline or exit. Another explanation is that the small share of path-breaking farms found by Ostermeyer (2015) may be the result from limitations of agent strategies in AgriPoliS.

Although a specific agricultural structure may not be seen as a societal goal in itself, farm structures may still play an important role from a societal perspective. As structures change slowly, there will be long-term effects on economic, social and environmental outcomes. This may also be the reason why structural changes often raise public concerns (Balmann and Valentinov, 2016; Chatalova et al., 2016). A distinction can be drawn between two core concerns regarding structural change. These concerns relate first to potential winners and losers, as structural change seldom leads to Pareto superior results. For the agricultural sector, this issue has been addressed by the technological treadmill (Cochrane, 1958) and more generally by the Schumpeterian notion of creative destruction (Schumpeter, 1942).Second, concerns regarding structural change may be related to the complexity of structural change itself, which may ultimately provoke an "ongoing discourse between the so-called industrial and agrarian philosophies of agriculture" (Chatalova et al., 2016, referring to Thompson, 2010).

Both of these concerns suggest that farm structures may affect the resilience and vulnerability of an agricultural system, and therefore its sustainability. Resilience refers to the ability of a system to withstand disturbances and the capacity to maintain function and state (Folke, 2006; Holling, 1973). As such, resilience concepts extend beyond vulnerability concerns; they explicitly address the ability to exploit new opportunities resulting from adaptations to environmental changes (Walker and Salt, 2012). Accordingly, the resilience of an agricultural region or a farm may also be evaluated regarding its ability to benefit from new opportunities.

Management literature sets forth a broad range of definitions of resilience. On a more conceptual and behavioural level, resilience is defined as "learning from adversity how to do better" (Wildavsky, 1988, p. 2), an outcome of organisational learning (Sitkin, 1992, p. 241) or the "positive psychological capacity to rebound" (Luthans, 2002, p. 702). From an outcome perspective, Gittell et al. (2006) define resilience as "a) the maintenance of positive adjustment under challenging conditions [...], b) the ability to bounce back from untoward events [...], and c) the capacity to maintain desirable functions and outcomes in the midst of strain" (p. 303, with reference to Sutcliffe and Vogus (2003); Weick et al. (1999); Wildavsky (1988)).

Farms are directly affected by the complexity of structural change, which includes persistent fierce competition as well as pressures resulting from the technological treadmill. On this treadmill, farmers are directly confronted with the role of innovators changing the game, having to adjust to changes, or exiting. The question as to how strategic skills affect the future of a farm can be subdivided into two sub-questions: first, which opportunities exist to change or adapt, and second, what defines a successful strategy. Both sub-questions are related to the resilience of a farm and farm management.

Returning to the competitive pressure of farms as well as the external shocks previously mentioned, resilience may be expressed in many ways. A rather simple form of resilient management can be understood as whether a farmer is able to survive an unexpected crisis through adaptation. However, exiting farming in an ordered way that minimises losses from devaluation and deterioration of fixed assets, or serves the well-being of the involved persons may also be understood as a strategy serving resilience. In this regard, even farm exits can be understood as entrepreneurial behaviour and vice versa, farm survival might not be a necessary condition for resilience. On the other hand, adaptation to external shocks or a changing business environment may also lead to completely new opportunities. The ability to exploit new opportunities may also express resilience. Both types of path breaking or path creating behaviour to adapt to changing environments can be considered as resilient

5.2.2 Behavioural theories and hypotheses

Usually, neoclassical approaches evaluate agricultural policies based on the assumption of rational decision makers, typically following the model of the *homo economicus* (e.g. Pareto, 1906; Camerer and Fehr, 2006). This model assumes that farmers are profit or utility maximisers responding to (monetary) incentives. These assumptions have been questioned by research on behavioural economics (Ariely, 2010; Kahnemann, 2011; Thaler, 2012). Accordingly, humans are best described as boundedly rational, and are subject to numerous cognitive biases. They often ignore substantial parts of the available information and use heuristics rather than optimisation when making decisions. This means that the behaviour of human participants may deviate from that of computer agents in maximising profits. With regard to our behavioural experiments, this leads to Hypothesis 1:

- Behaviour differs between human participants and optimising computer agents. Compared to the optimising computer agents, the participants in a game tend to pursue a deviating investment and growth strategy.

The prospect theory developed by Kahnemann and Tversky (1979) further specifies cognitive biases that affect behaviour under uncertainty: Humans generally evaluate deviations from the current state (gains and losses) rather than absolute values (see Kahnemann and Tversky, 1979, p. 277) and that "losses loom larger than gains" (p. 279). This leads to Hypothesis 2:

- Compared to optimising agents, the participants tend to be more effective at avoiding losses than at realising gains.

Recent applications in organisational theory recognise the role of cognitive processes and social-emotional aspects in the concept of path dependency. Mental models of the protagonists involved may be particularly relevant to path dependence in agriculture. According to Jones and Nagin (2013), "(m)ental models are personal, internal representations of external reality that people use to interact with the world around them. They are constructed by individuals based on their unique life experiences, perceptions, and understandings of the world. Mental models are used to reason and make decisions and can be the basis of individual behaviors. They provide the mechanism through which new information is filtered and stored." In general, farmers may have varying mental models even if they work under similar conditions in the same region (cf. Ostermeyer, 2015). The reason is that mental models serve specific purposes and have different roots. This leads to Hypothesis 3:

- The participants differ in their behavioural patterns, and clusters of behavioural patterns exist among the participants.

Starting from the assumption that path dependencies may cause a potential inefficiency, the question arises as to whether and under which circumstances a change towards a more efficient path is possible. Actors becoming aware of the inefficiency of the current path may try to escape from this path dependence. A starting point for overcoming path dependences can be found in a particular entrepreneurship of the actors.Garud and Karnøe (2001, p. 2) describe entrepreneurs as reflective and self-determined protagonists: "In our view, entrepreneurs meaningfully navigate a flow of events even as they constitute them. Rather than exist as passive observers within a stream of events, entrepreneurs are knowledgeable agents with a capacity to reflect and act in ways other than those prescribed by existing social rules and taken-for-granted technological artefacts." Overcoming path dependence through path creation or path breaking (Garud and Karnøe, 2001; Schreyögg et al., 2003) emphasises the role of entrepreneurs and how they can intentionally create desirable new paths. This leads to Hypothesis 4:

- (At least) some human participants exhibit path breaking or path creating behaviour in specific situations.

Both prospect theory (Hypothesis 2) and the concept of path breaking and path creating behaviour (Hypothesis 4) are important aspects in the resilience of businesses: Prospect theory is related to the aim and ability to withstand disturbances and the capacity to maintain the own function and state (Folke, 2006; Holling, 1973), whereas path breaking and path creation aim towards exploiting new opportunities resulting from environmental changes (Walker and Salt, 2012). Following these behavioural approaches, we would expect that in contrast to the optimising computer agents, human participants exhibit a variety of strategies: Some may aim just to survive while others either follow a loss minimising exit strategy or exploit potential profits. Each of these strategies can address a specific form of resilient behaviour under harsh conditions: robustness, adaptability, transformability. This leads to Hypothesis 5:

- In general, participants display more resilient behaviour than optimising computer agents through successful survival in cases of crisis, loss-minimising exits, and successful growth strategies. Additionally, the participants are particularly successful under challenging conditions.

5.3 Methodology and model description

5.3.1 Economic experiments

Economic experiments have become popular and are increasingly used to inform policy makers (Colen et al., 2016; Viceisza, 2012). There is an ongoing academic debate on 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, p. 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, abstract laboratory experiments yield clean data at relatively low cost. However, the external validity of experimental results is 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).

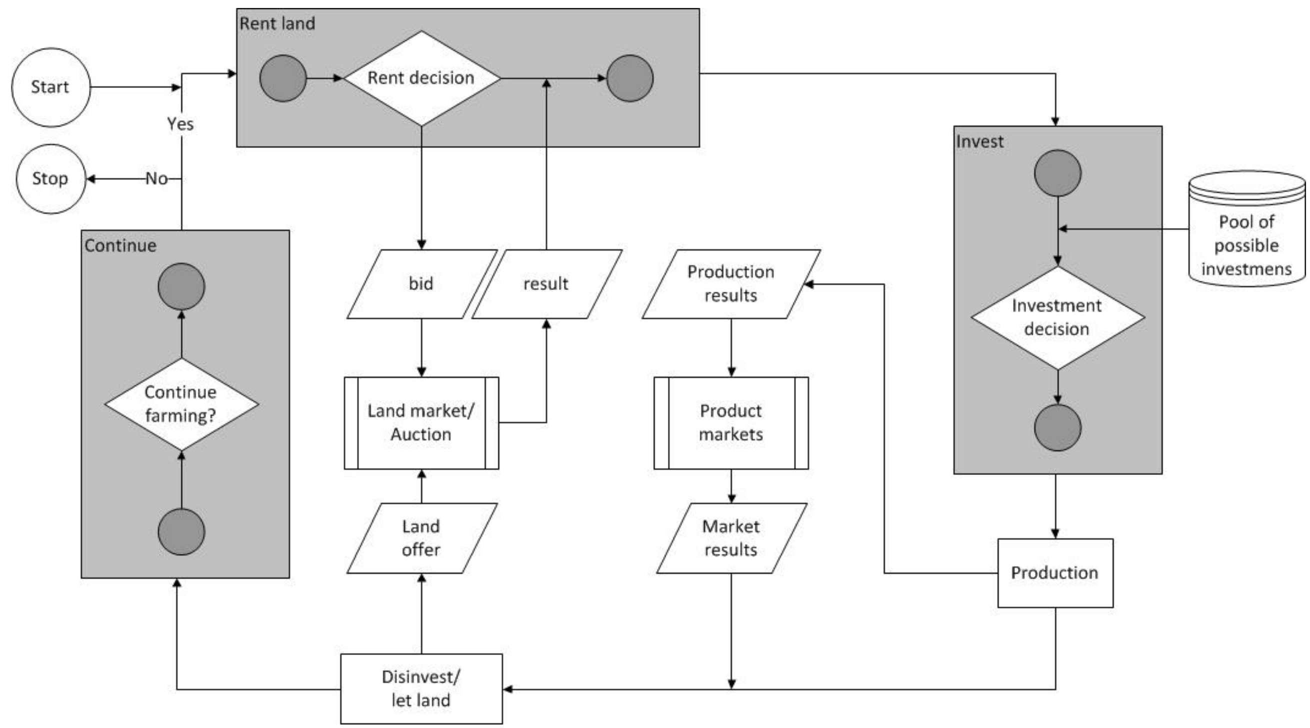
Realistic agent-based models may provide this context-specific environment and participants can become part of the agent-based simulations. Guyot and Honiden (2006) describe this type of experimental setting as an agent-based participatory experiment.

5.3.2 The FarmAgriPoliS model

Software FarmAgriPoliS can be understood as a business management game or experimental platform providing participants with a software-based environment of a simulated agricultural region. Within FarmAgriPoliS, one farm is managed by a human participant. The participant is assumed to manage this farm and to compete with computer-simulated optimising farms (agents) that derive their decisions from mixed-integer short-term profit maximisation (Appel et al., 2018). FarmAgriPoliS is based on AgriPoliS (Agricultural Policy Simulator; Happe, 2004; Happe et al., 2006; Kellermann et al., 2008) which represents a spatially explicit and dynamic agent-based model that simulates structural change in an agricultural region. Fig. 9 provides a flowchart that illustrates the course of actions per year of AgriPoliS and FarmAgriPoliS. Both models allow simulating farms, regional farm populations and structures, markets, agricultural production, and so on. Sahrbacher et al. (2014) provide a detailed documentation of AgriPoliS following the ODD standard protocol (Overview, Design concepts and Details). FarmAgriPoliS uses identical specifications routines for regions and specified farms as AgriPoliS does. In AgriPoliS, and therefore also in FarmAgriPoliS, the farms affect 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 (Kellermann et al., 2008, p. 28 et seq.). Afterwards, all farms can again submit bids that are compared again. For a given period, this procedure continues as long as land is available.

Apart from renting land, participants have to formulate price expectations and to decide in every period on farm exit or continuation and on investments in durable and capital-intensive assets such as buildings and machinery. In case of a farm exit, farms will continue to receive incomes for the production factors owned by the former farm. In particular, they receive the rent paid by the leaseholder for their owned land, wages for off-farm working family members in the case of family farms, and interest on their liquid capital. At the same time, the closed farms are affected by depreciations and interest costs for existing debts (cf. Kellermann et al., 2008, p. 44). The grey boxes in Fig. 9 highlight the situations in which a participant has to make a decision. For FarmAgriPoliS, 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. 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 optimisation. Thus, experiments with FarmAgriPoliS provide insights into how human participants behave in these competitive situations compared to computerised optimising agents as used in AgriPoliS.

A typical experiment lasts twenty rounds (equivalent to twenty simulated years). The participants' decisions on farm exit or continuation, bidding strategies for land, and investments in durable and capital-intensive assets such as buildings and machinery can be considered strategic decisions that drive a farm's performance in the long run. Short-term optimisations such as planning of the annual production are considered as non-strategic. It is therefore assumed that these can be made by the computer programme on the basis of the participants' price expectations and using mixed-integer op-



Own figure based on Balmann (1995)

Figure 9: Flowchart of one period in AgriPoliS and FarmAgriPoliS

timisation. For the strategic decisions, participants may access information on how a computer agent would decide, which provides a default for rental bids and investments from which participants can, however, deviate. Appel et al. (2018) (section 4) gives a more detailed description of FarmAgriPoliS.

Region For our experiments, we defined an economic environment adapted to the characteristics of the Altmark region located in the German Federal State of Saxony-Anhalt. The Altmark captures important features of the large-scale agricultural structures of eastern German agriculture. The study region has a comparatively high proportion of grassland at almost 27%, the soil quality is poor and the yield levels in arable farming are low. Most of the land is cultivated by farms with more than 200 hectares (ha). Farm sizes are, however, heterogeneous. In terms of numbers of farms, individual full- and part-time farms as well as partnerships are predominate in the Altmark. Although corporate farms (mainly limited companies and producer cooperatives) only account for some 10% of the farms, they use almost 45% of the agricultural land. Most farms have a high share of loan capital and rented land. Larger farms in particular mostly operate through the use of hired labour. Livestock production is dominated by farms with large stocks. Fattening pigs are mainly kept in herds of more than several thousand animals and dairy cows in herds of up 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, 2008b, 2014), emphasising the relative importance of livestock production. Ostermeyer (2015) gives a detailed description of how the Altmark region is implemented in AgriPoliS.

The Altmark region may be seen as more vulnerable than other agricultural regions in Germany due to the weak capital base, high share of rented land, high share of hired labour, and low proportion of high-quality arable land. It is often argued that smaller farms which rely on their own labour, land, and capital are less vulnerable as it is easier for them to tighten their belts in times of crises (e.g. low agricultural prices) (see Weiss, 1999).

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. However, the region is large enough to represent the specific characteristics of the region and relevant neighbourhood effects.

5.4 Design of behavioral experiments and subject pool

In order to study the decision-making of the participants in a competitive agricultural context, nine different scenarios were defined for the behavioural experiments. We defined three specific farm types with different sizes and individual production cost levels. These farms represent either larger family farms, partnership farms, or corporate farms (limited liabilities or producer cooperatives) which engage in arable and dairy farming. The farms are characteristically typical in terms of production, land use and employment for the study region. We also defined three different milk price developments (see Fig. 10) to study how participants respond to changing environmental conditions. Both factors, i.e. farm types and price scenarios were combined into a full factorial design. The scenarios are presented in Table 17.

Table 17: Game scenarios

Scen.	**Milk price (trend)**	**Farm**	**Production cost factor**[a]	**Size**	**Number of experiments**
1	Price 1 (constant)	Farm 1	Good (0.9)	Medium (665 ha)	15
2	Price 2 (fluctuating)	Farm 1	Good (0.9)	Medium (665 ha)	20
3	Price 3 (failed expectations)	Farm 1	Good (0.9)	Medium (665 ha)	15
4	Price 1 (constant)	Farm 2	Normal (1)	Large (1,480 ha)	16
5	Price 2 (fluctuating)	Farm 2	Normal (1)	Large (1,480 ha)	8
6	Price 3 (failed expectations)	Farm 2	Normal (1)	Large (1,480 ha)	24
7	Price 1 (constant)	Farm 3	Poor (1.15)	Medium (665 ha)	31
8	Price 2 (fluctuating)	Farm 3	Poor (1.15)	Medium (665 ha)	11
9	Price 3 (failed expectations)	Farm 3	Poor (1.15)	Medium (665 ha)	13

Note: a Factor multiplied with the variable costs of the farm for each production activity

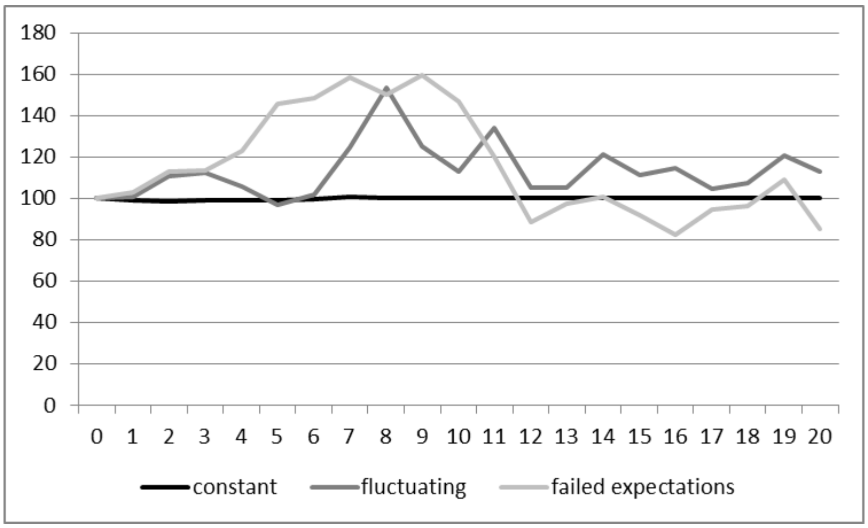


Figure 10: Index of milk price developments used for the experiments (Period 0 = 100)

Participants for our experiments were students recruited from three German universities in 2014 and 2015. A total of 49 students participated. Participants studied agriculture and related subjects (80%) either at Humboldt University Berlin (20%), Martin Luther University Halle-Wittenberg (53%), or Georg August University of Göttingen (27%). Participants were on average 25.1 years old (SD = 3.45), 35% were female, 63% already had a Bachelor's degree, and 63% had some practical experience in agriculture.

Participants were randomly assigned to scenarios and each participant had to play up to three different scenarios (drawing from an urn without replacement). In total, data sets of 144 experiments are available for the analysis. Every scenario was also simulated by replacing the respective participant by a computer agent which managed the farm through the standard optimisation routines of AgriPoliS with identical initialisation. These runs provided benchmarks for comparisons with the respective participant's behaviour.

Before the experiments, the participants were introduced to FarmAgriPoliS and were asked to maximise the final equity capital of the farm over the period of twenty rounds (years) in every experiment. They were also informed 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 capital relative to the computer benchmark; the equity bonus was limited to a maximum of 30 euros per experiment. In those scenarios in which the respective computer agent went bankrupt in terms of negative equity capital after 20 periods, the reference for payment calculation was replaced by a simulation run with an informed human participant investing just enough effort to ensure positive equity capital. Apart from the calculation of payments, the computer agent served as the benchmark for the subsequent analysis in all scenarios. Detailed instruction in 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 assisted them with the software, throughout the experiment.

5.5 Data collection

During the experimental session various data was collected. We logged the decisions of the participants and various indicators for the participants' farm as well as of all other computer farms, such as farm investments, land rentals, farm sizes, financial results, rents paid etc. As we have these data for every farm, we can reconstruct each single simulation run in detail and aggregate the farms' data to observe regional patterns as well.

In addition, a post-experimental questionnaire was used to collect data on the personal background (age, gender, educational level, etc.) and perceptions of the experiment. The participants were asked to answer without reference to their decisions in the experiments. Two item batteries based on validated psychological scales were used to identify decision-making styles

(GDSM; cf. Scott and Bruce, 1995; Mann et al., 1997) and to distinguish satisficing and maximising behaviour (cf. Schwartz et al., 2002). Scott and Bruce (1995) defined decision-making styles as learned, habitual behaviour patterns applied in decision-making situations. They developed a questionnaire measuring rationality (information collection and careful consideration of alternatives), intuitiveness, dependence (relying on other people), avoidance, and spontaneity in decision-making. The General Decision Making Scale (GDSM) is measured on a five-point-scale. A modified version of the Maximisation Scale by Schwartz et al. (2002) was used for measuring the maximisation tendency. The German translation of the items was taken from Greifeneder and Betsch (2006). Although the maximisation tendency is usually measured on a nine-point scale, we opted for a five-point scale to improve the fit to GDMS. Data on risk attitudes was gathered by self-assessment from participants and an incentivised Holt and Laury lottery (HLL; Holt and Laury, 2002). We applied an eleven-point scale for self-assessment with questions worded from the socioeconomic panel (see Ewald et al. 2012, referring to DIW 2010, p. 27).

5.6 Analysis

5.6.1 Descriptive

A descriptive analysis is used to systematically analyse the differences in the behaviour and performance between the participants and agents. In this regard, performance refers to financial indicators, as the participants were incentivised to maximise the farm's equity capital at the final period. As financial indicators we use liquidity, revenue, profit and equity capital, where

- Liquidity is the amount of money that is readily available for a farm for investments, production, savings and consumptions.
- Revenue is the farm's monetary returns from farm production.

- Profit is the money that a farm earns above the costs to produce the goods. A farmers' profit is calculated as:
Profit = Revenue – production costs + Interest on working capital + Subsidies – Rental payments – Interest paid – Wages paid – Current upkeep of machinery and equipment – Depreciation – Farming overheads – Transportation costs

- Equity capital is the difference between the value of the farm's assets and currents on the positive side and its liabilities on the negative side.

5.6.2 Regression

To analyse the determinants of the participants' performances in the experiment, we conducted OLS regressions where the relative difference in equity capital from the computer benchmark (Eq. 1) was used as the dependent variable. This accounts for different initialisations as well as the performance of the respective computer agents, which serves as benchmark.

$$Equity_{relative} = \frac{(Equity_{Participant} - Equity_{Benchmark})}{Equity_{Period=0}} \tag{1}$$

The analysis was based on equity in the final round of all scenarios. For the regressions, we accounted for the panel data structure by clustering standard errors for participants. We used two dummy variables for farm type and two dummy variables for price movement to control for the two factors we manipulated in the scenarios. We included the time a participant played on average per scenario and period (duration) to assess the potential effect that some participants may have been more careful in their decisions than others and whether it was the first, second or third experiment played by the participant during the session (order) (Table 18, Model 1). Further demographic variables were included such as gender and age (Table 18, Model 2) and the participants' general decision behaviour, represented by a psychological decision-making-style scale (GDMS; Scott and Bruce (1995)), a maximisation tendency scale (Schwartz et al., 2002), and risk attitude (HLL;

Holt and Laury (2002)) (Table 18, Model 3).

Table 18: Regression of participant performance at the end of the experiment (difference in equity capital compared to benchmark relative to initial equity)

	Model 1		Model 2		Model 3	
	Coef.	Robust Std. err.	Coef.	Robust Std. err.	Coef.	Robust Std. err.
Farm 2 (large)	**1.482****	0.545	**1.662****	0.531	**1.758***	0.653
Farm 3 (medium)	**1.365****	0.496	**1.481****	0.485	**2.148*****	0.547
Price 2 (fluctuating)	**0.7313***	0.335	**1.115****	0.346	**1.375****	0.401
Price 3 (failed expectations)	**3.397*****	0.547	**3.445*****	0.536	**3.445*****	0.661
Duration	0.035	0.139	-0.049	0.149	0.145	0.175
Order	-0.249	0.240	-0.289	0.239	-0.264	0.382
Female			-0.404	0.543	0.137	0.882
Age			**0.221***	0.083	**0.226***	0.096
Knowledge in farm management $^{a)}$					**0.728***	0.331
HLL (safe choices)					0.262	0.134
Risk (self-assessment)$^{b)}$					-0.101	0.171
Maximizing $^{c)}$					-0.66	0.451
Rational $^{d)}$					-0.02	0.887
Intuitive $^{d)}$					-0.251	0.567
Dependent $^{d)}$					0.094	0.319
Avoidant $^{d)}$					0.111	0.279
Spontaneous $^{d)}$					-0.05	0.355
Const.	-1.785	1.001	**-7.436****	2.368	-4.213	6.158
R^2	0.291		0.3471		0.4454	
F	10.22		9.4		4.51	
Number of obs.	144		144		105	

Note: significance level: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$
a) I have sound knowledge of agricultural management. - 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree
b) 0 = highly risk-tolerant, ..., 10 = completely risk-averse
c) 1 = strong satisficing behaviour, ..., 5 = strong maximizing behaviour
d) 1= very low expression of the resp. characteristic, ..., 5 = very high expression of the resp. characteristic
standard errors adjusted for 49 clusters

5.6.3 Trajectory Clustering

After comparing participants with computer agents, a cluster analysis was used to analyse and systematise the differences between the participants.

To this end, we used a Stata plugin developed by Jones and Nagin (2013) to calculate group-based trajectories, whereas the trajectories measure the course of the relative equity compared to the corresponding benchmark farm (Eq. 1) over time. Group-based trajectory modelling (Nagin, 2005) is a specialized form of finite mixture modelling and provides the opportunity to identify distinctive clusters of individuals following similar developmental trajectories within a population. The model parameters are estimated by using maximum likelihood, whereas a general quasi-Newton procedure is used to locate the parameters that maximise the likelihood function.

Subsequently, a one-way analysis-of-variance (ANOVA) with Stata was applied to test for significance in the differences observed between the clusters resulting from the group-based trajectory modelling. The resulting pairwise comparison between the cluster groups was adjusted for multiple comparisons using the Bonferroni method.

5.7 Results

5.7.1 Descriptive analysis

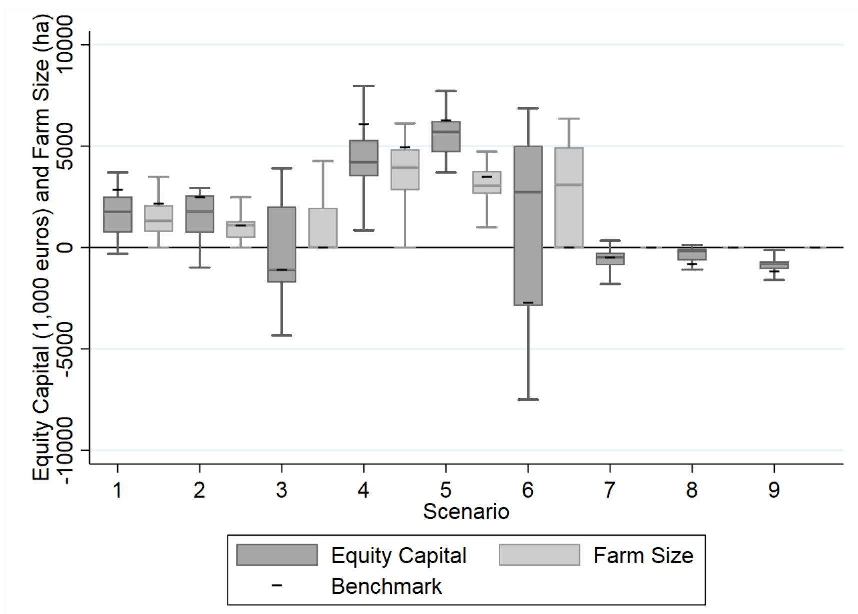
Based on a descriptive analysis, we examined how the participants performed compared to the computer agents which served as benchmarks. This analysis focused on systematic differences in the behaviour and performance between the participants and agents. In this regard, performance refers to financial outcome, as the participants were incentivised to maximise the farm's equity capital in the final period.

The first surprising result was that the participants were not more successful than the computer agents in total. In 52% of the experiments analysed, the participants reached an equity capital level below the benchmark at the end of every experiment.

The scenarios were designed in such a way that some of them provided promising growth opportunities (scenarios one, two, four and five) while others created more competitive pressure (scenarios three, six, seven, eight and nine). In these more challenging scenarios the benchmark farms (computer agent) went bankrupt and ended with negative equity capital. Prospect theory by Kahnemann and Tversky (1979) indicates that the participants would be more engaged in avoiding losses than in realising gains compared to the computer agents. Fig. 11 shows that the participants were more successful on average in scenarios where the benchmark farm went bankrupt. Table B.2 gives an overview of the statistical significance of these results. On the other hand, participants showed a lower performance on average in cases where the computerised agents were profitable. In principle, this finding could be seen as the result of a selection bias – that is, that the computer agents may have been more or less successful by chance in certain scenarios. However, those scenarios in which the computer agents were more successful are consistently scenarios with stable or positive market environments as well as scenarios in which the selected farms had a comparative cost advantage. On the other hand, the human protagonists were more successful on average in those scenarios characterised by price pressure and comparative disadvantage in the farm, so the differences can be considered as systematic.

In scenarios where the agents were more successful in financial terms, computer agents tended to pursue a stronger growth strategy and therefore operate in the end on larger farms than the participants (see Fig. 11 and Table B.2). There were also significant differences between computer agents and participants regarding their behaviour on the land market. Participants in general tended to rent more land, especially in the more challenging scenarios where the respective farms faced volatile returns and comparative disadvantages resulting from high costs (scenarios three, six, seven, eight and nine; see Table B.2).

The third key figure analysed was the difference in the value of production. Overall, participants tended to invest and produce less as reflected in the lower revenue in Table B.2. This is interrelated: Funds used for a more



Note: Negative equity capital indicates bankrupt farms

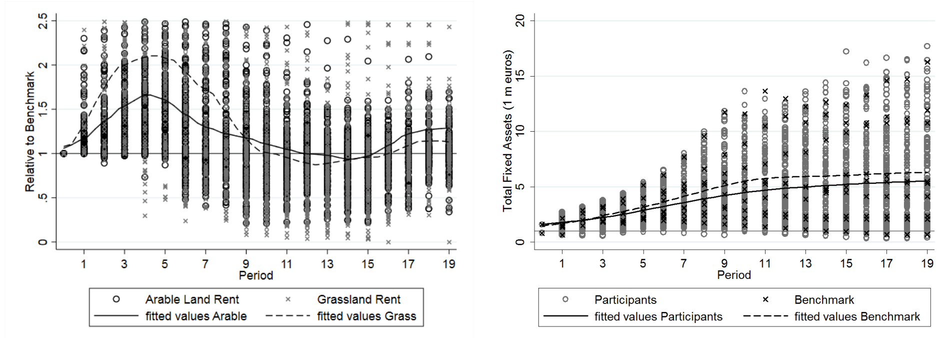
Figure 11: Boxplot of equity capital and farm size at the end of the experiment

intensive growth strategy regarding the farm's land bank detract from funds available for investment in production facilities such as stables, equipment and biogas plants. The remaining participants in agriculture only produced more in those scenarios where the benchmark farms quit.

The participants were informed about the expected marginal gain in profit respectively gross margins in every decision-making situation for rentals and investments. In addition, they were informed which decision the computer agent would make. According to the experiments, the participants deliberately differed from these suggestions. This often led to higher bids on the land market (and therefore higher rental prices, see Fig. 12 a) and lower investments in other assets (see Fig. 12 b). The participants rented land at prices which were clearly above the benchmark, especially in the first rounds. The differences gradually diminished over the course of each experiment. On the one hand, this finding can be attributed to the scenario setting – in some scenarios, the difficulty was designed such a way that both the computer agent and the participants were under permanent financial pressure. On the other hand, the level of the rents paid approached the increasing economic land rent over time, reducing the scope of action for bids by the computer agents and the participants (see Fig. 13 and Table B.3).

5.7.2 Regression analysis

According to the regressions presented in Table 18, participants were more successful than the computer agents in those experiments that seemed to be more challenging (scenarios three, six, seven, eight and nine; see Fig. 11). For these scenarios it was considered that the farms to be played suffered from relatively high variable costs (Farm 3) and that prices were uncertain. This finding was particularly strong when price development was not only uncertain, but also showed a declining trend after an initial rise (Price 3). Regarding the characteristics of the participants, we found in our regression



(a) Rental prices for arable land and grassland (relative to benchmark)

(b) Investments in fixed assets

Figure 12: Evolution of land rental prices and investments

Note: Fitted values: Kernel-weighted local polynomial smoothing; in addition to the fitted line, the graphs provide the corresponding single observation to give an impression on the distribution

that only the age of the participants and their knowledge of agricultural management (self-assessment) had a significantly positive impact on the performance.

5.7.3 Cluster analysis of participant performance

According to group-based trajectory clustering, the participants can be divided into four clusters. Fig. 14 shows the courses of the related estimated trajectories and Table B.4 shows the distribution of clusters by scenarios. An overview of the cluster characteristics is given in Table 19 (for summary statistics see Table B.5). The detailed results are presented in Table B.6 in the appendix.

In summary, the four clusters were as follows:

- Cluster 1 – "The negligent gamblers" The participants with the strongest ambitions (strongest maximising tendency) are in Cluster 1. Approximately 7% of the participants belonged to this group. Their decision-making style was intuitive and spontaneous. Additionally, they were

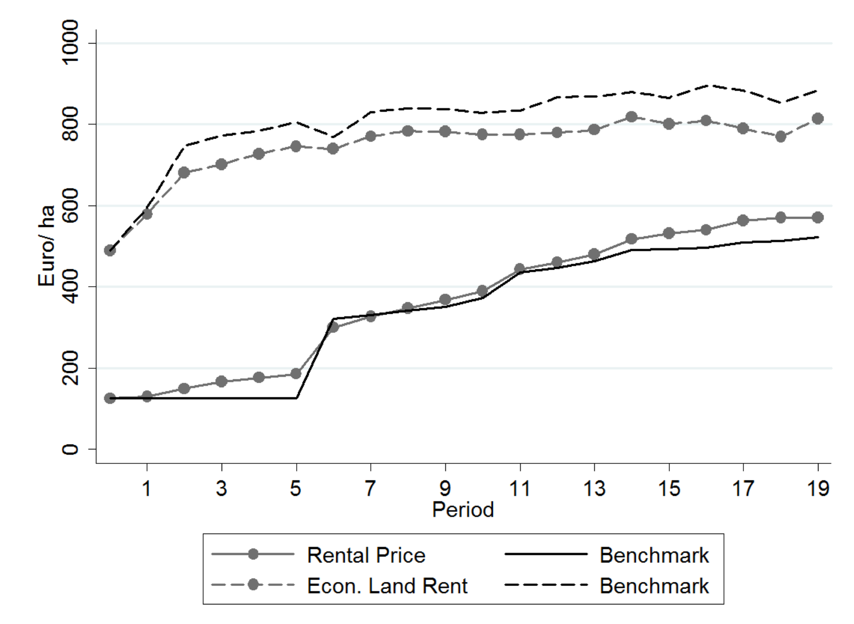


Figure 13: Average development of rental prices and economic land rent in scenario one for participants and computer agents (Benchmark)

Note: Economic land rent is an imputed variable and measures the economic value of using the production factor "land" which is comparable to the Ricardian (Ricardo, 1817) or von Thünen (1826) land rent. Rental price is the average rental price paid to the land owner.

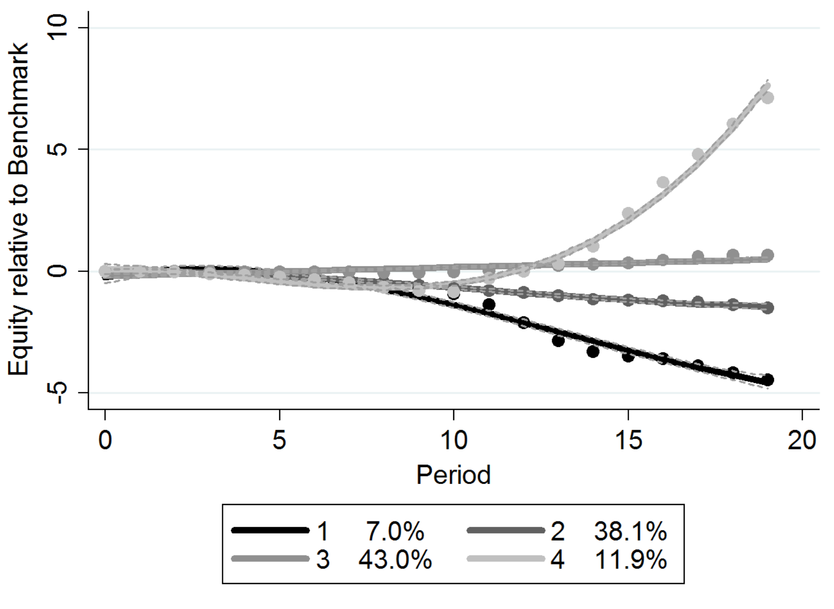


Figure 14: Calculated trajectories based on the equity capital relative to the benchmark

the youngest participants and assessed themselves as having the lowest level of knowledge of agricultural management. These members may therefore be considered as less-experienced participants. Although they had relatively good starting conditions regarding farm size and level of variable costs (represented by the production cost factor), this cluster exhibited the most unfavourable development in relative equity compared to the benchmark results achieved by the respective computer agents: After a promising start, the participants often ended up with huge losses on average. The participants faced high price volatility in eight out of the ten experiments belonging to this cluster. Accordingly, the poor performance may be explained by a deficit in coping with uncertainty amongst the participants.

- Cluster 2 – "Missed opportunities"
  The starting conditions for the farms of Cluster 2 were also quite good. The farms in this cluster were initially rather large, their production cost factor was at an average level (that is, close to one), and the participants mainly experienced fairly stable price development. While the respective computerised benchmark farms were quite successful and faced little economic pressure on average, the participants performed less successfully in these experiments. The participants were evidently unable to exploit the opportunities offered. Some 38% of all participants fell into this category. The participants may be described as rather risk neutral and acting intuitively according to the post experimental survey. Interestingly, this group showed the highest share of female participants.

- Cluster 3 – "The solid farm managers"
  Cluster 3 mainly included experiments with rather challenging scenarios, where the farms were on the small side and their production costs relatively high (see Table B.6).The respective benchmark farms exited farming or suffered bankruptcy in many of the scenarios shown. The

participants were quite successful compared to the benchmark farms. Around 43% of the participants belonged to this group, which included participants who deliberately decided to quit (8% of the participants in Cluster 3) and successfully prevented or minimised losses as a result (see Table B.7). The participants in Cluster 3 were slightly more risk averse in the Holt and Laury Lottery (higher number of safe choices) and according to their own self-assessment. They also had the lowest maximising tendency and therefore could be described as risk-averse satisficers.

- Cluster 4 – "The successful path-breakers"
  The participants with the most positive relative equity development were located in Cluster 4. They started with a relatively high initial farm size but were constantly confronted with challenging price developments (fluctuating, partly declining). These participants performed very well compared to their benchmark farms, as well as in absolute terms. As Table 19 shows, these participants developed large and financially well-equipped farms. Approximately 12% of the participants fell into this successful group. In contrast to the other clusters, the participants acted less intuitively and more rationally; they showed a higher maximisation tendency than Cluster 2 and Cluster 3. In addition, this cluster contained the oldest and possibly the most experienced participants. They also categorised themselves with the highest level of knowledge of agricultural management compared to other clusters. The participants? strategies in this group enabled them to leave the predetermined development paths and to open up new possibilities for successful farm management. These participants may be considered as more entrepreneurial, path breaking farmers.

Table 19: Cluster characteristics

Variable	Cluster 1 Mean	Cluster 1 Std. dev.	Cluster 2 Mean	Cluster 2 Std. dev.	Cluster 3 Mean	Cluster 3 Std. dev.	Cluster 4 Mean	Cluster 4 Std. dev.
Initial farm size (ha)	991	420.86	1,020.64	407.91	758.52	261.92	1,288.24	356.35
Initial equity capital (1,000 Euro)	813.02	150.04	815.46	153.11	705.78	103.88	920.56	127.75
Production cost factor [a)]	0.94	0.05	0.99	0.09	1.05	1.11	0.98	0.04
Av. equity capital (1,000 Euro)	439.79	1,824.05	1,377.92	1,350.30	1,149.34	1,179.39	2,723.19	1,394.98
Final equity capital (1,000 Euro)	-2,584.32	2,509.41	1,040.44	2,726.24	937.13	2,357.27	4,297.49	1,491.21
av. profit p.a. (1,000 Euro)	100.59	777.14	375.93	586.17	290.44	587.52	934.3	758.97
Final profit (1,000 Euro)	-460.86	279.45	135.57	718.19	134.89	889.23	696.71	449.55
Av. Size (ha)	1,014.90	975.2	1,218.36	1,147.19	911.27	852.56	2,272.79	1,356.47
Final size (ha)	0	0	1,300.27	1,519.69	934.58	1,525.67	4,177.35	1,429.82
Av. Revenue (1,000 Euro)	3,082.56	1,939.46	3,555.01	2,723.13	2,711.58	2,712.36	6,571.81	4,025.20
Gender (1=female)	0.4	0.49	0.44	0.5	0.26	0.44	0.24	0.42
Age	24	2.1	25.49	2.89	26.24	3.46	27.65	3.78
Knowledge in farm management[b)]	2.88	1.17	2.86	0.95	2.86	1.13	2.08	0.64
HLL (safe choices)	5.5	1.5	4.95	2.52	5.75	1.9	5.76	2.29
Risk (self-assessment)[c)]	4.7	1.42	4.55	1.99	5.16	1.83	4.35	1.57
Maximising[d)]	3.35	0.55	3.03	0.58	2.97	0.39	3.23	0.35
Rational[e)]	3.78	0.54	3.85	0.57	4	0.47	4.01	0.3
Intuitive[e)]	3.46	0.79	3.56	0.7	3.14	0.71	3.04	0.78
Dependent[e)]	2.96	0.79	3.09	0.8	3.2	0.8	3.33	0.64
Avoidant[e)]	2.44	0.94	2.62	1.1	2.68	0.85	2.92	0.96
Spontaneous[e)]	2.98	0.77	2.93	0.84	2.81	0.87	2.88	0.66
Number of farms	10		55		61		17	

Note: a) factor multiplied by variable costs of the farm for each production activity
b) I have sound knowledge of agricultural management. - 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree
c) 0 = highly risk tolerant, ..., 10 = completely risk averse
d) 1 = strong satisficing behavior, ..., 5 = strong maximizing behavior
e) 1= very low expression of the resp. characteristic, ..., 5 = very high expression of the resp. characteristic

5.8 Discussion

The results of Sections 5.7.1 and 5.7.2 support hypotheses 1, 2 and 3 as defined in Section 5.2.2. The participants deviated systematically in their strategies although on average, they were not more successful than the computerised benchmark farms. Key findings of the statistical analysis are:

- The participants focused more on growth through renting additional land than on investing in assets. As a result of this bias, they generated less added value on average.

- The participants performed more successfully than the computer agent in scenarios that were more challenging, that is, where farms encountered higher production costs than other farms and uncertain or even declining prices.

- Older and more educated participants tended to be more successful than the computer agent and other participants.

On average, the participants were not more successful than the optimising agents. However, the clustering confirmed the finding that the participants differed from the optimising benchmark farms in response to economic pressure and regarding certain individual characteristics such as age and knowledge in farm management. The clustering in Section 5.7.3 therefore further supports hypotheses of Section 5.2.2:

- In accordance with Hypothesis 3, the participants differed not only in behavioural patterns; there were evidently also clusters of behavioural patterns among the participants.

- In accordance with Hypothesis 4, the participants exhibited path breaking or path creating behaviour in some experiments by successfully developing and managing very ambitious growth strategies. Interestingly, this occurred most often in scenarios with mediocre or challenging starting conditions.

- In accordance with Hypothesis 5, the participants revealed more resilient behaviour than the computer agents in some 50% of the experiments. This especially occurred in more difficult situations through different types of strategy: successful survival in case of a crisis, successful exits, and successful growth.

The difference in behaviour and performance (i) between human participants and myopic optimising agents, and (ii) between different participants in participatory agent-based experiments on managing farms in a competitive environment can be further systematised: In contrast to optimising computer agents, the participants were on average more effective in avoiding losses but less successful in generating high profits and equity which is in accordance with prospect theory (Kahnemann and Tversky, 1979). The different strategies of computer agents and participants are also reflected in the investment and growth strategies revealed: Overall, participants tended to invest and produce less, but generally tended to rent more land and at higher prices, especially in the more challenging scenarios with volatile returns.

We also analysed the conditions in which participants were more successful than computer agents. As participants were more adept at avoiding losses, they should have been more successful in more challenging conditions, like those which exist for farms with comparative disadvantages and uncertain, partly declining price developments. Under these conditions, the participants performed substantially better than the computer agents. Alternatively, this result may be interpreted as rational but myopic profit-maximising computer agents struggling with uncertainty and pressure. That is, this phenomenon may hint towards a weakness of the computer agents in AgriPoliS and FarmAgriPoliS rather than towards a strength of the participants. The current decision algorithms in FarmAgriPoliS and AgriPoliS may be poor in coping with specific strategic issues. For instance, myopic optimisation may cause investments and land rentals in unfavourable situations, as may be the case if returns are deteriorating due to falling prices or increasing competitive pressure.

At the same time, the performance of the participants substantially differed. A cluster analysis revealed heterogeneity in behaviour amongst the participants. We identified four distinct experimental outcome clusters. Three clusters that included some 88% of the experiments corresponded with the prospect theory - that is, the participants were more successful at avoiding losses than at exploiting opportunities. However, approximately 12% of the participants succeeded in leaving predetermined development paths. In these experiments, the participants managed strong growth and performed substantially more successfully than computer agents and other participants. Interestingly, these participants faced relatively difficult scenarios with challenging price developments (fluctuating or even declining) and average cost structures. These very successful path breakers do not fit into prospect theory and characterise rather entrepreneurial actors. Both groups - loss avoiders according to prospect theory, and path breakers ? relate to different interpretations of resilience. The "solid farm managers" in particular represent the ability to withstand disturbances and the capacity to maintain function and state (Folke (2006), Holling (1973)) whereas the "successful path breakers" represent the ability to adapt successfully to new opportunities resulting from environmental changes (Walker and Salt, 2012).

Within the "solid farm managers" group, we further identified farmers that managed successful farm exits by developing an exit plan. However, this behaviour and its relative success also suggests considering resilience in agricultural structural change as not just preventing exits, but also in considering planned exits as entrepreneurial decisions in an adaptive and specific response to environmental and situational conditions and shocks.

Planned exits may be motivated by minimising losses from devaluation and deterioration in fixed assets, human capital, or the well-being of the people involved. More than half of the conscious farm exits in the experiments were successful exits in this regard. Taking these farm exits into account, some 55% of the participants' responses in the experiments belong to the clusters including the "solid farm managers" and "successful path-breakers". That is, a considerable number of participants revealed more resilient behaviour than computer agents.

At this point, it seems appropriate to cite Kahnemann and Tversky (1979) once more: "... we feel that the present analysis falls far too short of a fully adequate account of these complex phenomena" (p. 286). A future challenge will be to use these findings to make behavioural assumptions more realistic in models such as AgriPoliS. Moreover, the experiments revealed that the age of the participants and their (self-assessed) knowledge of agricultural management had a strong positive impact on a participant's performance, a finding that warrants repeating the experiments with well-educated and experienced farmers. Such experiments may reveal further weaknesses in the decision algorithms in AgriPoliS and FarmAgriPoliS regarding strategic decisions.

5.9 Conclusions

Considering the complexity of structural change in agriculture, the first lesson to be learnt from our analysis is that not just models of structural change should be able to reproduce key phenomena of the complex reality but also that the cognitive capacities of actors within the models should be able to cope in their decisions with complexity. However, our experiments indicate that not all actors will have similar cognitive capacities. Thus, the heterogeneity of farms and their performance may not just be attributed to starting conditions and more or less lucky conditions but also to the farmer themself. Most likely this applies to reality as well as to complex decisions within models.

A second lesson to be learnt relates to the understanding of resilience. It is not sufficient to consider resilient agricultural systems as merely having robust farms. As resilience concepts argue that resilience can also be based on the agents' and system's ability to adapt, it seems to be important to consider the adaptiveness and transformability of farms as indicators of resilient structures. This becomes even more relevant if the ability of an agricultural system to fulfil its societal functions is the main concern of, e.g., policy makers. Under such conditions, policies are misleading if they do not value the potential societal benefits of change. Concerning societal functions such as production of food and other agricultural products and the generation of farm income, key policy questions must balance whether farmers who do not have promising prospects are provided with adequate tools and incentives to recognise their options with farmers who have prospects are potentially able to recognise and eventually exploit promising strategies. This is at least true in the absence of negative externalities.

Funding

This work was supported by the German Research Foundation (DFG) and by the European Union's Horizon 2020 programme: The research was conducted within the Subproject 5 of the DFG research unit "Structural change in Agriculture (SiAg - FOR 986/2)", within the Subproject 6 of the DFG research unit "Agricultural Land Markets – Efficiency and Regulation (FOR Land - FOR 2569)" and within the H2020 project "Towards SUstainable and REsilient EU FARMing systems (SURE-Farm - No 727520)".

Acknowledgment

The authors would like to thank two anonymous reviewers and George van Voorn for their valuable comments and suggestions to improve the quality

of the paper.

6 Predator or prey? - Effects of Path-breaking on the local environment

6.1 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.

6.2 Introduction

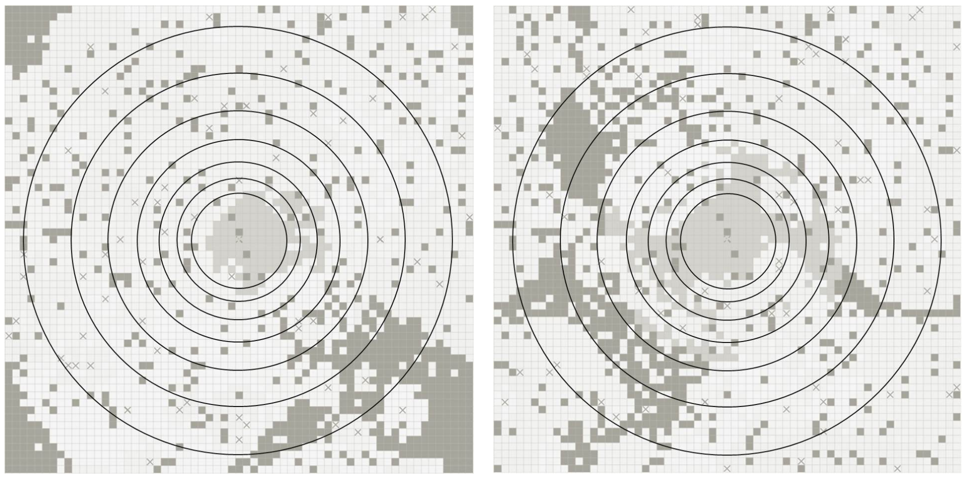
Cluster analyses of existing experiments (in total 143 based on 49 persons and 9 different scenarios with different output prices, initial farm sizes and production cost levels; see Section 5, p. 82 ff.) revealed a substantial heterogeneity in the behavior and success amongst the participants. We identified 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" (cf. Section 5.7.3, p. 106). The first three clusters that included some 88% of the experiments corresponded with prospect theory (cf. Kahnemann and Tversky (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 characterize 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 depend on the distance and therefore on the spatial distribution of farms?

6.3 Background

In FarmAgriPoliS, additionally to the data of the participants' farm, the data for all other farms in the model region are logged as well. The initialization of a region in AgriPoliS is randomized, which means that the individual farms are randomly located in the respective model region. Further, the farms are also randomly assigned with properties such as the operating age (decisive regarding generation change) and the production cost factor. According to the type of farm, a certain amount of owned and rented land is assigned to each farm. In the case of rented land, the duration of the rental contracts is also randomly assigned.

For the experiments and in order to minimize the effects caused by the random assignment of certain properties, the same regional initialization is



(a) Scenarios 1 to 3 and 7 to 9 (b) Scenarios 4 to 6

Note: Participants farm in the center, marked with X; circles indicating the logarithmic distance to the participants farm

Figure 15: Initialization of model region

used for several scenarios. The random numbers differ only between the scenario groups with different farm sizes for the participants. Thus, scenarios 1 to 3 and 7 to 9 have a participants' farm with initially 665 ha and thus also an identical initialization. In scenarios 4 to 6, the participants take over a larger farm with initially 1,480 ha. Scenarios 4 to 6 thus also have the same regional initialization (see Figure 6.3). And thus the regional environment within these two scenarios groups are identical, which facilitates the analysis of impacts of individual behavior on neighboring farms.

Regarding the land market, all farms in the model region compete for available land (i.e. land that is currently not rented by a farm) via a repeated auction. Within the auction, every farm first selects the available plot that is most valuable to 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 in the respective period/year.

6.4 Hypothesis

As land is locally a scarce resource and not mobile, 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 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 farm in the region has a negative impact on the neighboring farms.

This negative effect can be shown, in particular, by 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 farms' performance is lower. This leads to Hypothesis 2:

- Neighboring farms benefit from a poorly performing farm.

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 farm the more it can benefit.

6.5 Results

6.5.1 Structural change/Regional results

Farms and Farm Sizes To get a first impression about 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 20 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%.

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 number of farms and the farm sizes in other Clusters remain fairly close to the benchmark - especially in Cluster 1. In these scenarios, participants quickly

Table 20: Number of farms and farm sizes of all farms in the region (including participant) depending on Cluster - all scenarios

		Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Period	Indicator	absolut	relative to Benchmark (%)	absolut	relative to Benchmark (%)	absolut	relative to Benchmark (%)	absolut	relative to Benchmark (%)
0	Number of Farms	63.00	100.00	63.00	100.00	63.00	100.00	63.00	100.00
	av. Farm size (ha)	257.38	100.00	257.38	100.00	257.38	100.00	257.38	100.00
9	Number of Farms	53.70	99.44	53.62	100.44	52.72	100.06	56.18	100.21
	av. Farm size (ha)	301.96	100.56	302.42	99.56	307.56	99.94	288.64	99.79
19	Number of Farms	20.30	99.51	25.84	102.16	19.28*	96.90	16.65***	124.67
	av. Farm size (ha)	798.77	100.49	627.60	97.89	840.88	103.20	974.05***	80.21

Note: significance level: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

exit farming and thus lose their impact on regional development. For Clusters 2 and 3, the deviation from the benchmark is less than five percent. In Cluster 3 there are slightly less, but larger farms, while in Cluster 2 it is the other way around. Anyway, only in Cluster 3 the number of farms at the end of the experiment is slightly significant.

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 look at the financial situation, e.g., the development of farm incomes, 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.

At the beginning of the simulation, the aggregated regional income of all other farms (excluding the farm managed by the participant) increases partly distinctly compared to the benchmark (see Figure 17). Particularly, Cluster 1 and Cluster 4 have a positive effect. The participants of these Clusters have the strongest ambitions (strongest maximizing tendency) and are very successful in the beginning. However, these participants finally end up with huge losses (detailed description under section 5.7.3, p. 106). This initial positive effect diminishes over time. In case of Cluster 1, the aggregated farm household income increases again and, in the end, is well above the level of the benchmark. In Cluster 4, the aggregated farm household income becomes increasingly lower than in the benchmark. The development in Clusters 2 and 3 are almost identical to the benchmark situation.

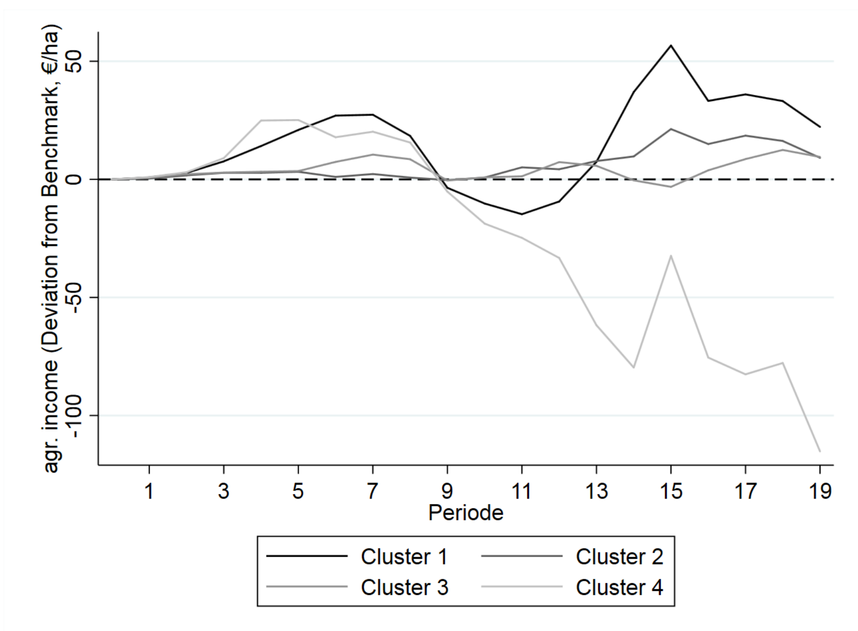


Figure 16: Development of aggregated farm household income in the region relative to the Benchmark without participant

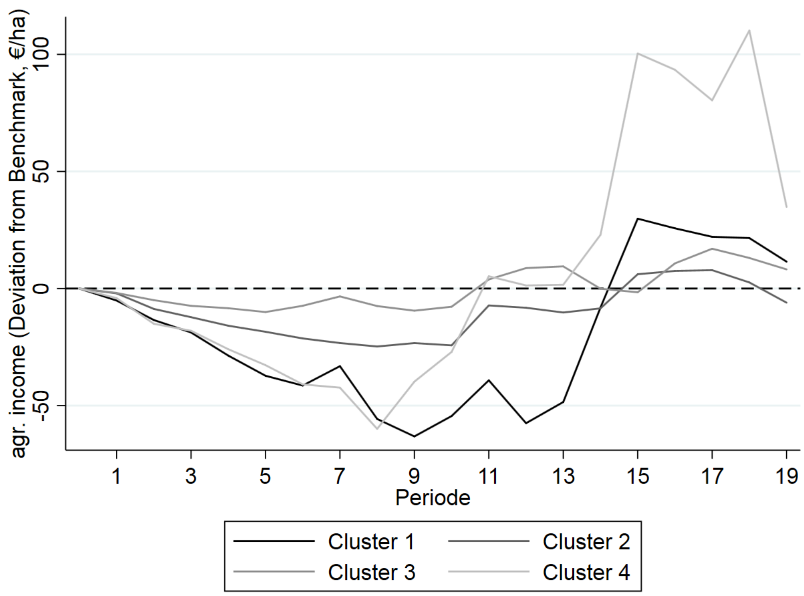


Figure 17: Development of aggregated farm household income in the region relative to the Benchmark (including participant)

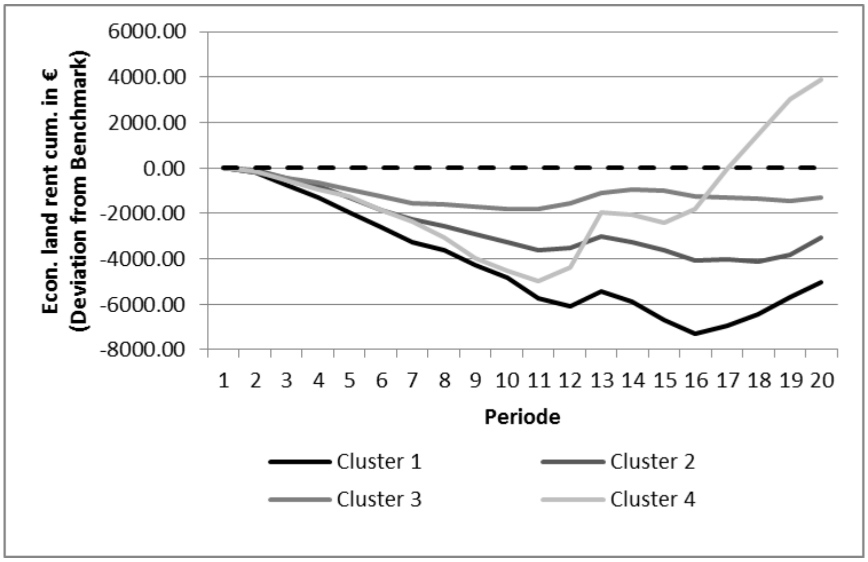


Figure 18: Development of cumulated economic land rents in the region (Deviation from Benchmark; including participant)

But this only holds as long as the participant's farm is excluded from the aggregated regional income. If the participants are included (see Figure 16), the aggregated regional income starts below the benchmark level in all Clusters. Cluster 4 has in the longer run a clear positive effect, Cluster 1 a smaller positive effect and Cluster 2 and 3 almost no effect. Which means that the Cluster participants themselves account for a major share of regional farm incomes (including negative incomes in Cluster 1).

To estimate the effects on the regional added value, we cumulate the aggregated economic land rents of all farms in the region (Figure 18). 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 their benchmarks in the beginning. While in all other clusters the cumulated economic land rents stay below the benchmark level, in Cluster 4 this relation turns and become positive in the end.

- 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 than the benchmark situation.

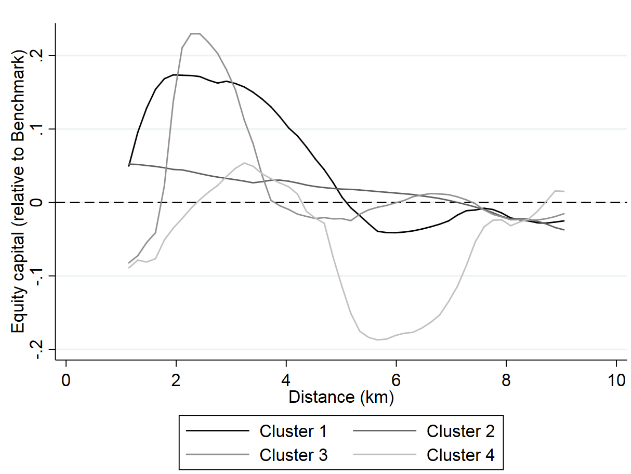
- In contradiction to Hypothesis 2, in Cluster 1 the other farms of the model region cannot benefit from the poorly performing participant. No significant effect on the regional level is detected regarding farm sizes and numbers of active farms. The cumulated economic land rents in that cluster show the most negative deviation from the benchmark situation. Therefore, we can assume that the region does not benefit from a poorly performing participant.

6.5.2 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.

Equity Capital To analyze the development of the farms' equity (see Figure 19), we use for every farm in the region the relative difference in equity capital from the respective farm in the benchmark situation (see Equation 1). This accounts for different initializations and scenarios.

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



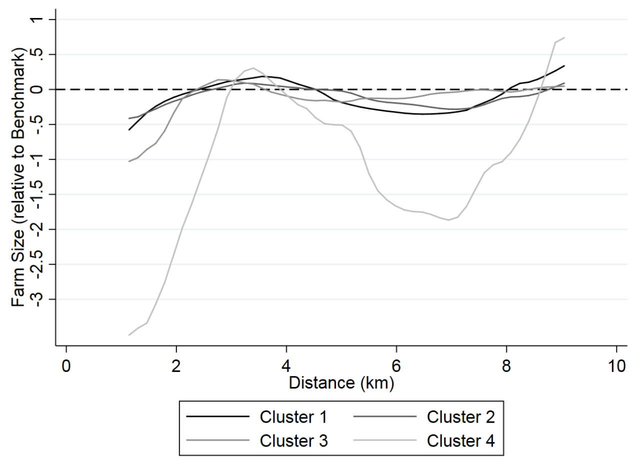
Note: Kernel-weighted local polynomial smoothing (Epanechnikov)

Figure 19: Spatial distribution of equity capital at the end of experiment (relative to the Benchmark; excluding the participant)

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.

Farm Size This wave-like shape can also be observed in the relative farm sizes (Figure 20). 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.

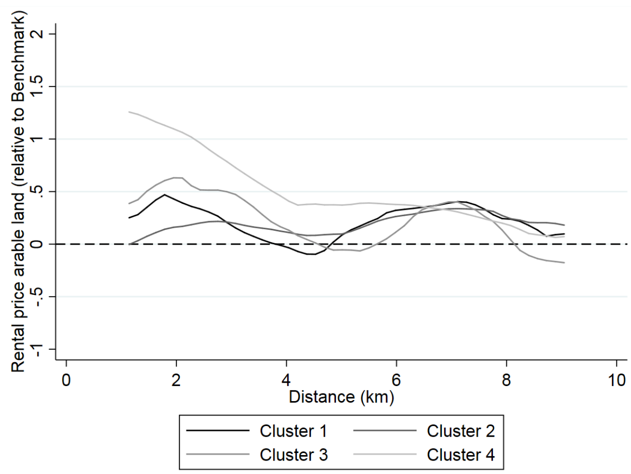


Note: Kernel-weighted local polynomial smoothing (Epanechnikov)

Figure 20: Spatial distribution of farm sizes at the end of experiment (relative to Benchmark; excluding the participant)

Rental prices 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 21 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 bids 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.

Reflections on functional form Since all considered variables of the spatial analysis show a similar wave-shaped pattern, this section provides a brief discussion of the functional form. Fourier coefficients are used to calculate the spatial distribution of the equity capital (see Figure 19). Since we are primarily interested in the influence of the distance, the Cluster effect is



Note: Kernel-weighted local polynomial smoothing (Epanechnikov)

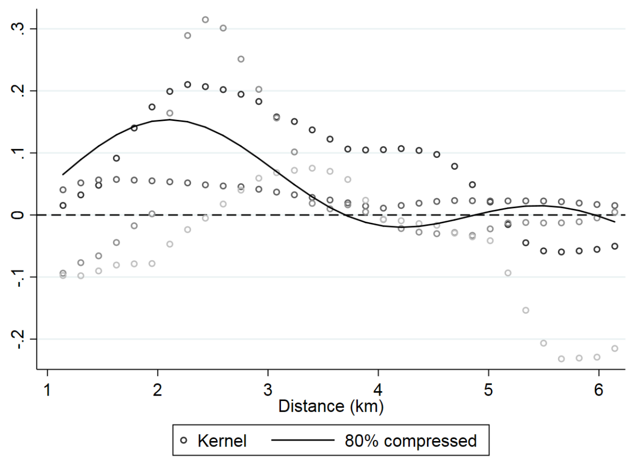
Figure 21: Spatial distribution of rental prices for arable land at the end of experiment (relative to Benchmark; excluding the participant)

ignored in this 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 22.

The resulting function can be expressed as Equation 2 with the coefficients given in Table 21.

$$\begin{aligned} x' &= \frac{2\Pi}{32} * x \\ y &= \sum_{j=-2}^{2} a_j * cos(j * x') + b_j * sin(j * x') \end{aligned} \tag{2}$$

As Figure 22 shows, the curves flatten with increasing distance. Thus it can be concluded that the participants' influence on other model farms in



Note: single circles: generated from Kernel-weighted local polynomial smoothing (Epanechnikov) of the four Clusters (cf. Figure 19)

Figure 22: Fourier transformation of spacial distribution of equity capital at the end of experiment (relative to Benchmark; excluding the participant)

Table 21: Fourier transformation - coefficients

j	a	b
-2	-0.0255	0.0110
-1	-0.0167	-0.0321
0	0.0279	
1	-0.0167	0.0321
2	-0.0255	-0.0110

the region decreases with increasing distance.

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

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

6.5.3 Structural equation modeling

Additionally to the graphical results of the previous sections, the influence of the different Clusters may 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; Kline (2011)).

In general, a graphic structure of the (assumed) relationships and influencing factors is set up first (see Figure 23) 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".

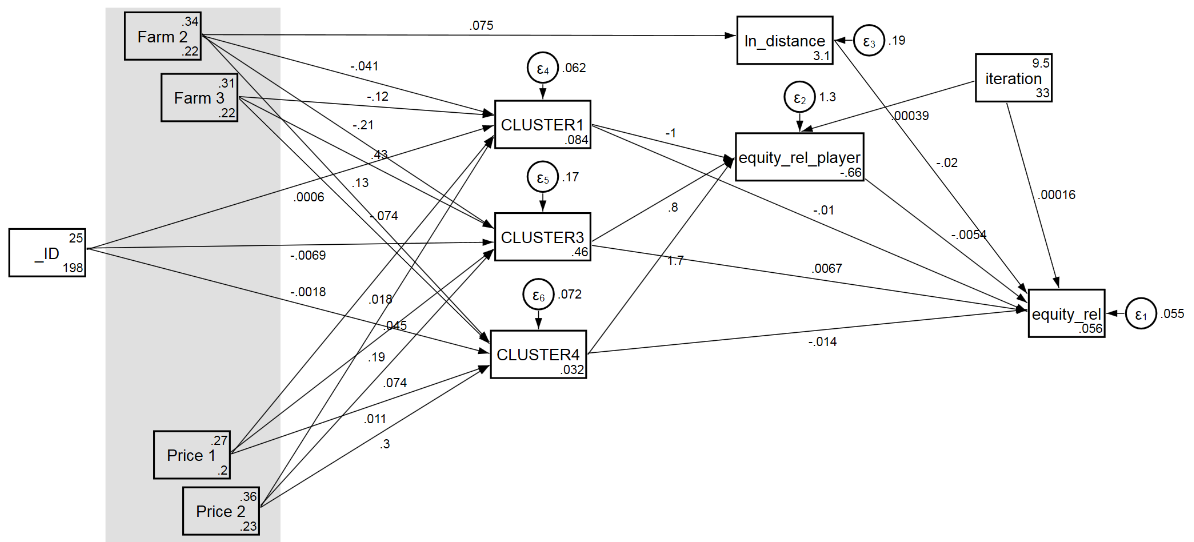


Figure 23: Structural equation model of the neighborhood effects on farms' equity capital (relative to Benchmark)

Note: Variables determined by the scenario are marked gray

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 the larger, the closer this farm is to the participants' farm (cf. Figure 22). This is also consistent with Gravity models (Tinbergen, 1962).

As Table 22 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 22).

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 21. The effect is, as already described, undulating. What positively influences the direct neighbor can be negative again for the 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 profitability and development opportunities. This, in turn, strengthens the neighbors' neighbors.

Table 22: SEM results for estimated measures

		Coef.	Robust Std. Err.
Equity capital[a)]			
	Equity capital participant[a)]	**-0.005*******	0.002
	ln Distance	**-0.020*******	0.003
	CLUSTER1	-0.010	0.008
	CLUSTER3	**0.007***	0.003
	CLUSTER4	**-0.014****	0.004
	Period	0.000	0.000
	Const.	**0.056*******	0.009
	var(e.Equity capital[a)])	0.055	0.007
Farm size[a)]			
	Equity capital participant[a)]	**-0.108*******	0.013
	ln Distance	**0.042****	0.014
	CLUSTER1	**-0.106****	0.032
	CLUSTER3	**0.062*******	0.016
	CLUSTER4	-0.011	0.026
	Period	**-0.010*******	0.001
	Const.	**-0.131****	0.042
	var(e.Farm size))	1.498	0.197
Rental price arable land[a)]			
	Equity capital participant[a)]	**0.052*******	0.008
	ln Distance	**-0.032***	0.014
	CLUSTER1	0.033	0.022
	CLUSTER3	0.031	0.019
	CLUSTER4	**-0.084****	0.028
	Period	**0.010*******	0.002
	Const.	0.041	0.044
	var(e.Rental price arable land[a)])	1.891	0.090
Rental price grassland[a)]			
	Equity capital participant[a)]	**0.112*******	0.023
	ln Distance	**-0.112***	0.051
	CLUSTER1	0.002	0.060
	CLUSTER3	-0.030	0.044
	CLUSTER4	-0.030	0.050
	Period	**0.009****	0.004
	Const.	**0.363***	0.155
	var(e.Rental price grassland[a)])	5.163	0.797

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

Table 23: SEM results for structure of the model

		Coef.	Robust Std. Err.
Equity capital participant$^{a)}$			
	CLUSTER1	**-0.997*** **	0.133
	CLUSTER3	**0.802*** **	0.045
	CLUSTER4	**1.712*** **	0.151
	Period	0.000	0.016
	Const.	**-0.660*** **	0.149
ln Distance			
	Betrieb 2	**-0.010*** **	0.000
	Const.	**3.164*** **	0.000
CLUSTER1			
	Farm 2	-0.041	0.063
	Farm 3	**-0.117** **	0.041
	ID participant	0.001	0.001
	Price 1	0.018	0.050
	Price 2	0.045	0.054
	Const.	0.084	0.047
CLUSTER3			
	Farm 2	**-0.213** **	0.081
	Farm 3	**0.432*** **	0.084
	ID participant	**-0.007* **	0.003
	Price 1	**0.189* **	0.087
	Price 2	0.074	0.094
	Const.	**0.456*** **	0.104
CLUSTER4			
	Farm 2	**0.131* **	0.062
	Farm 3	-0.074	0.044
	ID participant	-0.002	0.002
	Price 1	0.011	0.020
	Price 2	**0.299*** **	0.056
	Const.	0.032	0.053
	var(e.Equity capital participant$^{a)}$)	1.259	0.172
	var(e.ln Distance)	0.146	0.002
	var(e.CLUSTER1)	0.062	0.016
	var(e.CLUSTER3)	0.165	0.016
	var(e.CLUSTER4)	0.072	0.010

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

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 of other (neighboring) farms. Only Cluster 3 (the solid managers) has a positive effect.

In addition, Cluster 4 has a significantly negative impact on the level of rental prices for arable land. However, with the generally smaller farm sizes (see Section 6.5.1 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.

6.6 Conclusion

Our analysis confirmed the thesis that farms in a region and their development are not independent, 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 the 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, on 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".

7 Summary and Conclusions

From a methodological perspective, this thesis provides examples of how agent-based models can contribute to the analysis of structural change in agriculture. Appel et al. (2016) (Section 3, page 28 ff) asses the investment behavior of farms on the farm level as well as on the regional level, regarding biogas production; the effects of biogas production on structural change, regional cultivation patterns, the land market and on the overall performance of farms. AgriPoliS as a spatially explicit and dynamic agent-based model enables ex post and ex ante analyses of agricultural structural change, particularly regarding the impact of alternative policies and assumptions on agriculture by comparing actual policies with counterfactual assumptions. Policy impacts that can be analyzed include shares of different crops, profits of biogas and non-biogas farms, rental prices for arable and grazing land, as well as farm size developments.
In particular, Appel et al. (2016) find that biogas policies influence the development of individual farms as well as agricultural regions. Because different direct and indirect effects overlap, the impacts are of a complex nature. The complementarity of biogas and livestock production causes an additional intensification of land use and more investments in livestock production. Furthermore, the higher competition on the land market leads to increasing land prices. Those facts add up to changes in the agricultural structure of the analyzed regions. On average, biogas farms may not even benefiting from biogas subsidies because a significant share of the value added is transferred via increased rental prices to the land owners. In the end, every support for a specific type of investment has to be seen as a tax for competing production alternatives. Moreover, every subsidy for a specific type of farm creates disadvantages for competing farms. These indirect effects do not only affect farms investing in biogas, but rather the whole sector. Further reforms of the REA should therefore better consider the implications of limited land resources in agriculture.

In AgriPoliS, farmers' behavior is implemented according to the traditional agricultural economic assumption of farmers as rational price-takers. This approach to modeling farmer behavior embraces several common weaknesses, all of which are related to decisions in complex situations. These weaknesses include sensitivity of optimization model results to uncertain expectations, ignorance of strategic issues, and the assumption of perfect rationality amongst agents.

In order to improve the understanding of farmers' behavior, this thesis discusses the possibility of utilizing the existing agent-based model AgriPoliS for behavioral experiments. Appel et al. (2018) (Section 4, page 56 ff) document the software FarmAgriPoliS and evaluate the suitability for experimental use. The regions and specified farms used in FarmAgriPoliS are based on real agricultural regions and farms for which AgriPoliS has been adapted. Therefore, the situational settings to which agents, respectively participants, are confronted are the same in AgriPoliS and FarmAgriPoliS. If one assumes that agents in AgriPoliS have to make decisions that are framed in a way which is realistic, then this can also be assumed for agents in FarmAgriPoliS. Thus, a basic assumption for using FarmAgriPoliS for behavioral experiments is that participants face a salient context which requires decisions close to those situations faced by actual farm managers (Guyot and Honiden, 2006).

In FarmAgriPoliS, each participant controls a specific agent (or farm). Analogous to AgriPoliS, the farm is equipped with a certain amount of machinery, buildings, owned and rented land, labor, 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 strategic decisions that drive a farm's performance in the long run. Short-term optimizations such as planning of the annual production are made for the participants based on his or her price expectations using mixed-integer optimization. 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, however, deviate.

Experimental results of using FarmAgriPoliS are presented in Appel and Balmann (2018) (Section 5, p. 82) and Section 6 (p. 118 ff). It is demonstrated that there are systematic differences in behavior and achievement between human participants and myopic optimizing agents, and between participants.
Cluster analyses of experimental data revealed a substantial heterogeneity in the behavior and success amongst the participants. Four distinct experimental outcome clusters are identified. 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" (cf. Section 5.7.3, p. 106). The first three clusters that include some 88% of the experiments corresponded with prospect theory (cf. Kahnemann and Tversky (1979)) - that is, the participants were more successful in avoiding losses than in exploiting opportunities. However, in approximately 12% of the of the experiments 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 unfavorable farms cost structures. In these experiments, the participants managed strong growth and were substantially more successful than computer agents and other participants. These very successful path-breakers do not fit into prospect theory, and characterize specific entrepreneurs which developed specific strategies.
A further analysis of the regional influence of path-breaking farms which dramatically increase their farm-size proves that farms in a region are not independent regarding their development, but are mutually dependent. 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. Most likely these farms benefit from the reduced opportunities of the immediate neighbors of the path breaker.

To conclude, FarmAgriPoliS can be seen as an additional tool for better understanding structural change in agriculture including the behavior of farmers. As a software for agent-based participatory experiments it provides the participants with a salient context which requires decisions close to those situations faced by actual farm managers.
The use of FarmAgriPoliS is not limited to the validation of the behavioral assumptions used in the agent-based model AgriPoliS by just comparing computer agents with human participants. It further allows to analyze how human participants act in a strategic farm management context and how they differ in their behavior. The detected behavioral patterns can be well linked to existing theories of general human behavior (prospect theory) as well as to theories of entrepreneurial behavior (path-breaking, path-creation).
FarmAgriPoliS is further valid to assess the effects of different behavioral patterns on farm level, as well as on regional structures. Therefore, not only path-breaking behavior can be detected, but also the implications of such path-breaking behavior for other farms in the neighborhood can be analyzed.
A future challenge will be to use these findings to make behavioral assumptions more realistic in models such as AgriPoliS. Further systematizing, testing and validation will in any case require additional experiments with a higher number of participants, additional scenarios and experiments with farmers instead of agricultural students.

A UML

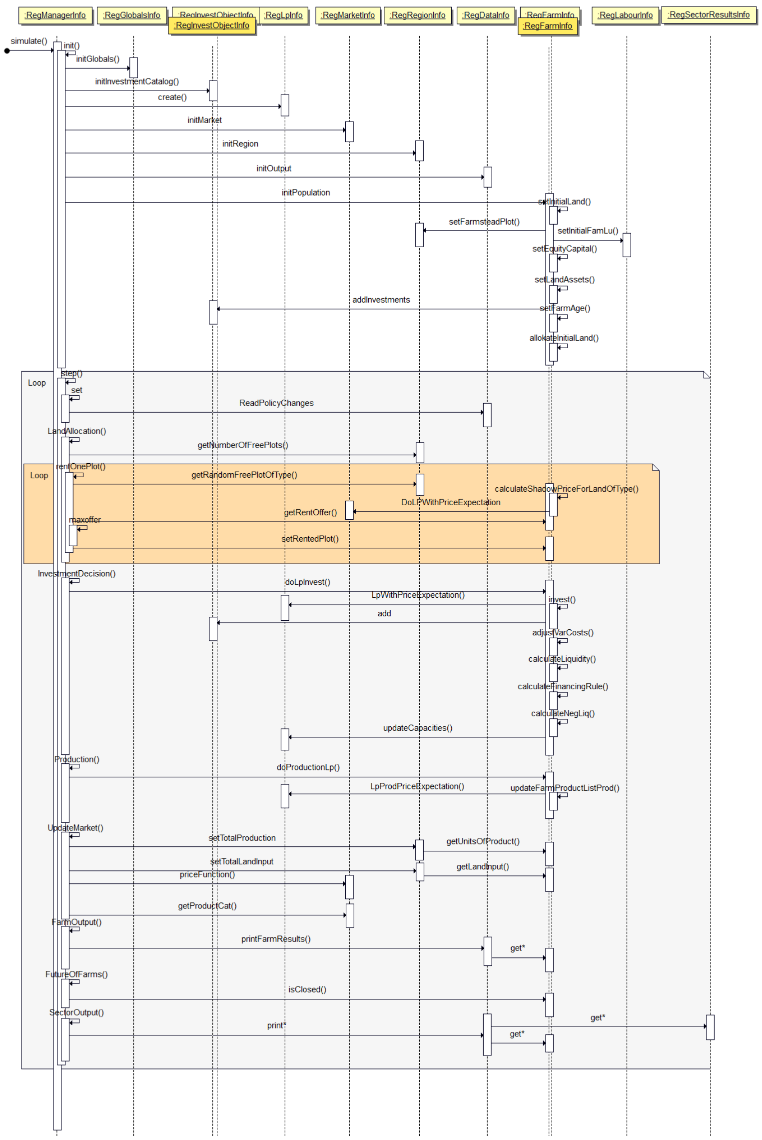


Figure A.1: Sequence diagram of one simulation run of FarmAgriPoliS (simplified; without User interaction)

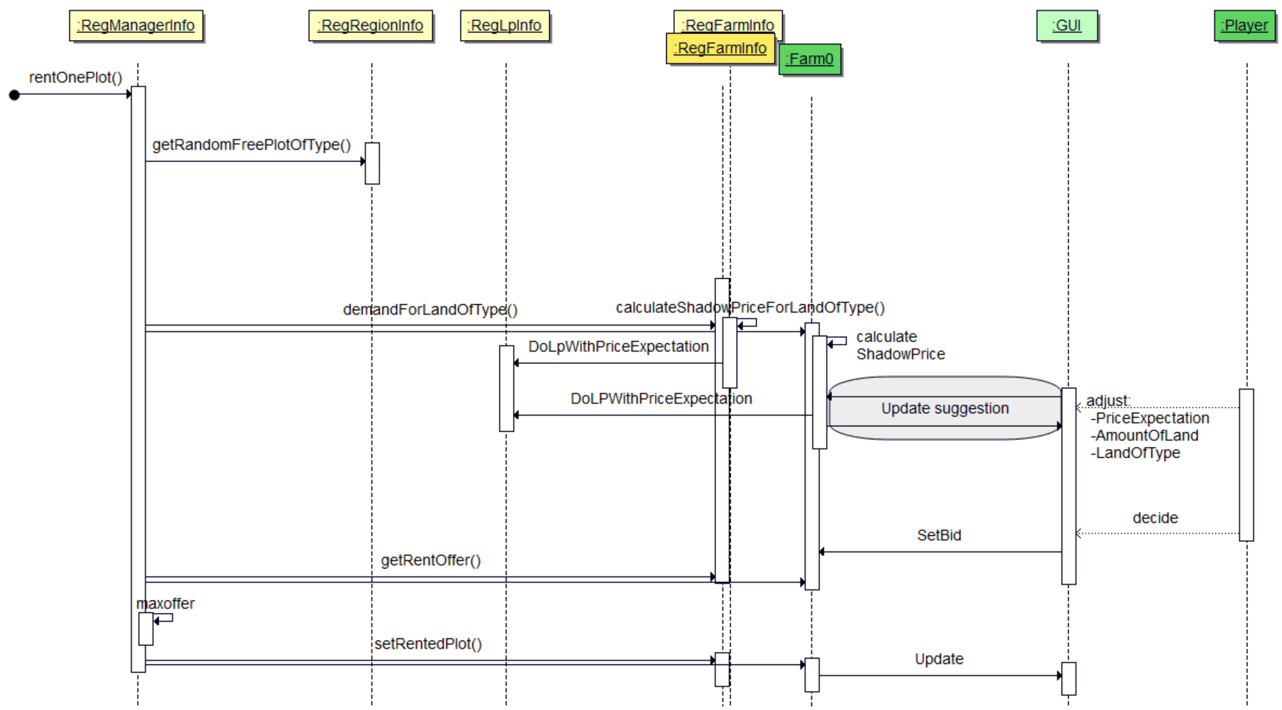


Figure A.2: Sequence diagram of land market in FarmAgriPoliS

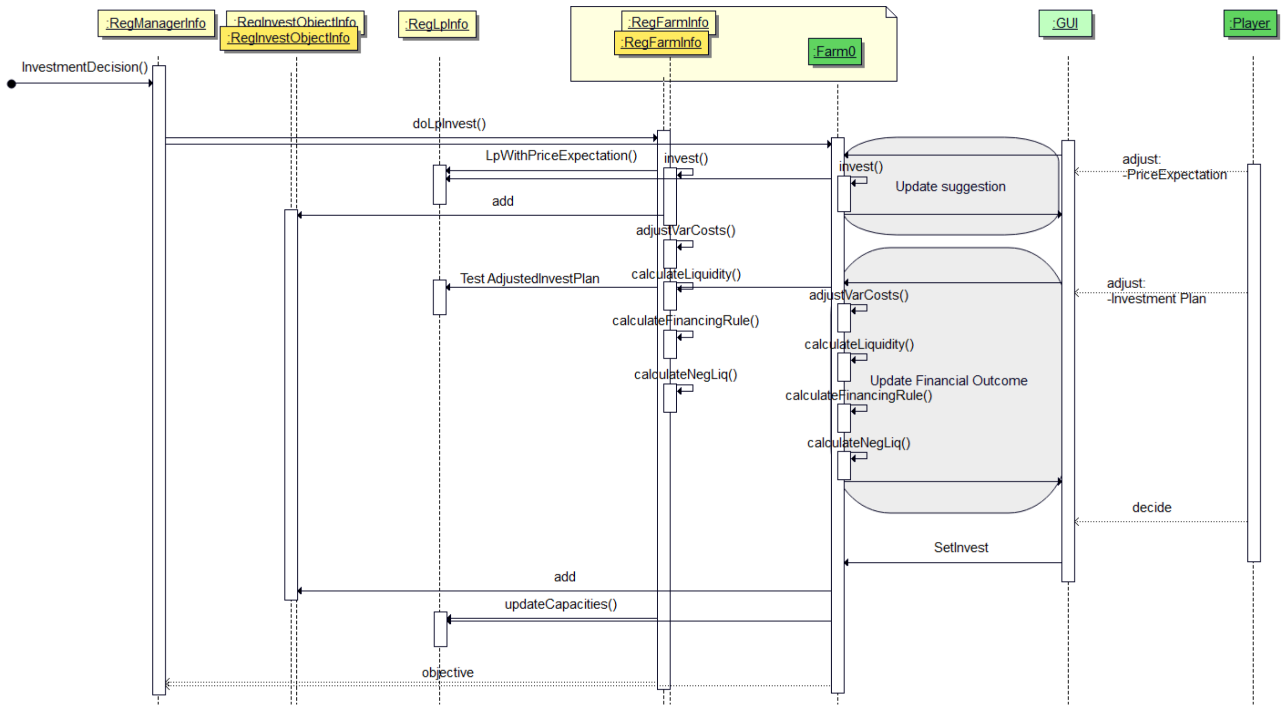


Figure A.3: Sequence diagram of investment decision in FarmAgriPoliS

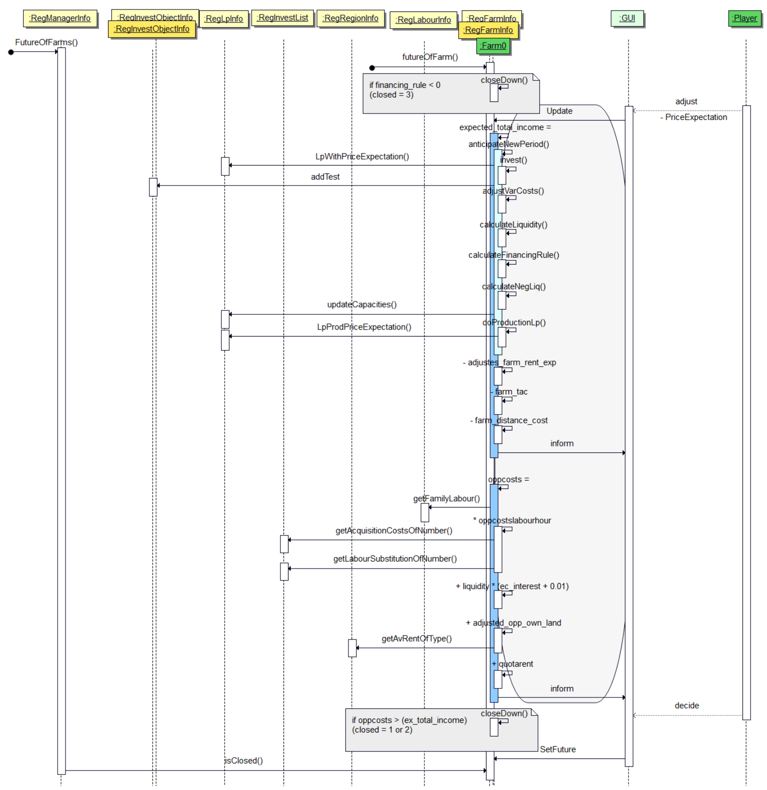


Figure A.4: Sequence diagram of farm exit decision in FarmAgriPoliS

B Supplementary tables

Table B.1: Classification and distribution of safe choices (HLL)

Number of safe choices	Risk preference classification	Freq. of choices	Perc. of choices
0 - 1	highly risk loving	3	6
2	very risk loving	1	2
3	risk loving	6	12
4	risk neutral	7	14
5	slightly risk averse	6	12
6	risk averse	9	18
7	very risk averse	8	16
8	highly risk averse	6	12
9 - 10	stay in bed	3	6
	Total	49	100

Table B.2: Student's T-test for selected indicators (period 19)

	Scen.	Obs.	Benchmark	Mean	Std. err.	Std. dev.	$(T < t)$	$(\|T\| > \|t\|)$	$(T > t)$
Equity capital (1,000 Euro)	1	15	2,843	1,733	270	1,045	0.0005***	0.0011**	0.9995
	2	20	2,484	1,430	293	1,312	0.0010**	0.0019**	0.999
	3	15	-1,099	-387	669	2,589	0.8476	0.3048	0.1524
	4	18	6,084	4,239	491	2,084	0.0008***	0.0016**	0.9992
	5	8	6,271	5,587	448	1,267	0.0852	0.1703	0.9148
	6	24	-2,723	1,053	887	4,343	0.9999	0.0003***	0.0001***
	7	20	-490	-533	117	523	0.3592	0.7184	0.6408
	8	11	-822	-303	114	378	0.9995	0.0010**	0.0005***
	9	13	-1,174	-714	222	801	0.9698	0.0605*	0.0302*
Liquidity (1,000 Euro)	1	15	1,295	449	182	703	0.0002***	0.0004***	0.9998
	2	20	893	107	212	947	0.0007***	0.0015**	0.9993
	3	15	-2,021	-1,629	571	2,213	0.7481	0.5039	0.2519
	4	18	2,712	1,707	322	1,367	0.0031**	0.0062**	0.9969
	5	8	1,674	2,020	309	873	0.8505	0.299	0.1495
	6	24	-4,895	-1,305	722	3,535	1.0000	0.0000***	0.0000***
	7	20	-745	-850	103	461	0.1606	0.3212	0.8394
	8	11	-1,235	-685	105	349	0.9998	0.0004***	0.0002***
	9	13	-1,641	-1,193	234	844	0.9602	0.0796*	0.0398*
Profit (1,000 Euro)	1	15	842	214	146	566	0.0004***	0.0007***	0.9996
	2	20	359	111	90	403	0.0064**	0.0127*	0.9936
	3	15	-441	-104	149	577	1.0000	0.0000***	0.0000***
	4	18	1,915	1,142	233	987	0.0000***	0.0000***	1.0000
	5	8	1,719	1,350	213	602	0.0000***	0.0000***	1.0000
	6	24	-1,005	-84	216	1,056	1.0000	0.0000***	0.0000***
	7	20	-116	-138	9	38	1.0000	0.0000***	0.0000***
	8	11	-177	-143	12	39	1.0000	0.0000***	0.0000***
	9	13	-216	-192	20	73	1.0000	0.0000***	0.0000***
ESU [a)]	1	15	2,638	1,726	291	1,129	0.0037**	0.0074**	0.9963
	2	20	1,953	1,590	189	845	0.0349*	0.0698*	0.9651
	3	15	500	1,104	295	1,141	0.9701	0.0598*	0.0299*
	4	18	6,055	4,245	440	1,866	0.0004***	0.0007***	0.9996
	5	8	6,327	5,002	575	1,627	0.0273*	0.0547	0.9727
	6	24	1,401	2,590	451	2,208	0.9927	0.0147*	0.0073**
	7	20	0	226	44	196	1.0000	0.0001***	0.0000***
	8	11	255	220	30	98	0.1333	0.2666	0.8667
	9	13	115	291	61	218	0.9934	0.0133*	0.0066**
Farm size (ha)	1	15	2,160	1,531	247	957	0.0117	0.0234	0.9883
	2	20	1,085	954	157	701	0.2059	0.4117	0.7941
	3	15	0	823	351	1,360	0.9828	0.0345*	0.0172*
	4	18	4,940	3,578	414	1,756	0.0022**	0.0043**	0.9978
	5	8	3,490	3,084	386	1,092	0.1642	0.3284	0.8358
	6	24	0	2,626	503	2,462	1.0000	0.0000***	0.0000***
	7	20	0	23	23	104	0.8351	0.3299	0.1649

	8	11	0	3	3	11	0.8296	0.3409	0.1704
	9	13	0	112	76	274	0.9164	0.1673	0.0836
Rented arable land (ha)	1	15	509	639	24	91	1.0000	0.000***	0.000***
	2	20	718	783	19	85	0.999	0.003**	0.001**
	3	15	503	579	42	162	0.955	0.091	0.045*
	4	18	467	481	19	79	0.762	0.476	0.238
	5	8	597	585	13	36	0.192	0.385	0.808
	6	24	40	407	41	203	1.000	0.000***	0.000***
	7	20	683	689	21	96	0.603	0.794	0.397
	8	11	870	758	49	162	0.022*	0.045*	0.978
	9	13	748	575	39	142	0.000***	0.001**	1.000
Rented grassland (ha)	1	15	637	658	26	102	0.778	0.443	0.222
	2	20	819	808	28	127	0.359	0.718	0.641
	3	15	478	557	52	201	0.924	0.152	0.076
	4	18	423	415	28	117	0.387	0.774	0.613
	5	8	643	652	45	127	0.575	0.85	0.425
	6	24	13	202	35	170	1.000	0.000***	0.000***
	7	20	494	664	33	148	1.000	0.000***	0.000***
	8	11	759	755	82	272	0.481	0.961	0.519
	9	13	495	529	68	247	0.684	0.632	0.316
Revenue (1,000 Euro)	1	15	6,627	4,449	726	2,810	0.005**	0.009**	0.995
	2	20	4,961	4,152	442	1,976	0.042*	0.083	0.959
	3	15	1,724	3,460	817	3,164	0.974	0.052	0.026*
	4	18	15,322	10,639	1,019	4,324	0.000***	0.000***	0.999
	5	8	15,833	12,309	1,386	3,919	0.019*	0.039*	0.981
	6	24	4,310	7,711	1,221	5,979	0.995	0.011*	0.005**
	7	20	0	775	113	506	1.000	0.000***	0.000***
	8	11	688	687	69	229	0.495	0.990	0.505
	9	13	413	1,013	174	627	0.998	0.005**	0.002**
Revenue cumulated (1,000 Euro)	1	15	71,173	56,651	4,931	19,098	0.005**	0.011*	0.995
	2	20	64,029	57,339	3,331	14,896	0.029*	0.059	0.971
	3	15	58,203	60,399	5,898	22,844	0.642	0.715	0.358
	4	18	157,291	123,104	7,919	31,674	0.000***	0.000***	0.999
	5	8	163,224	144,209	12,128	34,302	0.081	0.161	0.919
	6	24	122,599	120,005	8,449	41,393	0.381	0.762	0.619
	7	20	18,326	24,040	1,295	5,934	0.999	0.000***	0.000***
	8	11	20,613	24,723	1,286	4,266	0.995	0.009**	0.005**
	9	13	19,637	29,543	1,915	6,905	0.999	0.000***	0.000***

Note: significance level: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

a) 1 ESU = 1,200 Euro standard gross margin

Table B.3: Ratio between rental prices and economic land rent

		Period																				
Scen.		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean
1	Particip.	0.25	0.22	0.22	0.24	0.24	0.25	0.4	0.42	0.44	0.47	0.5	0.57	0.59	0.61	0.63	0.66	0.67	0.71	0.74	0.7	0.48
	Bench.	0.25	0.21	0.17	0.16	0.16	0.16	0.42	0.4	0.41	0.42	0.45	0.52	0.51	0.53	0.56	0.57	0.55	0.58	0.6	0.59	0.41
2	Particip.	0.25	0.23	0.22	0.24	0.29	0.29	0.25	0.3	0.35	0.42	0.33	0.56	0.66	0.48	0.65	0.64	0.86	0.91	0.65	0.81	0.47
	Bench.	0.25	0.2	0.16	0.15	0.19	0.18	0.14	0.28	0.31	0.37	0.28	0.5	0.59	0.42	0.6	0.59	0.8	0.82	0.58	0.73	0.41
3	Particip.	0.25	0.25	0.29	0.24	0.17	0.15	0.16	0.17	0.19	0.28	0.54	2.77	1.47	1.02	1.16	1.39	0.8	0.81	0.55	0.74	0.67
	Bench.	0.25	0.21	0.23	0.18	0.11	0.1	0.13	0.14	0.19	0.3	0.59	3.3	1.57	1.04	1.3	1.87					0.72
4	Particip.	0.11	0.12	0.13	0.13	0.17	0.2	0.28	0.29	0.37	0.39	0.44	0.48	0.49	0.53	0.53	0.54	0.56	0.58	0.58	0.59	0.38
	Bench.	0.11	0.11	0.08	0.07	0.1	0.14	0.24	0.24	0.33	0.33	0.38	0.42	0.44	0.48	0.49	0.5	0.53	0.55	0.55	0.56	0.33
5	Particip.	0.1	0.1	0.08	0.08	0.12	0.14	0.22	0.21	0.25	0.32	0.27	0.42	0.46	0.36	0.49	0.5	0.67	0.66	0.5	0.59	0.33
	Bench.	0.1	0.1	0.07	0.06	0.06	0.06	0.19	0.2	0.24	0.31	0.25	0.4	0.45	0.32	0.47	0.48	0.68	0.65	0.48	0.57	0.31
6	Particip.	0.1	0.1	0.09	0.09	0.08	0.08	0.12	0.12	0.12	0.24	0.45	2.17	1.23	1.08	1.39	1.03	0.77	0.76	0.62	0.81	0.57
	Bench.	0.1	0.09	0.07	0.05	0.04	0.03	0.09	0.09	0.09	0.25	0.43	2.67	1.32	1.23	2.02						0.57
7	Particip.	0.71	0.43	0.44	0.41	0.42	0.5	0.56	0.63	0.68	0.89	1.01	1.45	1.69	1.94	2.52	2.63	2.73	4.26	2.04		1.36
	Bench.	0.71	0.39	0.35	0.31	0.31	0.31	0.37	0.41	0.43	0.72	0.87	1.56	1.78	2.16	2.7	3.03	3.91				1.2
8	Particip.	0.69	0.4	0.39	0.4	0.43	0.58	0.46	0.31	0.45	1.03	0.67			1.44	5.95	2.52					1.12
	Bench.	0.69	0.34	0.31	0.29	0.29	0.43	0.37	0.24	0.31	1.28	0.78										0.49
9	Particip.	0.67	0.38	0.4	0.35	0.27	0.28	0.25	0.25	0.22	0.28	0.88			1.88	2.14	1.8	1.37	1.44	1.12	3.16	0.95
	Bench.	0.67	0.34	0.3	0.25	0.2	0.2	0.18	0.18	0.14	0.17	1.03										0.33

Table B.4: Distribution of clusters by scenarios

	Cluster				
Scenario	**1**	**2**	**3**	**4**	**Total**
1		10	5		15
2	3	8	9		20
3	3	3	5	4	15
4	2	11	3		16
5		6	2		8
6	2	7	2	13	24
7		8	13		31
8		1	10		11
9		1	12		13
Total	10	55	61	17	143

Table B.5: Summary statistics

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Initial farm size (ha)	143	938.57	386.21	665	1,480.00
Production cost factor	143	1.01	0.1	0.9	1.15
Equity capital (1,000 Euro)	2,859	1,374.82	1,433.72	-7,503.74	8,343.65
Liquidity (1,000 Euro)	2,859	187.28	939.21	-9,473.73	4,477.03
Profit p.a. (1,000 Euro)	2,859	386.62	659.55	-3,326.60	3,735.63
ESU	2,859	1,312.24	1,268.07	-157.61	7,501.99
Size (ha)	2,859	1,198.59	1,062.31	0	6,360.00
Rented arable land (ha)	2,859	376.16	226.36	56	1,329.23
Rented grassland (ha)	2,859	332.96	253.45	0	1,204.02
Revenue cumulated (1,000)	2,859	3,521.11	3,093.72	156.22	19,015.30
Gender (1=female)	143	0.34	0.47	0	1
Age	143	25.96	3.32	20	36
Knowledge in farm management [a)]	105	2.77	1.04	1	5
HLL (safe choices)	143	5.43	2.21	0	10
Risk (self-assessment) [b)]	143	4.8	1.87	2	9
Maximising [c)]	143	3.05	0.49	1.77	4.31
Rational [d)]	143	3.93	0.51	2.5	5
Intuitive [d)]	143	3.31	0.75	1.6	4.8
Dependent [d)]	143	3.16	0.78	1	5
Avoidant [d)]	143	2.67	0.97	1	4.8
Spontaneous [d)]	143	2.88	0.83	1	5

Note: a) I have solid knowledge in agricultural management. - 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree
b) 0 = highly risk-tolerant, ..., 10 = completely risk-averse
c) 1 = strong satisficing behaviour, ..., 5 = strong maximizing behaviour
d) 1= very low expression of the resp. characteristic, ..., 5 = very high expression of the resp. characteristic

Table B.6: Mean deviation between clusters (adjusted p-values of pairwise comparison)

Variable	Cluster	Cluster 1	Cluster 2	Cluster 3
Scenario***	2	0.57 (1.000)		
	3	**2.25 (0.041)**	**1.68 (0.002)**	
	4	1.79 (0.381)	1.22 (0.417)	-0.46 (1.000)
Initial farm size*** (ha)	2	29.64 (1.000)		
	3	-232.48 (0.309)	**-262.11 (0.000)**	
	4	297.235 (0.200)	**267.6 (0.037)**	**529.71 (0.000)**
Initial equity capital*** (1,000 Euro)	2	2.44 (1.000)		
	3	-107.24 (0.105)	**-109.68 (0.000)**	
	4	107.54 (0.246)	**105.1 (0.026)**	**214.779 (0.000)**
Production cost factor***	2	0.049 (0.831)		
	3	**0.115 (0.004)**	**0.066 (0.002)**	
	4	0.036 (1.000)	-0.013 (1.000)	**-0.078 (0.020)**
Av. equity capital*** (1,000 Euro)	2	**938.14 (0.000)**		
	3	**709.55 (0.000)**	**-228.59 (0.013)**	
	4	**2,283.40 (0.000)**	**1,345.26 (0.000)**	**1,573.85 (0.000)**
Av. Profit p.a.*** (1,000 Euro)	2	**275.34 (0.000)**		
	3	**189.84 (0.000)**	**-85.5 (0.006)**	
	4	**833.71 (0.000)**	**558.37 (0.000)**	**643.87 (0.000)**
Av. size*** (ha)	2	**203.46 (0.041)**		
	3	-103.63 (0.987)	**-307.09 (0.000)**	
	4	**1,257.89**	**1,054.44**	**1,361.53**

		(0.000)	**(0.000)**	**(0.000)**
	2	472.45		
		(0.190)		
Av. revenue*** (1,000 Euro)	3	-370.98	**-843.43**	
		(0.535)	**(0.000)**	
	4	**3,489.25**	**3,016.80**	**3,860.23**
		(0.000)	**(0.000)**	**(0.000)**
	2	0.036		
		(1.000)		
Female***	3	**-0.137**	**-0.174**	
		-0.001	**(0.000)**	
	4	**-0.165**	**-0.201**	-0.027
		(0.000)	**(0.000)**	(1.000)
	2	**1.49**		
		0		
Age***	3	**2.24**	**0.75**	
		(0.000)	**(0.000)**	
	4	**3.65**	**2.15**	**1.45**
		(0.000)	**(0.000)**	**(0.000)**
	2	-0.014		
		(1.000)		
Knowledge in farm management***	3	-0.018	-0.003	
		(1.000)	(1.000)	
	4	**-0.792**	**-0.777**	**0.774**
		(0.000)	**(0.000)**	**(0.000)**
	2	**-0.55**		
		(0.006)		
HLL***	3	0.25	**0.81**	
		(0.771)	**(0.000)**	
	4	0.26	**0.82**	0.01
		(1.000)	**(0.000)**	(1.000)
	2	-0.15		
		(1.000)		
Risk***	3	**0.46**	**0.62**	
		(0.006)	**(0.000)**	
	4	-0.35	-0.19	**-0.81**
		(0.207)	(0.552)	**(0.000)**
	2	**-0.31**		
		(0.000)		
Maximising***	3	**-0.38**	**-0.06**	
		(0.000)	**(0.010)**	
	4	**-0.12**	**0.2**	**0.26**
		(0.043)	**(0.000)**	**(0.000)**
	2	0.08		
		(0.230)		
Rational***	3	**0.23**	**0.15**	
		(0.000)	**(0.000)**	

	4	**0.24** **(0.000)**	**0.16** **(0.000)**	0.01 (1.000)
Intuitive***	2	0.1 (0.494)		
	3	**-0.32** **(0.000)**	**-0.42** **(0.000)**	
	4	**-0.42** **(0.000)**	**-0.52** **(0.000)**	**-0.11** **(0.103)**
Dependent***	2	0.13 (0.172)		
	3	**0.24** **(0.000)**	**0.11** **(0.005)**	
	4	**0.37** **(0.000)**	**0.24** **(0.000)**	**-0.13** **(0.038)**
Avoidant***	2	0.18 (0.101)		
	3	**0.24** **(0.006)**	0.06 (0.656)	
	4	**0.48** **(0.000)**	**0.3** **(0.000)**	**0.23** **(0.000)**
Spontaneous**	2	-0.04 (1.000)		
	3	-0.17 (0.050)	**-0.12** **(0.002)**	
	4	-0.09 (1.000)	-0.05 (1.000)	0.07 (0.854)

Note: Prob.> F: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table B.7: Deliberate farm exits by cluster

ID	Cluster	Scenario	Equity capital (1,000 Euro)[a)] Participant	Benchmark	Difference
22-01-15-3	2	1	739.79	2,843.39	-2,103.60
20-05-15-2	2	2	-369.58	2,484.32	-2,853.90
27-08-14-1	2	3	-1,102.41	-1,098.92	-3.49
29-01-15-1	2	4	379.95	6,084.24	-5,704.29
22-01-15-1	2	4	-606.16	6,084.24	-6,690.40
27-08-14-4	2	7	-184.43	-490.36	305.93
19-05-15-3	2	7	-267.25	-490.36	223.11
20-05-15-6	2	7	-317.57	-490.36	172.79
19-05-15-2	2	7	-883.38	-490.36	-393.02
Mean			-290.11	1,603.98	-1,894.10
19-05-15-4	3	7	161.62	-490.36	651.98
20-05-15-1	3	7	307.58	-490.36	797.94
22-01-15-3	3	7	335.8	-490.36	826.15
22-04-15-1	3	8	-79.07	-822.28	743.21
27-08-14-1	3	8	133.62	-822.28	955.9
Mean			171.91	-623.12	795.04

Note: a) Equity capital at the end of experiment

C Game Manual (German)

Anleitung und Informationen FarmAgriPoliS

Wie verläuft das Experiment und wie lang dauert die Teilnahme?

Die Teilnahme unterteilt sich in folgende Phasen:

1. Zunächst lesen Sie sich bitte diese Anleitung zum Spiel vollständig durch.
2. Dann erfolgt eine Einführung in die Software. Sie können sowohl im Anschluss daran und zu jedem späteren Zeitpunkt Fragen zum Spiel oder zum Ablauf stellen.
3. Sie spielen zunächst ein Szenario, welches der Einführung und dem Kennenlernen der Möglichkeiten der Software dient.
4. Im Anschluss werden Sie ein bis drei weitere Szenarien spielen. Üblicherweise ist das Spiel nach 20 Jahren/Spielperioden beendet. Vorher ist Schluss, wenn ihr Betrieb illiquide wird und Sie sich entscheiden, aus der landwirtschaftlichen Produktion auszusteigen.
5. Im Anschluss an das Spiel werden wir Sie auffordern, gemeinsam mit uns, einen kurzen Fragebogen auszufüllen. Dieser Fragebogen enthält als letztes Element eine Lotterie.
6. Im Anschluss an den Fragebogen benötigen wir ein wenig Zeit, um Ihre Vergütung zu errechnen und vorzubereiten. Nach Erhalt und Quittierung des Geldes ist das Experiment beendet.

Die **Gesamtzeit** für diese Schritte beträgt **höchstens fünf Stunden**.

Was ist FarmAgriPoliS?

In diesem Spiel sind Sie als Landwirt dazu aufgefordert, **einen Betrieb als Betriebsleiter zu übernehmen**. Sie konkurrieren dabei auf dem Landmarkt mit computergesteuerten Nachbarbetrieben in einer **Region**, welche der **Altmark in Sachsen-Anhalt** nachempfunden ist.

Nacheinander werden Sie **verschiedene Szenarien** spielen. In diesen Szenarien übernehmen Sie **unterschiedliche Betriebstypen** und müssen unter Umständen mit **schwankenden Milchpreisen** umgehen.

Ziel ist es, den Betrieb durch sich ändernde Rahmenbedingungen (Preise, Politiken) zu führen, und dessen Eigenkapital zu erhöhen. Sie stehen dabei im Konkurrenzkampf mit ihren Nachbarn. Diese werden durch den Computer gesteuert und haben das Ziel, den Gewinn des nächsten Jahres zu maximieren.

Im Spiel müssen Sie die folgenden Entscheidungen treffen:

- **Wie viel Fläche soll zugepachtet werden?**
- **In welche Maschinen, Ställe und Anlagen soll neu investiert werden?**
- **Welche Preise sind zu erwarten?**
- **Möchten Sie lieber aus der landwirtschaftlichen Produktion aussteigen und außerhalb arbeiten?**

Wie läuft ein typisches Spiel ab und welche Informationen stehen zur Verfügung?

Sie übernehmen einen bestehenden Betrieb, der bereits mit allen erforderlichen Maschinen und Gebäuden ausgestattet ist, und sie dürfen diesen Betrieb bis zu 20 Spieljahre führen. Jede Ihrer Entscheidungen hat Einfluss auf die weitere Entwicklung des Betriebes und letztendlich auf das Betriebsvermögen. Das Spielziel ist einfach: erfolgreich sein und **das betriebliche Vermögen steigern**!

Während des gesamten Spiels stehen Ihnen **Informationen zur wirtschaftlichen Situation Ihres Betriebs, die Betriebsausstattung im Betriebsspiegel und Daten zur Entwicklung der Region** zur Verfügung. Einige **Kennzahlen** werden auch **grafisch** dargestellt.

FarmAgriPoliS bietet Ihnen für jedes Programmfenster eine entsprechende Informationsseite an, die zusammenfasst, was im jeweiligen Schritt des Spiels passiert und welche Entscheidungen Sie treffen können. Weiterführende Informationen finden Sie im **Hilfe-Menü**.

Wir stehen außerdem jederzeit persönlich für Fragen zur Verfügung!

Die detaillierte Produktionsplanung des Betriebs wird vom Computer übernommen. Sie entscheiden ausschließlich über **Pacht, Investitionen und Ausstieg aus der Landwirtschaft**. Bei diesen Entscheidungen wird Ihnen jeweils als **Hilfestellung** angezeigt, **wie ein Computerspieler in Ihrem Fall entscheiden würde**. Sie können von diesen Entscheidungen im Rahmen Ihrer Betriebsausstattung jedoch abweichen. Zur Erinnerung: Computerspieler haben das Ziel, den Gewinn des nächsten Jahres zu maximieren.

Eine typische Spielperiode besteht aus **drei Schritten**:

> Auf dem **Bodenmarkt** können Sie zusätzliche Fläche pachten. Der Vorschlag des Computers errechnet sich aus dem **halben Schattenpreis** des Landes auf der Grundlage Ihrer aktuellen Betriebsausstattung. Die anfallenden **Transportkosten** sind in Ihrem Gebot **bereits berücksichtigt**. Für weiter von Ihrem Betrieb entfernte Flächen bieten Sie entsprechend weniger. Die Dauer neu abgeschlossener Pachtverträge wird zufällig festgelegt und liegt zwischen 5 und 18 Jahren. Verfügbare Flächen, aktuelle Pachtpreise genutzter Flächen und Informationen über deren Eigentümer können Sie in der Regionsansicht abrufen, in dem Sie mit der Maus auf eine Fläche klicken.
>
> In den **Entscheidungen über Investitionen** können Sie im Rahmen Ihrer finanziellen Möglichkeiten und Ihrer Betriebsausstattung, Investitionen tätigen. Dabei macht Ihnen der Computer Vorschläge. Sollten Sie mit Preisschwankungen rechnen, können Sie Ihre **Preiserwartung anpassen** und erhalten entsprechend der geänderten Preise vom Computer angepasste Vorschläge. Natürlich können Sie im Rahmen Ihrer Betriebsausstattung alle Investitionen tätigen, auch wenn Ihnen der Computer dies nicht empfiehlt.
>
> Im dritten Schritt entscheiden Sie über **Verbleib oder Ausstieg aus der Landwirtschaft**. Hierzu können Sie die Opportunitätskosten einer Tätigkeit außerhalb der Landwirtschaft mit Ihrem Einkommen aus der Landwirtschaft vergleichen. Entscheiden Sie sich zum Ausstieg, wird das Einkommen für die verbleibenden Spielperioden **Ihrem Betriebsvermögen zugerechnet** und entsprechend vergütet.

Wie wird meine Teilnahme vergütet?

Die **Vergütung** der Teilnahme setzt sich aus **drei Teilen** zusammen:

1. Sie erhalten unabhängig vom Spielerfolg eine **Aufwandsentschädigung in Höhe von 25 Euro**.
2. Hinzu kommt ein **variabler Teil in Abhängigkeit vom Spielerfolg in den Szenarien (maßgeblich ist das Eigenkapital Ihres Betriebes)**, welcher sich am Ergebnis eines typischen Spielers orientiert. Als Benchmark gilt hier ein Eigenkapitelwert, den wir nach dem Spiel einer Tabelle entnehmen. Für **jede 2 Prozent**, die Sie von diesem Wert abweichen, erhalten Sie einen Euro. Bei Erreichen von 100 Prozent erhalten Sie 5 Euro. Sollten Sie in einem Szenario also zum Beispiel 120 Prozent des Betriebsvermögens eines typischen Spielers erreichen, erhalten Sie insgesamt 5 + 20/2 = 15,00 Euro für dieses Szenario. Erreichen Sie 90 oder weniger Prozent, so erhalten Sie für dieses Szenario nichts. Pro Szenario können Sie **maximal 30,00 Euro** erhalten.
3. Nach Beendigung des Spiels und dem Ausfüllen des Fragebogens fordern wir Sie auf, noch an einer **Lotterie** teilzunehmen. Hier können Sie abhängig vom Würfelglück zusätzliches Geld gewinnen.

Nach der Beendigung des Fragebogens errechnen wir auf Basis Ihres Spielerfolges die Auszahlung. Diese erhalten Sie **in bar im Anschluss an die Teilnahme**.

Was gibt es im Umgang mit dem Computer zu beachten?

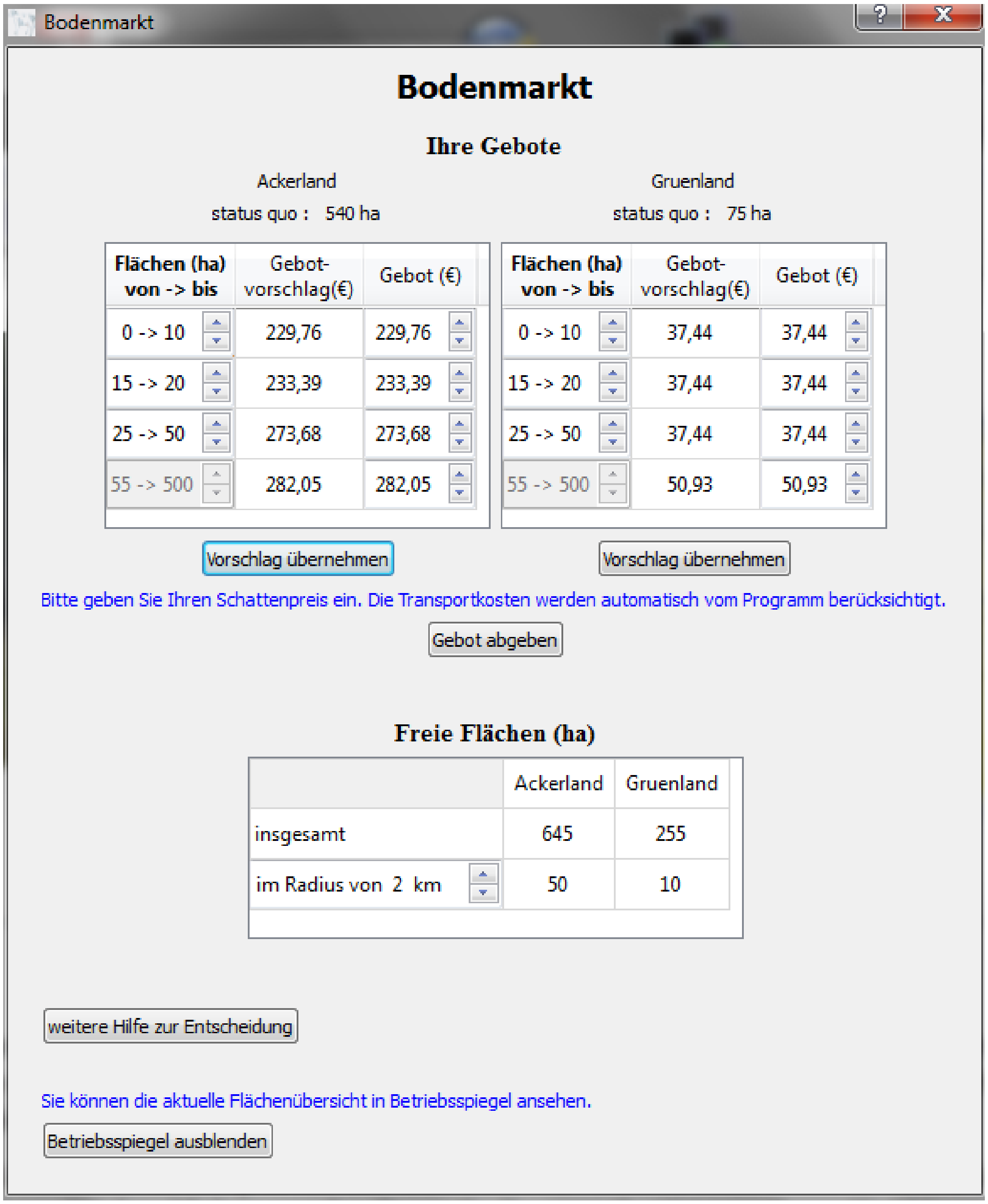
Innerhalb von FarmAgriPoliS werden zum Teil sehr aufwendige Rechenoperationen und Optimierungen durchgeführt, die dazu führen können, **dass der Computer manchmal mehrere Minuten braucht, um zum nächsten Schritt zu gelangen**. Bitte haben Sie in diesem Fall **Geduld**. Sollten Sie den Eindruck haben, dass der Computer eingefroren oder das Programm abgestürzt ist, so informieren Sie uns bitte. **Bitte nutzen Sie in der Wartezeit keine anderen Anwendungen**!

Wer finanziert FarmAgriPoliS, wozu dient es und was passiert mit den Daten?

FarmAgriPoliS wurde zu **Forschungszwecken** im Rahmen des **von der Deutschen Forschungsgemeinschaft (DFG) finanzierten** Teilprojekts 5 der DFG-Forschungseinheit **„Structural Change in Agriculture (SiAg)“** am Leibniz-Institut für Agrarentwicklung in Transformationsökonomien in Halle programmiert, um das Entscheidungsverhalten von Studierenden und Landwirten zu untersuchen. Alle hier gewonnenen Daten werden **zu Forschungszwecken gewonnen** und **nur in anonymisierter Form verwendet und publiziert**. Die Vergütung erfolgt aus DFG-Forschungsgeldern des SiAg-Projekts.

Haben Sie Fragen hierzu?

DER BODENMARKT



DIE INVESTITIONEN

Bei den Investitionsentscheidungen ist es im Spiel technisch nicht ohne weiteres möglich, eventuell greifende Restriktionen, welche eine Investition verhindern, anzuzeigen. Darum sind im Folgenden alle Investitionstypen aufgeführt und beschrieben. Es wird erklärt, welche Voraussetzungen im Einzelnen erfüllt sein müssen, damit man eine bestimmte Investition tätigen kann. Es wird auch erklärt wie sich die Auslastung der Kapazität erklärt. Grundvoraussetzung ist ein positiver Deckungsbeitrag. Absichtliche Verluste durch die Produktionsplanung sind nicht möglich.

Jede Investition wird zu 70% durch langfristiges Fremdkapital finanziert. Desweiteren sind Liquiditätsrestriktionen einzuhalten. Falls diese nicht eingehalten werden, kann teures kurzfristiges Fremdkapital geliehen werden. Wird das Eigenkapital negativ, wird der Betrieb endgültig illiquide und das Spiel ist beendet.

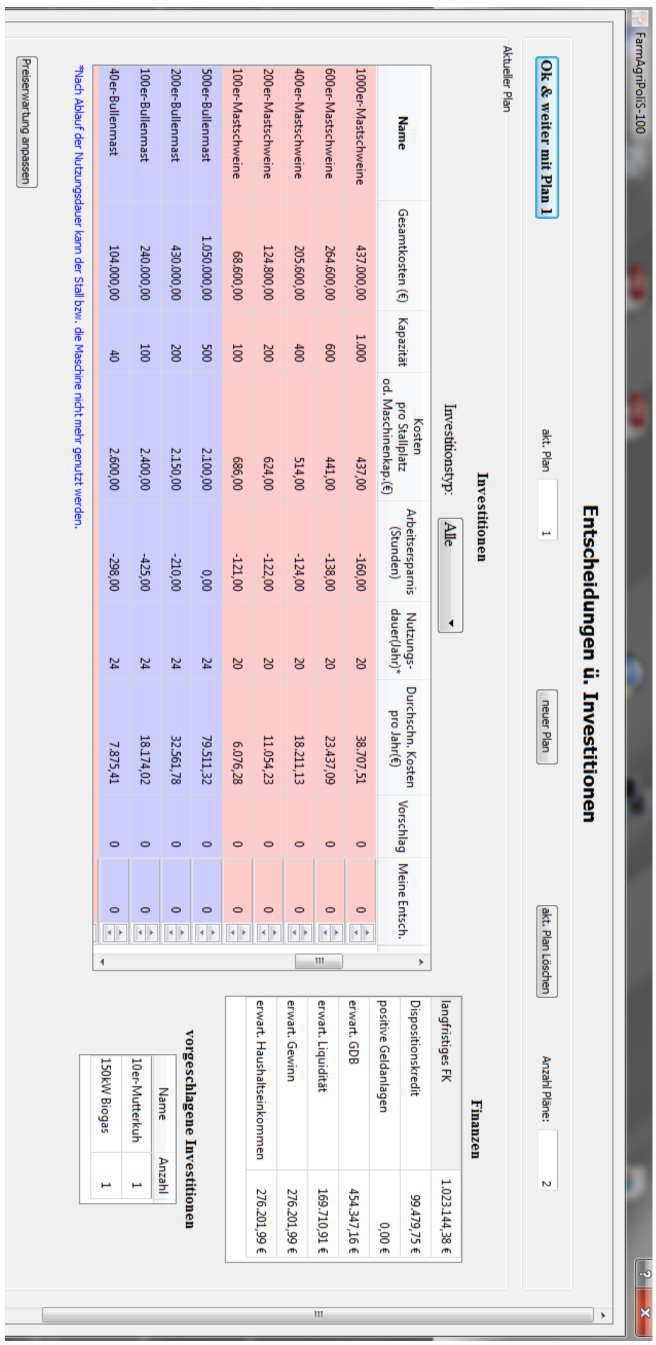
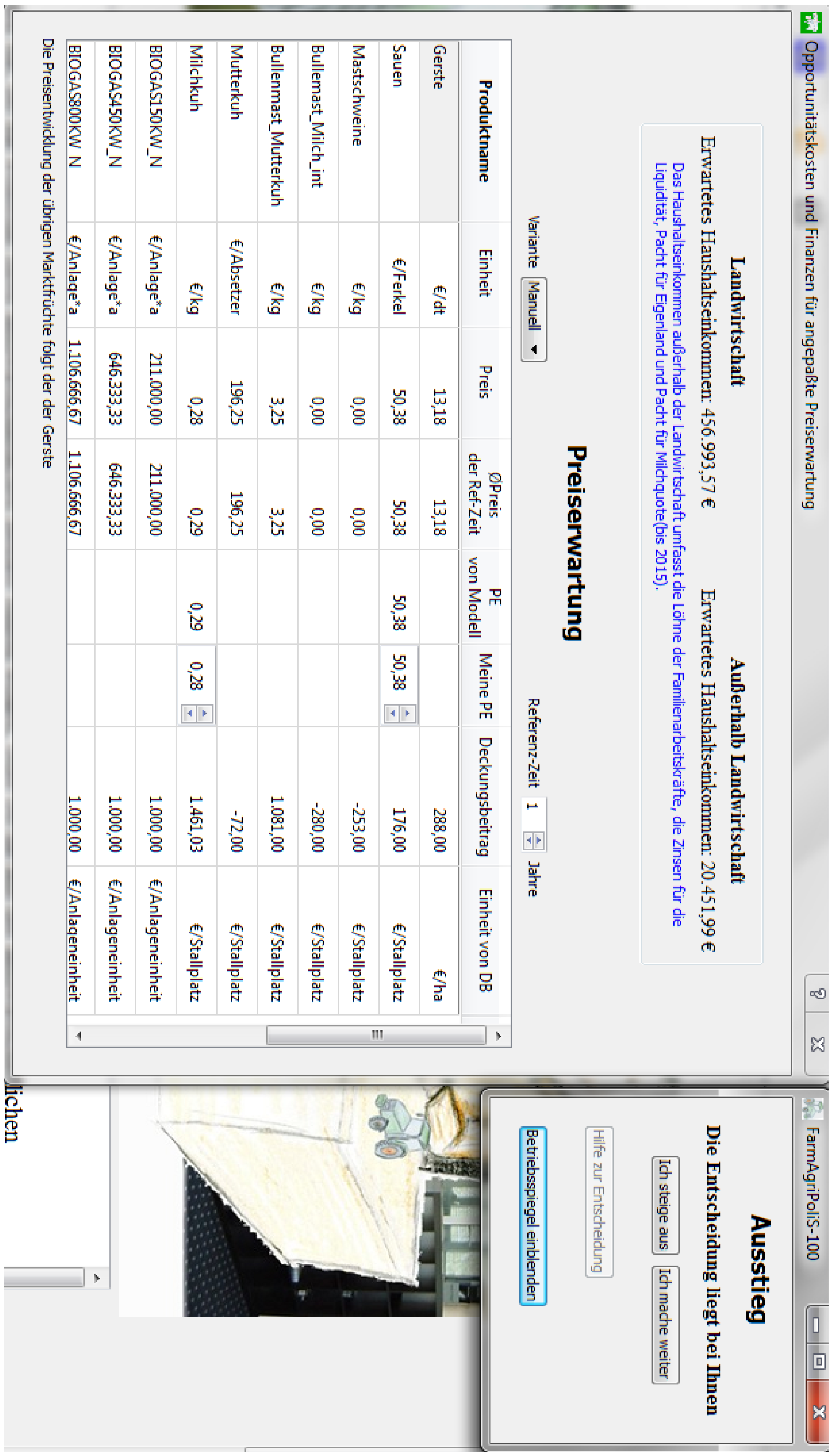


Tabelle 1: Investitionstypen, Beschreibung und Restriktionen

Investitionstyp	**Beschreibung**	**Zusätzliche Bedingungen/Auslastung**
Sauen	Sauenstall	Keine **zusätzlichen** Restriktionen.
Mastschweine	Mastschweinestall	Keine **zusätzlichen** Restriktionen.
Bullenmast	Bullenmaststall	Für die Bullenmast wird Weidefläche benötigt. Pro Stallplatz werden zwei Hektar Grünland benötigt.
Mutterkuh	Mutterkuhstall	Für die Mutterkuhzucht wird Weidefläche benötigt. Pro Stallplatz werden zwei Hektar Grünland benötigt. Außerdem werden Kälber (Aufzuchtstall oder Zukauf) benötigt
Milchkuh	Milchkuhstall	Für die Milchviehhaltung wird Weidefläche benötigt. Pro Stallplatz werden zwei Hektar Grünland benötigt. Außerdem werden Kälber (Aufzuchtstall oder Zukauf) und Melkkapazitäten benötigt
Melkstand	Schafft Melkkapazität	Keine **zusätzlichen** Restriktionen.
Melkroboter	Schafft Melkkapazität (geringerer Arbeitsaufwand)	Keine **zusätzlichen** Restriktionen.
Aufzuchtstall	Stall zur Aufzucht von Jungrindern	Für die Aufzucht von Färsen wird Weidefläche benötigt. Pro Stallplatz wird ein Hektar Grünland benötigt.
Biogasanlage	Biogasanlagen erzeugen Strom, welcher nach dem Erneuerbare-Energien-Gesetz mit 18,05 (größte Anlage) bis 20,70 ct/kWh (kleinste Anlage) vergütet wird. Die Betriebszeit ist mit 8.000 h/Jahr angesetzt.	Es stehen drei verschiedene Substratmischungen zur Verfügung. Die Auswahl ist Teil der Produktionsplanung und wird vom Computer übernommen. Die Substrate enthalten einen Anteil von 10–20% Grassilage, benötigen also indirekt Grünland. Der Maisanteil beträgt 20–60%. Es wird also indirekt auch Ackerland benötigt. Desweiteren **kann** Rindergülle eingesetzt werden, wenn diese vorhanden ist. Außerdem werden Maschinen benötigt.
Maschine	Maschinen werden zur Bestellung von Ackerfläche und Weideland, sowie zur Betreibung von Biogasanlagen benötigt. Für die meisten Marktfrüchte wird ca. eine Einheit pro Hektar benötigt. Kartoffeln benötigen 2,5 Einheiten pro Hektar.	Keine **zusätzlichen** Restriktionen.

DIE AUSSTIEGSENTSCHEIDUNG



WEITERE INFORMATIONEN

Landschaften:

Hier finden Sie einen Überblick über die Pachtflächen in der Region. Sie können hier auch Daten zu Betriebsgröße, Ausstattung etc. von anderen Einzelbetrieben der Region abrufen.

Daten Region:

Hier können Sie Informationen über Betriebsgrößen, -einkommen, Eigenkapital, Preise etc. über die Region abrufen und schauen, wo Sie im Vergleich zu anderen Betrieben stehen. Für zahlreiche Daten besteht außerdem die Möglichkeit, vergangene Spielperioden abzurufen.

Politiken:

Unter diesem Punkt finden Sie aktuelle und vergangene Politik- und Preismeldungen.

Mein Betrieb:

Unter diesem Punkt finden Sie Informationen zu Ihrem Betrieb, Bilanzen, Pachtverträge. Ihnen stehen auch Daten vergangener Spielperioden zur Verfügung.

D FAQ (German)

1. **Warum erscheint bei der Investitionsentscheidung die Meldung „Die gegenwärtige Betriebsausstattung erlaubt das nicht“?**

Dies kann verschiedene Gründe haben. Eine genaue Aufschlüsselung ist aus technischen Gründen nicht möglich. Außer ausreichendem Kapital müssen für viele Investitionen weitere Bedingen erfüllt sein. Diese sind in der Übersicht zu den Investitionstypen genauer erläutert.

2. **Ich habe in einen Stall investiert. Dieser ist aber nicht voll ausgelastet oder wird gar nicht genutzt. Warum?**

Die Produktionsplanung wird vom Programm übernommen. Ein nicht voll genutzter Stall kann verschiedene Ursachen haben. Die Erfordernisse sind in der Übersicht zu den Investitionstypen aufgeführt. So kann es sein, dass Ihr Betrieb nicht über genügend Grünland verfügt. Milchkühe benötigen darüber hinaus Melkkapazitäten. Ein weiterer Grund kann sein, dass sich die Produktion nicht lohnt, da mit anderen Produkten ein höherer Deckungsbeitrag erreicht werden kann oder der Deckungsbeitrag negativ würde.

3. **Was sind Entnahmen und wie werden sie berechnet?**

Entnahmen dienen der Entlohnung von Eigenkapital und der Zahlung von Steuern. In FarmAgriPoliS fallen pauschal 80 Prozent auf die erzielten Gewinne an.

4. **Wie werden Investitionen finanziert?**

Alle Investitionen werden grundsätzlich zu 70% fristenkongruent mit Fremdkapital finanziert. Die restlichen 30% werden aus Bargeld des Betriebs oder kurzfristigem Fremdkapital (zu höheren Zinsen) finanziert.

5. **Wann wird mein Betrieb illiquide? Und was passiert dann?**

Wenn der Betrieb illiquide wird, kann kurzfristiges Fremdkapital genutzt werden, um den Konkurs zu verhindern. Wird das Eigenkapital negativ, geht der Betrieb in den Konkurs und das Spiel ist beendet.

6. **Wo sehe ich, wie viel ich für eine bestimmte Fläche an Pacht bezahle?**

In der Regionsansicht kann man auf einzelne Flächen klicken und so den Pachtpreis sehen. Unter „Mein Betrieb“ gibt es eine Übersicht über Pachtverträge.

7. **Welche Preise kann ich im Spiel beeinflussen, welche sind vorgegeben?**

Die Pachtpreise entstehen durch die Gebote des Spielers und die Gebote der Computeragenten. Alle anderen Preise sind exogen vorgegeben und können vom Spieler nicht (z.B. durch Verknappung oder Ausweitung des Angebots) beeinflusst werden.

8. **Was ist ein Schattenpreis?**

Der Schattenpreis ist eine abstrakte Größe und stellt den Preis dar, bei dem der Grenzgewinn des zusätzlich eingesetzten Faktors null ist, der Spieler also indifferent ist. Anders ausgedrückt entspricht der Schattenpreis für Boden der durch eine zusätzliche Einheit an Fläche ermöglichten Steigerung des Gesamtdeckungsbeitrages.

9. Wie funktioniert die Auktion der Flächen?

Auf dem Pachtmarkt geben alle Spieler ihre Gebote ab. Die entstehenden Transportkosten werden automatisch vom Programm berücksichtigt. Der Meistbietende erhält den Zuschlag zum Preis des zweithöchsten Gebots. Transportkosten fallen, in Abhängigkeit der Entfernung der Fläche von der Produktionsstätte, zusätzlich an.

10. Wie lang sind die Pachtverträge?

Die Länge der Pachtverträge wird vom Computer zufällig festgelegt. Sie liegt mit gleichverteilter Wahrscheinlichkeit zwischen 5 und 18 Jahren.

11. Werden jedes Jahr neue Flächen frei? Wenn ja wie viele?

In jedem Jahr laufen Pachtverträge aus. Die frei werdenden Flächen werden dann in der Auktion neu verpachtet. Geht ein Betrieb in den Konkurs, so stehen die Flächen dem Pachtmarkt zur Verfügung.

12. Warum habe ich als juristische Person keine Familien-AK, und was ist der Unterschied zu Fremd-AK?

Nur Familienbetriebe verfügen über Familien-AK. Diese werden bei Aufgabe des Betriebs durch Einkommen außerhalb der Landwirtschaft entlohnt.

13. Kann ich die Rechtsform des Betriebes wechseln?

Nein, die Rechtsform kann nicht geändert werden und steht für die Dauer eines Spiels fest.

14. Was ist die Managementfähigkeit?

Die Managementfähigkeit eines Betriebsleiters drückt seine Fähigkeiten aus, einen Betrieb zu führen. Gute Manager erhalten einen Abschlag von bis zu 20% auf die variablen Kosten. Betriebe die von schlechten Managern geführt werden haben variable Kosten, die bis zu 20% über dem Durchschnitt liegen.

15. Kann ich nachträglich sehen, was ich in früheren Jahren investiert/gepachtet habe?

Ja, die Pachtübersichten und Betriebsspiegel vergangener Jahre sind im Menü „Mein Betrieb“ einsehbar.

16. Wo kann ich Betriebsergebnisse der Vorjahre sehen?

Die Gewinn- und Verlustrechnung, Bilanzen und Betriebsspiegel vergangener Jahre sind im Menü „Mein Betrieb“ einsehbar.

17. Ist die Aufrechterhaltung der Liquidität Teil der Restriktionen des Computervorschlags?

Ja, der Computer rechnet mit Liquiditätsrestriktionen. Es ist grundsätzlich nicht möglich, über diese Restriktion hinaus zu investieren. Bei fallenden Preisen kann es jedoch vorkommen, dass ein Betrieb durch eine Neuinvestition illiquide wird bzw. zur Erhaltung der Liquidität nicht alle Anlagen und Flächen nutzen kann.

18. Warum kann ich auslaufende Investitionen nicht genau ersetzen?

Die Betriebe sind mit regionstypischen Ausstattungen und Kapazitäten initialisiert. Diese Daten wurden einer Regionalstatistik entnommen. Die zu Verfügung stehenden Investitionsmöglichkeiten wurden an die üblichen Größen in der Region angelehnt. Aufgrund der unterschiedlichen Datengrundlagen kann es darum bei weiteren Investitionen, vor allem bei Ställen, vorkommen, dass diese sich nicht eins zu eins in der gleichen Größe ersetzen lassen.

19. Wie erfolgt die Bezahlung, sollte der Computer abstürzen?

Sollte der Computer einmal während des Spiels abstürzen, so können Sie auf eigenen Wunsch (innerhalb der für das Spiel angesetzten Zeiten) ein zusätzliches Szenario spielen. Es erfolgt außerdem eine Vergütung auf Basis des abgebrochenen Szenarios.

E Questionnaire (German)

– Fragebogen FarmAgriPoliS –

Liebe Spielerin, lieber Spieler,

wir kommen nun zum Fragebogen. Dieser dient uns zur Analyse des Einflusses persönlicher Merkmale auf die Entscheidungen im Spiel. Die hier gewonnenen Daten werden ausschließlich anonymisiert und nur zu Forschungszwecken verwendet.

Bitte beantworten Sie die Fragen möglichst spontan! Sollten Sie einmal keine passende Antwort finden, so wählen sie nach Möglichkeit die am ehesten zutreffende!

Vielen Dank für Ihre Teilnahme!

ID:____________

1. Wie sehr stimmen Sie folgenden Aussagen zu oder lehnen diese ab (Spielverständnis/Spaß)?

		Stimme voll zu	Stimme eher zu	Weder noch	Lehne eher ab	Lehne voll ab
a)	Das Spielziel war klar formuliert.	☐	☐	☐	☐	☐
b)	Ich habe einige Zeit gebraucht, bis ich das Spiel verstanden habe.	☐	☐	☐	☐	☐
c)	Am Ende habe ich das Spiel verstanden.	☐	☐	☐	☐	☐
d)	Die Fülle der Informationen und Möglichkeiten im Spiel haben mich oft überfordert.	☐	☐	☐	☐	☐
e)	Das Spiel hat mir Spaß gemacht.	☐	☐	☐	☐	☐
f)	Das Spiel kommt der landwirtschaftlichen Realität sehr nah.	☐	☐	☐	☐	☐

2. Wie sehr stimmen Sie folgenden Aussagen zu oder lehnen diese ab (Heuristiken/Motivation)?

		Stimme voll zu	Stimme eher zu	Weder noch	Lehne eher ab	Lehne voll ab
a)	Ich habe mich stets an den Vorschlägen des Programms orientiert.	☐	☐	☐	☐	☐
b)	Ich habe bewusst Vorschläge des Programms ignoriert, um meinen Betrieb zu vergrößern.	☐	☐	☐	☐	☐
c)	Ich habe versucht, das Betriebseinkommen zu steigern.	☐	☐	☐	☐	☐
d)	Ich habe versucht, das Eigenkapital meines Betriebes zu steigern.	☐	☐	☐	☐	☐
e)	Ich habe versucht, viel Fläche zu pachten.	☐	☐	☐	☐	☐
f)	Nach einiger Zeit, habe ich immer nach dem gleichen Schema entschieden.	☐	☐	☐	☐	☐
g)	Ich hatte bei meinen Entscheidungen im Spiel ein klares Ziel vor Augen.	☐	☐	☐	☐	☐
h)	Ich wollte mich bei den Entscheidungen im Spiel möglichst wenig anstrengen.	☐	☐	☐	☐	☐
i)	Ich habe bei jeder Entscheidung neu und intensiv nachgedacht.	☐	☐	☐	☐	☐
j)	In den Schwankungsszenarios habe ich eine andere Strategie gewählt.	☐	☐	☐	☐	☐
k)	Ich habe im Spiel manchmal einfach etwas Neues ausprobiert.	☐	☐	☐	☐	☐
l)	Ich habe mich im Spiel häufig mit meinen Nachbarn verglichen.	☐	☐	☐	☐	☐
m)	Meine Position im Vergleich zu den Computeragenten hat mein Verhalten beeinflusst.	☐	☐	☐	☐	☐

3. **Bitte beschreiben Sie kurz in ein paar einfachen Worten, wie Sie Entscheidungen auf dem Pachtmarkt getroffen haben!**

____

____

____

____

____

____

____

____

4. **Bitte beschreiben Sie kurz in ein paar einfachen Worten, wie Sie Investitionsentscheidungen getroffen haben!**

____

____

____

____

____

____

____

____

5. **Bitte beschreiben Sie kurz in ein paar einfachen Worten, wie Sie die Entscheidungen den Betrieb aufzugeben getroffen haben!**

____

____

____

____

____

____

____

____

6. Wie sehr stimmen Sie folgenden Aussagen zu oder lehnen diese ab (nicht auf das Spiel bezogen)?

		Stimme voll zu	Stimme eher zu	Weder noch	Lehne eher ab	Lehne voll ab
a)	Ich prüfe Informationen stets doppelt, um sicher zu gehen, dass meine Entscheidungen auf Fakten basieren.	☐	☐	☐	☐	☐
b)	Ich treffe meine Entscheidungen systematisch und logisch.	☐	☐	☐	☐	☐
c)	Meine Entscheidungen benötigen sorgfältiges Nachdenken.	☐	☐	☐	☐	☐
d)	Wenn ich Entscheidungen treffe, ziehe ich mehrere Optionen in Betracht, um ein bestimmtes Ziel zu erreichen.	☐	☐	☐	☐	☐
e)	Wenn ich Entscheidungen treffe, verlasse ich mich auf meine Instinkte.	☐	☐	☐	☐	☐
f)	Wenn ich Entscheidungen treffe, verlasse ich mich auf meine Intuition.	☐	☐	☐	☐	☐
g)	Ich treffe grundsätzlich Entscheidungen, die sich richtig anfühlen.	☐	☐	☐	☐	☐
h)	Wenn ich eine Entscheidung treffe, ist es mir wichtiger, dass sich diese richtig anfühlt, als das ich sie rational begründen kann.	☐	☐	☐	☐	☐
i)	Wenn ich eine Entscheidung treffe, vertraue ich meinen inneren Gefühlen und Reaktionen.	☐	☐	☐	☐	☐
j)	Wenn ich wichtige Entscheidungen treffe, benötige ich oft die Hilfe anderer Personen.	☐	☐	☐	☐	☐
k)	Ich treffe selten Entscheidungen, ohne vorher andere Personen um Rat gefragt zu haben.	☐	☐	☐	☐	☐
l)	Mit der Unterstützung Anderer fällt es mir leichter, wichtige Entscheidungen zu treffen.	☐	☐	☐	☐	☐
m)	Ich nutze den Rat anderer Personen, wenn ich meine wichtigen Entscheidungen treffe.	☐	☐	☐	☐	☐
n)	Ich bevorzuge es, wenn mich jemand anderes in die richtige Richtung führt, wenn ich eine wichtige Entscheidung treffen muss.	☐	☐	☐	☐	☐
o)	Ich vermeide wichtige Entscheidungen bis der Druck hoch ist.	☐	☐	☐	☐	☐
p)	Ich verschiebe Entscheidungen wann immer dies möglich ist.	☐	☐	☐	☐	☐
q)	Ich suche häufig Ablenkung, wenn wichtige Entscheidungen zu treffen sind.	☐	☐	☐	☐	☐
r)	Ich treffe wichtige Entscheidungen grundsätzlich in der letzten Minute.	☐	☐	☐	☐	☐
s)	Ich stelle viele Entscheidungen zurück, da mich das Nachdenken darüber unruhig werden lässt.	☐	☐	☐	☐	☐
t)	Ich treffe Entscheidungen meist spontan.	☐	☐	☐	☐	☐
u)	Ich treffe Entscheidungen oft im Augenblick.	☐	☐	☐	☐	☐
v)	Ich treffe schnelle Entscheidungen.	☐	☐	☐	☐	☐
w)	Ich treffe oft impulsive Entscheidungen.	☐	☐	☐	☐	☐
x)	Wenn ich Entscheidungen treffe, dann tue ich was mir im Moment als natürlich erscheint.	☐	☐	☐	☐	☐

7. Wie sehr stimmen Sie folgenden Aussagen zu oder lehnen diese ab (nicht auf das Spiel bezogen)?

		Stimme voll zu	Stimme eher zu	Weder noch	Lehne eher ab	Lehne voll ab
a)	Wenn ich fernsehe, zappe ich durch die Programme und überfliege oft die zur Verfügung stehenden Alternativen, sogar wenn ich eigentlich eine bestimmte Sendung sehen möchte.	☐	☐	☐	☐	☐
b)	Wenn ich im Auto Radio höre, prüfe ich oft die anderen Radiosender daraufhin, ob etwas Besseres gespielt wird, sogar wenn ich relativ zufrieden mit dem bin, was ich gerade höre.	☐	☐	☐	☐	☐
c)	Mit Beziehungen ist es wie mit Kleidungsstücken: Ich gehe davon aus, dass ich viele ausprobieren muss, bevor ich die perfekte Passung finde.	☐	☐	☐	☐	☐
d)	Egal wie zufrieden ich mit meinem Beruf bin, es ist immer sinnvoll, nach besseren Optionen Ausschau zu halten.	☐	☐	☐	☐	☐
e)	Ich fantasiere oft darüber, ein Leben zu leben, das sich sehr von meinem jetzigen unterscheidet.	☐	☐	☐	☐	☐
f)	Ich bin ein großer Freund von Ranglisten (die besten Filme, die besten Sänger, die besten Sportler, die besten Bücher, etc.).	☐	☐	☐	☐	☐
g)	Es fällt mir häufig schwer, ein Geschenk für einen Freund zu kaufen.	☐	☐	☐	☐	☐
h)	Wenn ich einkaufen gehe, fällt es mir schwer, Kleidungsstücke zu finden, die ich richtig gut finde.	☐	☐	☐	☐	☐
i)	Videos auszuleihen ist sehr schwierig. Ich mühe mich stets damit ab, das Beste auszusuchen.	☐	☐	☐	☐	☐
j)	Ich finde Schreiben schwierig, sogar wenn es nur darum geht, einem Freund einen Brief zu schreiben. Es ist so schwer, die richtigen Worte zu finden. Auch von einfachen Sachen mache ich oft mehrere Entwürfe.	☐	☐	☐	☐	☐
k)	Egal was ich tue: Ich messe mich am höchsten Standard.	☐	☐	☐	☐	☐
l)	Ich gebe mich nie mit dem Zweitbesten zufrieden.	☐	☐	☐	☐	☐
m)	Wenn ich eine Entscheidung treffen soll, versuche ich mir alle anderen Möglichkeiten vorzustellen, sogar die, die momentan gar nicht zur Verfügung stehen.	☐	☐	☐	☐	☐

8. Ihr Geschlecht:

Männlich ☐ Weiblich ☐

9. Ihr Geburtsjahr:_____________________

10. Wieviele Personen leben derzeit dauerhaft in Ihrem Haushalt?____________________

11. Haben Sie Kinder?

Ja ☐ Nein ☐

a. Wenn ja: Wieviele?____________________________________

12. Über welches Geld (Einkommen, Transferleistungen, Unterhalt etc.) verfügen Sie monatlich?

Weniger als 600 Euro	☐	600 Euro bis weniger als 1.000 Euro	☐
1.000 Euro bis weniger als 2.000 Euro	☐	2.000 Euro und mehr	☐

13. Haben Sie ein Bachelorstudium absolviert?

Ja ☐ Nein ☐

a. Wenn ja: Welches?____________________________________

14. Verfügen Sie über praktische Erfahrungen in der Landwirtschaft, z.B. eigener Betrieb, durch ein Praktikum oder den elterlichen Betrieb?

Ja ☐ Nein ☐

Wenn ja: Bitte beschreiben Sie kurz (Dauer, Art der Tätigkeit)!

____

____

____

____

15. In welchem Studiengang studieren Sie derzeit?

Agrarökonomik	☐	Integrated Natural Resource Management	☐
International Master in Rural Development	☐	Agrarwissenschaften	☐

a. Wenn anderer, welcher?____

16. Wie sehr stimmen Sie folgenden Aussagen zu oder lehnen diese ab?

		Stimme voll zu	Stimme eher zu	Weder noch	Lehne eher ab	Lehne voll ab
a)	Der Umgang mit dem Computer fällt mir leicht.	☐	☐	☐	☐	☐
b)	Ich spiele häufig Computerspiele.	☐	☐	☐	☐	☐
c)	Der Umgang mit dem Computer macht mir Spaß.	☐	☐	☐	☐	☐
d)	Ich verfüge über gute Kenntnisse der landwirtschaftlichen Betriebslehre.	☐	☐	☐	☐	☐

17. Wie schätzen Sie sich persönlich ein: Sind Sie allgemein ein risikobereiter Mensch oder versuchen Sie, Risiken zu vermeiden? (Bitte kreuzen Sie auf der Skala den Wert an, der Ihrer Risikobereitschaft am besten entspricht, wobei der Wert 0 bedeutet „gar nicht risikobereit" und der Wert 10 „sehr risikobereit". Mit den Werten dazwischen können Sie Ihre Einschätzung abstufen.)

0 (gar nicht risikobereit)	1	2	3	4	5	6	7	8	9	10 (sehr risikobereit)
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

18. Wir kommen nun zur Lotterie. Bitte entscheiden Sie sich <u>in jeder der folgenden zehn</u> Entscheidungs-situationen für <u>eine</u> Alternative! Nach Ihrer Wahl wird eine der Situationen zufällig ausgewählt. Mittels eines Würfels wird dann über die Höhe der Auszahlung entschieden. Mit einer Wahrscheinlichkeit von einem Zehntel (p = 0.1) erhalten Sie die Zahlung im Anschluss an die Teilnahme in bar.

Zunächst wird mit einem zehnseitigen Würfel <u>eine Zeile</u> zufällig ausgewählt. Danach wird mittels eines weiteren Wurfs der Auszahlungsbetrag bestimmt. Sollte zum Beispiel Zeile 6 gewählt werden, erhalten Sie den abhängig von ihrer Wahl den niedrigeren Betrag, wenn der Würfel sieben oder mehr Augen zeigt. Sie erhalten den höheren Betrag, wenn der Würfel sechs oder weniger Augen zeigt. In einem dritten Schritt, wird mit einem zehnseitigen Würfel entschieden, <u>ob</u> Sie die Zahlung erhalten. Wenn der Würfel die zehn zeigt, erhalten Sie den ermittelten Betrag.

Entscheidungs-situation	Handlungsalternative 1	Handlungsalternative 2	Ich wähle Alternative 1	Ich wähle Alternative 2
1	mit 10 % Wahrscheinlichkeit Gewinn von €20,00 mit 90 % Wahrscheinlichkeit Gewinn von €16,00	mit 10 % Wahrscheinlichkeit Gewinn von €38,50 mit 90 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
2	mit 20 % Wahrscheinlichkeit Gewinn von €20,00 mit 80 % Wahrscheinlichkeit Gewinn von €16,00	mit 20 % Wahrscheinlichkeit Gewinn von €38,50 mit 80 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
3	mit 30 % Wahrscheinlichkeit Gewinn von €20,00 mit 70 % Wahrscheinlichkeit Gewinn von €16,00	mit 30 % Wahrscheinlichkeit Gewinn von €38,50 mit 70 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
4	mit 40 % Wahrscheinlichkeit Gewinn von €20,00 mit 60 % Wahrscheinlichkeit Gewinn von €16,00	mit 40 % Wahrscheinlichkeit Gewinn von €38,50 mit 60 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
5	mit 50 % Wahrscheinlichkeit Gewinn von €20,00 mit 50 % Wahrscheinlichkeit Gewinn von €16,00	mit 50 % Wahrscheinlichkeit Gewinn von €38,50 mit 50 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
6	mit 60 % Wahrscheinlichkeit Gewinn von €20,00 mit 40 % Wahrscheinlichkeit Gewinn von €16,00	mit 60 % Wahrscheinlichkeit Gewinn von €38,50 mit 40 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
7	mit 70 % Wahrscheinlichkeit Gewinn von €20,00 mit 30 % Wahrscheinlichkeit Gewinn von €16,00	mit 70 % Wahrscheinlichkeit Gewinn von €38,50 mit 30 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
8	mit 80 % Wahrscheinlichkeit Gewinn von €20,00 mit 20 % Wahrscheinlichkeit Gewinn von €16,00	mit 80 % Wahrscheinlichkeit Gewinn von €38,50 mit 20 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
9	mit 90 % Wahrscheinlichkeit Gewinn von €20,00 mit 10 % Wahrscheinlichkeit Gewinn von €16,00	mit 90 % Wahrscheinlichkeit Gewinn von €38,50 mit 10 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐
10	mit 100 % Wahrscheinlichkeit Gewinn von €20,00 mit 0 % Wahrscheinlichkeit Gewinn von €16,00	mit 100 % Wahrscheinlichkeit Gewinn von €38,50 mit 0 % Wahrscheinlichkeit Gewinn von €1,00	☐	☐

F Curriculum vitae

Persönliche Informationen

Name	Appel, Dipl. Ing. agr., Franziska
Geburtsdatum	21 Januar 1986
Geburtsort	Herzberg (Elster)
Geschlecht	weiblich
Wohnsitz	Von-Arnim-Straße 21 06118 Halle (Saale)
Staatsangehörigkeit	deutsch

Bildungsweg

2009	Diplom in Wirtschafts-und Sozialwissenschaften des Landbaus, Martin-Luther-Universität Halle-Wittenberg
2005	Abitur, Geschwister-Scholl-Gymnasium, Sangerhausen

Beruflicher Werdegang

2009 - bis jetzt	Wissenschaftliche Mitarbeiterin, Leibniz-Institute für Agrarentwicklung in Transformationsökonomien (IAMO)
2009 - 2011	Tutorin, Martin-Luther-Universität Halle-Wittenberg
2007 - 2009	Studentische Hilfskraft, Leibniz-Institute für Agrarentwicklung in Transformationsökonomien (IAMO)

G Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich die vorliegende Arbeit selbstständig und ohne fremde Hilfe verfasst habe. Es wurden keine anderen als die in der Arbeit angegebenen Quellen und Hilfsmittel benutzt. Die den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen sind als solche kenntlich gemacht.

Hiermit erkläre ich, dass ich noch keine vergeblichen Promotionsversuche unternommen habe und die vorliegende Dissertation nicht in der gegenwärtigen bzw. in einer anderen Fassung bereits einer anderen Fakultät / anderen wissenschaftlichen Einrichtung vorgelegt habe.

Halle/Saale,

Unterschrift

References

Able, N., Ross, H., and Walker, P. Mental Models in Rangeland Research, Communication and Management. *The Rangeland Journal*, 20(1):77–91, 1998. doi: 10.1071/RJ9980077.

Ackermann, R. Pfadabhängigkeit, Institutionen und Regelreform. *Die Einheit in der Gesellschaftswissenschaten*, 120, 2001. Tübingen, Mohr Siebeck.

AEE. Technical report.

Agrarheute. Milchpreise, 2012. URL `http://agrarheute.com`.

Aldrich, C. *Simulations and the Future of Learning*. Pfeiffer, San Diego, 2004.

Antona, M., D'Aquino, P., Aubert, S., Barreteau, O., Boissau, S., Bousquet, F., Daré, W., Etienne, M., Le Page, C., Mathevet, R., and Trébuil, G. Our companion modelling approach (La modélisation comme outil d'accompagnement). *Journal of Artificial Societies and Social Simulation*, 6(2), 2003. doi: 10.1051/nss:2005023.

Appel, F. and Balmann, A. Human behaviour versus optimising agents and the resilience of farms – Insights from agent-based participatory experiments with FarmAgriPoliS. *Ecological Complexity*, 2018. doi: 10.1016/j.ecocom.2018.08.005. in press.

Appel, F., Ostermeyer-Wiethaup, A., and Balmann, A. Effects of the German Renewable Energy Act on structural change in Agriculture – The case of biogas. *Utilities Policy*, 41:172–182, 2016.

Appel, F., Balmann, A., Dong, C., and Rommel, J. FarmAgriPoliS – An Agricultural Business Management Game for Behavioral Experiments, Teaching, and Gaming. Technical report, IAMO Discussion Paper No. 173, Halle (Saale), 2018. URL `https://www.iamo.de/fileadmin/documents/dp173.pdf`.

Ariely, D. *Predictably Irrational, Revised and Expanded Edition - The Hidden Forces That Shape Our Decisions*. HarperCollins, New York, revised an edition, 2010. ISBN 978-0-061-35324-6.

Arthur, W. B. Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *The Economic Journal*, 99(394):116–131, 1989. doi: 10.2307/2234208. URL `http://www.jstor.org/stable/2234208`.

Axelrod, R. Advancing the Art of Simulation in the Social Sciences. In Conte, R., Hegselmann, R., and Terna, P., editors, *Simulating Social Phenomena*, pages 21–40. Springer Verlag, Berlin, 1997.

Axelrod, R. and Tesfatsion, L. A Guide for Newcomers to Agent-based Modeling in the Social Sciences, Appendix A. In Tesfatsion, L. and Judd, K., editors, *Handbook of Computational Economics*, volume 2, pages 1647–1659. Elsevier, Agent-Based Computational Economics, Handbooks in Economics Series. Amsterdam edition, 2006.

Bach, N. *Mentale Modelle als Basis von Implementierungsstrategien - Konzepte für ein erfolgreiches Change Management*. Technische Universität Ilmenau, Ilmenau, 2010. URL http://www.db-thueringen.de/servlets/DerivateServlet/Derivate-20061/ilm1-2010200029.pdf.

Balkhausen, O., Banse, M., and Grethe, H. Modelling CAP Decoupling in the EU: A Comparison of Selected Simulation Models and Results. *Journal of Agricultural Economics*, 59(19):57–71, 2006. doi: 10.1111/j.1477-9552.2007.00135.x.

Balmann, A. *Pfadabhängigkeiten in Agrarstrukturentwicklungen - Begriff, Ursachen und Konsequenzen*. Duncker & Humblot Berlin, 1995.

Balmann, A. Farm-based modelling of regional structural change: A cellular automata approach. *European Review of Agricultural Economics*, 24(1):85–108, 1997. doi: 10.1093/erae/24.1.85.

Balmann, A. Braucht der ostdeutsche Bodenmarkt eine stärkere Regulierung? *Agra-Europe*, (13/15):49–56, 2015.

Balmann, A. and Schaft, F. Zukünftige ökonomische Herausforderungen der Agrarproduktion: Strukturwandel vor dem Hintergrund sich ändernder Märkte, Politiken und Technologien. *Archives of Animal Breeding*, 2008.

Balmann, A. and Valentinov, V. Towards a Theory of Structural Change in Agriculture: Just Economics? In *EAAE 149th Seminar*, Rennes, 2016. URL http://ageconsearch.umn.edu/bitstream/246420/2/Balmann{_}Valentinov{_}149EAAE{_}Rennes.pdf.

Balmann, A., Odening, M., Weickard, H., and Brandes, W. Path-dependence without increasing returns to scale and network externalities. *Journal of Economic Behavior & Organization*, 1996. doi: 10.1016/0167-2681(95)00055-0.

Balmann, A., Dautzenberg, K., Happe, K., and Kellermann, K. On the dynamics of structural change in agriculture: Internal frictions, policy threats and vertical integration. *Outlook on Agriculture*, 35(2):115–121, 2006.

Balmann, A., Appel, F., Franz, R., Graubner, M., Ostermeyer, A., and Sahrbacher, C. Analyse der Wettbewerbsfähigkeit der Milcherzeugung und -verarbeitung in Sachsen-Anhalt zur Ermittlung geeigneter Politikmaßnahmen und Politikoptionen im Rahmen des EPLR. Technical report, 2010.

Bardt, H., Niehues, J., and Techert, H. Die Förderung erneuerbarer Energien in Deutschland – Wirkungen und Herausforderungen des EEG. Technical report, BMELV – Bundesministerium für Landwirtschaft, Ernährung und Verbraucherschutz, 2012.

Barreteau, O., Bousquet, F., and Attonaty, J.-M. Role-playing games for opening the black box of multi-agent systems: Method and teachings of its application to Senegal River valley irrigated systems. *Journal of Artificial Societies and Social Simulations*, 4 (2), 2001.

Barreteau, O., Le Page, C., and D'Aquino, P. Role-Playing Games, Models and Negotiation Processes. *Journal of Artificial Societies and Social Simulation*, 6(2), 2003.

Berger, T. Agent-based spatial models applied to agriculture: a simulation tool for technology diffusion, resource use changes and policy analysis. *Agricultural Economics*, 25 (2/3):254–260, 2001.

Berger, T. and Schreinemachers, P. Creating Agents and Landscapes for Multiagent Systems from Random Samples. *Ecology & Society*, 11, 2006.

BLF. Technical report.

BMJ – Bundesministerium der Justiz. Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG)., 2008. URL `available:http://www.gesetze-im-internet.de/bundesrecht/REA_2009/gesamt.pdf`.

BMJ – Bundesministerium der Justiz. Erstes Gesetz zur Änderung des Erneuerbare-Energien-Gesetzes, 2010. URL `http://www.bgbl.de/Xaver/start.xav?startbk=Bundesanzeiger_BGBl&bk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl110s1170.pdf%27]`.

BMJ – Bundesministerium der Justiz. Gesetz zur Neuregelung des Rechtsrahmens für die Förderung der Stromerzeugung aus erneuerbaren Energien, 2011. URL `http://www.bmu.de/english/renewable_energy/doc/47883.phphttp://www.bgbl.de/Xaver/start.xav?startbk=Bundesanzeiger_BGBl`.

Boehlje, M. Structural Changes in the Agricultural Industries: How Do We Measure, Analyze and Understand Them? *American Journal of Agricultural Economics*, 81(5): 1028–1041, 1999.

Brandes, W. Über Selbstorganisation in Planspielen – Ein Erfahrungsbericht. *Schriften des Vereins für Sozialpolitik*, 195(IV):61–83, 2002.

Brandes, W., Müller, H., and Weikard, H. P. Puten und Perlhühner - Ein vorlesungsbegleitendes Unternehmens-Planspiel für das Grundstudium, 1990.

Braun, J., Lorleberg, W., and Wacup, H. Regionale Struktur- und Einkommenswirkungen der Biogasproduktion in NRW. Technical report, Fachhochschule Südwestfalen, Soest, 2009. URL https://www4.fh-swf.de/media/downloads/fbaw_1/forschung_1/abgeschlossene_fp/agraroekonomie/AB-Struktur-Einkommenswirkung_Biogas.pdf.

Brendel, F. Energie im großen Stiel - Auswirkungen des Biogas-Booms auf Umwelt, Artenvielfalt und Landwirtschaft. Technical report, WWF, Berlin, 2011. URL http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Biogas_Energie_im_grossen_Stiel.pdf.

Camerer, C. F. and Fehr, E. When Does "Economic Man" Dominate Social Behavior? *Science*, 311(5757):47–52, 2006. ISSN 0036-8075. doi: 10.1126/science.1110600. URL http://science.sciencemag.org/content/311/5757/47.

Chatalova, L., Müller, D., Valentinov, V., and Balmann, A. The Rise of the Food Risk Society and the Changing Nature of the Technological Treadmill. *Sustainability*, 8(6): 584, jun 2016. ISSN 2071-1050. doi: 10.3390/su8060584. URL http://dx.doi.org/10.3390/su8060584.

Cochrane, W. W. *Farm Prices: Myth and Reakity.* University of Minnesota Press, 1958.

Colen, L., Gomez y Paloma, S., Latacz-Lohmann, U., Lefebvre, M., Préget, R., and Thoyer, S. Economic Experiments as a Tool for Agricultural Policy Evaluation: Insights from the European CAP. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 64(4):667–694, 2016. ISSN 1744-7976. doi: 10.1111/cjag.12107. URL http://dx.doi.org/10.1111/cjag.12107.

Cowan, R. and Gunby, P. Sprayed to Death: Path Dependence, Lock-in and Pest Control Strategies. *The Economic Journal*, 106(436):521–542, 1996. ISSN 00130133, 14680297. doi: 10.2307/2235561. URL http://www.jstor.org/stable/2235561.

Craton, P. Teaching for transformation. *New Directions for Adult and Continuing Education*, 93:63–72, 2002.

David, P. A. Clio and the Economics of QWERTY. *The American Economic Review*, 75 (2):332–337, 1985. ISSN 00028282. doi: 10.2307/1805621. URL http://www.jstor.org/stable/1805621.

Day, R. H. *Recursive programming and production response* -. North-Holland, Amsterdam, 1963.

Denzau, A. and North, D. Shared Mental Models: Ideologies and Institutions. *Kyklos*, 47 (1):3–31, 1994.

DIW. Leben in Deutschland: Befragung 2010 zur sozialen Lage der Haushalte, 2010. URL `http://www.diw.de/dokuments/dokumentenarchiv/17/diw_01.c.369781.de/soepfrabo_personen_2010.pdf`.

Dries, L., Reardon, T., and Swinnen, J. The Rapid Rise of Supermarkets in Central and Eastern Europe: Implications for the Agrifood Sector and Rural Development. . *Development Policy Review*, 22(5):525–556, 2004.

Eckert, E. and Bell, A. Invisible Force: Farmers' Mental Models and How They Influence Learning and Actions. *Journal of Extension*, 43(3), 2005. URL `http://www.joe.org/joe/2005june/a2.php`.

Eckert, E. and Bell, A. Continuity and Change: Themes of Mental Model Development Among Small-Scale Farmers. *Journal of Extension*, 44(1), 2006. URL `http://www.joe.org/joe/2006february/a2.php`.

Eisgruber, L. Farm Operation Simulator and Farm Management Decision Exercise. Technical report, Purdue University, Agricultural Experiment Station, 1990.

Epanechnikov, V. A. Non-Parametric Estimation of a Multivariate Probability Density. *Theory of Probability & Its Applications*, 14(1):153–158, 1969. doi: 10.1137/1114019.

Ewald, J., Maart, S. C., and Mußhoff, O. Messung der subjektiven Risikoeinstellung von Entscheidern: Existieren Methoden- und Personengruppenunterschiede? *German Journal of Agricultural Economics*, 61(3), 2012.

Fachverband Biogas. Biogas Segment Statistics 2014. Technical report, 2014. URL `http://www.biogas.org/edcom/webfvb.nsf/id/DE{\_}Branchenzahlen/{\$}file/14-11-25{\_}Biogasindustryfigures{\_}2014-2015{\_}english.pdf`.

Fachverband Biogas. Assessment on a Request, 2015.

Fiore, S. M., Harrison, G. W., Hughes, C. E., and Rutström, E. E. Virtual experiments and environmental policy. *Journal of Environmental Economics and Management*, 57 (1):65–86, 2009.

Folke, C. Resilience: The emergence of a perspective for social?ecological systems analyses. *Global Environmental Change*, 16(3):253–267, 2006. ISSN 0959-3780. doi: https://doi.org/10.1016/j.gloenvcha.2006.04.002. URL `http://www.sciencedirect.com/science/article/pii/S0959378006000379`.

Freeman, T., Nolan, J., and Schoney, R. An agent-based simulation model of structural change in Canadian Prairie Agriculture, 1960–2000. *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie*, pages 537–554, 2009.

Garud, R. and Karnøe, P. *Path Creation as a Process of Mindful Deviation*. Lawrence Erlbaum Associates, Mahwah, London, 2001.

Garud, R., Kumaraswamy, A., and Karnøe, P. Path Dependence or Path Creation. *Journal of Management Studies*, 47(4):760–774, 2001. doi: 10.1111/j.1467-6486.2009.00914.x.

GIANTS Software. Farming Simulator, 2015. URL `http://www.farming-simulator.com/?lang=en{\&}sublang=gb`.

Gittell, J., Cameron, K., Lim, S., and Rivas, V. Relationships, layoffs, and organizational resilience: airline industry responses to September 11. *Journal of Applied Behavioral Science*, 42:300–329, 2006. doi: 10.1177/0021886306286466.

Goddard, E., Weersink, A., Chen, K., and Turvey, C. G. Economics of Structural Change in Agriculture. *Canadian Journal of Agricultural Economics*, 41(4):475–489, 1993.

Greifeneder, R. and Betsch, C. Lieber die Taube auf dem Dach!: Eine Skala zur Erfassung interindividueller Unterschiede in der Maximierungstendenz. *Zeitschrift f{ü}r Sozialpsychologie*, 37(4):233–243, 2006.

Grundmann, P. and Klauss, H. The impact of global trends in bioenergy production, food supply and global warming potential – an impact assessment of land-use changes in four regions in Germany using linear programming. *Journal of Land Use Science*, 9(1): 34–58, 2014.

Grundmann, P., Kenkmann, T., Luckhaus, C., and Plöchl, M. Biogas in der Landwirtschaft – Leitfaden für Landwirte und Investoren im Land Brandenburg. Technical report, Ministerium für Ländliche Entwicklung, Umwelt und Verbraucherschutz des Landes Brandenburg, Potsdam, 2006.

Guyot, P. and Honiden, S. Agent-Based Participatory Simulations: Merging Multi-Agent Systems and Role-Playing Games. *Journal of Artificial Societies and Social Simulation*, 9(4), 2006.

Habermann, H. and Breustedt, G. Einfluss der Biogaserzeugung auf landwirtschaftliche Pachtpreise in Deutschland. *German Journal of Agricultural Economics*, 60(2):85–100, 2011.

Hanff, H., Neubert, G., and Brudel, H. Datensammlung für die Betriebsplanung und die betriebswirtschaftliche Bewertung landwirtschaftlicher Produktionsverfahren im Land Brandenburg. Technical report, MLUV – Ministerium für Ländliche Entwicklung, Umwelt und Verbraucherschutz des Landes Brandenburg, 2008. URL `http://lelf.brandenburg.de/media_fast/4055/Datensammlung_08.pdf`.

Happe, K. 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*, 30, 2004.

Happe, K., Kellermann, K., and Balmann, A. Agent-based Analysis of Agricultrual Policies: An Illustration of the Agricultural Policy Simulator AgriPoliS, its Adaptation and Behaviour. *Ecology and Society*, 11(1), 2006. URL `http://www.ecologyandsociety.org/vol11/iss1/art49`.

Happe, K., Balmann, A., Kellermann, K., and Sahrbacher, C. Does structure matter? The impact of switching the agricultural policy regime on farm structures. *Journal of Economic Behavior & Organization*, 67:431–444, 2008.

Harrison, G. W. and List, J. A. Field experiments. *Journal of Economic Literature*, 42 (4):1009–1055, 2004.

Heady, E. O. Models for agricultural policy: The CARD example. *European Review of Agricultural Economics*, 10(1):1–14, 1983. doi: 10.1093/erae/10.1.1.

Hellerstein, D., Higgins, N., and Horowitz, J. The predictive power of risk preference measures for farming decisions. *European Review of Agricultural Economics*, 40(5):807, 2013. doi: 10.1093/erae/jbs043. URL `+http://dx.doi.org/10.1093/erae/jbs043`.

Hemmerling, U. Was folgt auf die EEG-Notbremse?, 2013. URL `http://www.bauernverband.de/altmaiers-energiewende-folgt-eeg-notbremse`.

Hinners-Tobrägel, L. and Brandes, W. Das Planspiel "Wachsen oder Weichen". *Zeitschrift f{ü}r Agrarinformatik*, 5:88–96, 1997.

Hobohm, J. and Mellahn, S. Investitionen durch den Ausbau erneuerbarer Energien in Deutschland. Technical report, Prognos AG, Berlin, 2010. URL `https://www.prognos.com/publikationen/alle-publikationen/237/show/3b1c5044747e321248867d1b29199423/`.

Holling, C. S. Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, pages 1–23, 1973. doi: 10.1146/annurev.es.04.110173.000245.

Holt, C. A. and Laury, S. K. Risk Aversion and Incentive Effects. *American Economic Review*, 92(5):1644–1655, 2002.

Howitt, R. E. A CALIBRATION METHOD FOR AGRICULTURAL ECONOMIC PRODUCTION MODELS. *Journal of Agricultural Economics*, 46(2):147–159, 1995. ISSN 1477-9552. doi: 10.1111/j.1477-9552.1995.tb00762.x. URL `http://dx.doi.org/10.1111/j.1477-9552.1995.tb00762.x`.

Howley, P. The Happy Farmer: The Effect of Nonpecuniary Benefits on Behavior. *American Journal of Agricultural Economics*, 97(4):1072–1086, 2015. doi: 10.1093/ajae/aav020.

Hüttel, S., Odening, M., Kataria, K., and Balmann, A. Price Formation on Land Market Auctions in East Germany – An Empirical Analysis. 2012.

Johnson-Laired, P. Mental Models. Towards a cognitive science of language, inference, and consciousness. In *Cognitive Science series 6*. Cambridge, Mass.:Harvard Univ. Press, 1983.

Jones, B. L. and Nagin, D. S. A Note on a Stata Plugin for Estimating Group-based Trejectory Models. *Sociological Methods Research*, 42(4):608–613, 2013. doi: 10.1177/0049124113503141.

Jones, N. A., Ross, H., Lynam, T., Perez, P., and Leitch, A. Mental models: an interdisciplinary synthesis of theory and methods. *Ecology and Society*, 16(1), 2011. URL http://www.ecologyandsociety.org/vol16/iss1/art46/.

Juris – Bundesministerium der Justiz und für Verbraucherschutz. Gesetz für den Ausbau erneuerbarer Energien, 2014. URL http://www.gesetze-im-internet.de/eeg_2014/index.html.

Kahnemann, D. *Thinking fast and slow*. Macmillan, New York, 2011.

Kahnemann, D. and Tversky, A. Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47(2):263–292, 1979.

Kay, A. A Critique of the Use of Path Dependency in Policy Studies. *Public Administration*, 83(3):553–571, 2005.

Kellermann, K., Happe, K., Sahrbacher, C., Balmann, A., Brady, M., Schnicke, H., and Osuch, A. Agripolis 2.1 - Model documentation. Technical report, IAMO, 2008.

Kilian, S., Anton, J., Röder, N., and Salhofer, K. Impacts of 2003 CAP Reform on Land Prices: From Theory to Empirical Results. In *109th EAAE Seminar*, Viterbo, 2008.

Kline, R. *Principles and Practice of Structural Equation Modeling*. Guilford, 3 edition, 2011.

KLU. Biogaserzeugung und -nutzung: Ökologische Leitplanken für die Zukunft. Technical report, Kommission Landwirtschaft beim Umweltbundesamt (KLU), Dessau-Roßlau, 2013. URL https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/biogaserzeugung{_}und{_}-nutzung{_}oekologische{_}leitplanken{_}fuer{_}die{_}zukunft.pdf.

KTBL. Wirtschaftlichkeitsrechner Biogas, 2010. URL http://daten.ktbl.de/biogas/.

Landtag von Sachsen-Anhalt. Antwort der Landesregierung auf eine Kleine Anfrage zur schriftlichen Beantwortung. Technical report, Landtag von Sachsen-Anhalt, 2014. URL http://dorothea-frederking.de/userspace/SA/dorothea{_}frederking/Dokumente/Kleine{_}Anfragen/Kleine{_}Anfragen{_}mit{_}Antworten{_}der{_}LR/Drs.{_}6-2889{_}KA{_}Bestand{_}und{_}Groesse{_}von{_}Biogasanlagen.pdf.

LFL. Datenbankauszug "Biogas Betreiber Datenbank Bayern" (BBD). Technical report, Bayerische Landesanstalt für Landwirtschaft - LfL, 2014. URL http://www.lfl.bayern.de/mam/cms07/iba/dateien/bbd{_}biogasinzahlen{_}bayern{_}20131231{_}stat.pdf.

Longworth, J. W. MANAGEMENT GAMES AND THE TEACHING OF FARM MANAGEMENT*1. *Australian Journal of Agricultural Economics*, 13(1):58–67, 1969. ISSN 1467-8489. doi: 10.1111/j.1467-8489.1969.tb00055.x. URL http://dx.doi.org/10.1111/j.1467-8489.1969.tb00055.x.

Lupp, G., Steinhäußer, R., Starick, A., Gies, M., Bastian, O., and Albrecht, J. Forcing Germany's renewable energy targets by increased energy crop production: A challenge for regulation to secure sustainable land use practices. *Land Use Policy*, 36:296–306, 2014.

Luthans, F. The need for and meaning of positive organizational behavior. *Journal of Organizational Behavior*, 23:695–706, 2002. doi: 10.1002/job.165.

Mann, L., Burnett, P., Radford, M., and Ford, S. The Melbourne Decision Making Questionaire: An instrument for measuring patterns for coping with decisional conflict. *Journal of Behavioral Decision Making*, 10(1):1–19, 1997. doi: 10.1002/(SICI)1099-0771(199703)10:1⟨1::AID-BDM242⟩3.0.CO;2-X.

Maurin, J. Energie aus Gülle und Mais - Der Aufstand der Biogasbauern, 2015. URL http://www.taz.de/!5221195/.

Meyer, U. and Schubert, C. Die Konstitution technologischer Pfade. Überlegungen jenseits der Dichotomie von Pfadabhängigkeit und Pfadkreation. 2005.

Möhring, A., Mack, G., Zimmermann, A., Ferjani, A., Schmidt, A., and Mann, S. Agent-based modeling on a national scale – Experiences from SWISSland. *Agroscope Science*, 30:1–56, 2016.

Müller-Frank, S. Renditeobjekt Ackerland - Die Auswirkungen von Bodenspekulationen auf die deutsche Landwirtschaft, 2013. URL http://www.deutschlandfunk.de/renditeobjekt-ackerland.724.de.html?dram:article{_}id=244778.

Mußhoff, O., Hirschauer, N., and Hengel, P. Are Business Management Games a Suitable Tool for Analyzing the Boundedly Rational Behavior of Economic Agents? *Modern Economy*, 2(4):468–478, 2011.

Nagin, D. S. *Group-Based Modeling of Development.* Harvard University Press, 2005.

Nolan, J., Parker, D., van Kooten, G., and Berger, T. An Overview of Computational Modeling in Agricultural and Resource Economics. *Canadian Journal of Agricultural Economics*, 57:417–429, 2009.

North, D. C. *Institutions, Institutional Change, and Economic Performance*. Cambridge University Press, Cambridge, 1990.

Ostermeyer, A. Milchproduktion zwischen Pfadabhängigkeit und Pfadbrechung - Partizipative Analysen mit Hilfe des agentenbasierten Modells AgriPoliS. Technical report, IAMO, 2015.

Pareto, V. *Manual of political economy.* 1906.

Pierson, P. Increasing Returns, Path Dependence, and the Study of Politics. *American Political Science Review*, 129:220–229, 2000. doi: 10.2307/2586011.

Railsback, S. and Grimm, V. *Agent-Based and Individual-Based Modeling: A Practical Introduction.* Princeton University Press, 2011.

Reardon, T. and Berdegué, J. A. The Rapid Rise of Supermarkets in Latin America: Challenges and Opportunities for Development. *Development Policy Review*, 20(4): 371–388, 2002.

Reardon, T. and Swinnen, J. Agrifood Sector Liberalisation and the Rise of Supermarkets in Former State-controlled Economies: A Competitive Overview. *Development Policy Review*, 22(5):515–23, 2004.

Regionale Planungsgemeinschaft Altmark. Wieder erfolgreich im Bundeswettbewerb: Die Altmark ist Bioenergie-Region, 2012. URL `http://altmark.eu/bioenergie-region`.

Reutemann, T., Engel, S., and Pareja, E. How (not) to pay: Field experimental evidence on the design of REDD+ payments. *Ecological Economics*, 129:220–229, 2016. doi: 10.1016/j.ecolecon.2016.05.020.

Ricardo, D. *Principles of Political Economy and Taxation.* 1817.

Richter, R. Prozesskosten im Ackerbau in Sachsen-Anhalt - Ausgabe 2009. Technical report, LLFG – Landesanstalt für Landwirtschaft, Forsten und Gartenbau Sachsen-Anhalt, 2009. URL `https://llg.sachsen-anhalt.de/fileadmin/Bibliothek/`

Politik_und_Verwaltung/MLU/LLFG/Dokumente/04_themen/betriebswirtschaft/prozesskosten/ri_prozess_09.pdf.

Röhling, I. and Keymer, U. Biogasanlagen in Bayern 2006 - Ergebnisse einer Umfrage. Technical report, Bayerische Landesanstalt für Landwirtschaft – LfL, München, 2006. URL http://www.lfl.bayern.de/mam/cms07/iba/dateien/biogasanlagenumfrage_bayern_2006.pdf.

Rommel, J., Hermann, D., Müller, M., and Mußhoff, O. Comprehension in risk elicitation experiments. *Applied Economics Letters*, 24(9):627–634, 2017.

Sahrbacher, C., Sahrbacher, A., Kellermann, K., Happe, K., Balmann, A., and Brady, M. ODD-Protocol of AgriPoliS. Technical report, IAMO, 2012. URL http://projects.iamo.de/agripolis/documentation/ODD{_}AgriPoliS.pdf.

Sahrbacher, C., Sahrbacher, A., and Balmann, A. Parameterisation of AgriPoliS: A Model of Agricultural Structural Change. In Smajgl, A. and Barreteau, O., editors, *Empirical Agent-Based Modelling - Challenges and Solutions, Volume 1, The Characterisation and Parameterisation of Empirical Agent-Based Models*, chapter 6, pages 105–121. Springer, New York, 2014. doi: 10.1007/978-1-4614-6134-0_6.

Schreinemachers, P. and Berger, T. An agent-based simulation model of human-environment interactions in agricultural systems. *Environmental Modelling & Software*, 26(7):845–859, 2011. ISSN 1364-8152. doi: https://doi.org/10.1016/j.envsoft.2011.02.004. URL http://www.sciencedirect.com/science/article/pii/S1364815211000314.

Schreyögg, G., Sydow, J., and Koch, J. Organisatorische Pfade – Von der Pfadabhängigkeit zur Pfadkreation? In Schreyögg, G. and Sydow, J., editors, *Managementforschung 13: Strategische Prozesse & Pfade*, pages 257–294. Gabler-Verlag, Wiesbaden, 2003.

Schröder, D. Ärger um Biogasanlage - Kalter Krieg in Ostfriesland, 2010. URL http://www.spiegel.de/wirtschaft/unternehmen/aerger-um-biogasanlage-kalter-krieg-in-ostfriesland-a-664487.html.

Schumpeter, J. *Capitalism, Socialism and Democracy.* 1942.

Schwartz, B., Ward, A., Monterosso, J., Lyubomirsky, S., White, K., and Lehman, D. R. Maximizing versus satisficing: Happiness is a matter of choice. *Journal of Personality & Social Psychology*, 83:1178–1197, 2002. doi: 10.1037//0022-3514.83.5.1178.

Schwarze, J., Holst, G. S., and Musshoff, O. Do farmers act like perfectly rational profit maximisers? Results of an extra-laboratory experiment. *International Journal of Agricultural Management*, 4(1):11–20, 2014.

Scott, S. G. and Bruce, R. A. Decision-making style: The development and assessment of a new measure. *Educational and Psychological Measurement*, 55(5):818–831, 1995. doi: 10.1177/0013164495055005017.

Sitkin, S. B. Learning through failure: the strategy of small losses. *Research in Organizational Behavior*, 14:231–266, 1992.

Sombart, W. *Die drei Nationalökonomien. Geschichte und System der Lehre von der Wirtschaft*. Zeller Verlag, Mettingen, 1967.

Stack, M. and Gartland, M. P. Path Creation, Path Dependency, and Alternative Theories of the Firm. *Journal of Economic Issues*, 37(2):487–494, 2003. doi: 10.1080/00213624.2003.11506597.

StaLa. Agrarstrukturerhebung Teil 3: Betriebswirtschaftliche Ausrichtung, Standarddeckungsbeiträge, sozialökonomische Verhältnisse der landwirtschaftlichen Betriebe. Technical report, Statistisches Landesamt Sachsen-Anhalt, Halle/ Saale, 2008a. URL `http://www.stala.sachsen-anhalt.de/download/stat_berichte/6C404_4j_2007.pdf`.

StaLa. Bodennutzung in landwirtschaftlichen Betrieben - Agrarstrukturerhebung 2007. Technical report, Statistisches Landesamt Sachsen-Anhalt, Halle/Saale, 2008b.

StaLa. Ausgewählte Merkmale der landwirtschaftlichen Betriebe nach Kreisen 2013. Technical report, Statistisches Landesamt Sachsen-Anhalt, Halle/Saale, 2014. URL `http://www.stala.sachsen-anhalt.de/Internet/Home/Daten{\%}7B{\_}{\%}7Dund{\%}7B{\_}{\%}7DFakten/4/41/411/41121/Ausgewaehlte-Merkmale-nach-Kreisen-2013-.html.Archievedat:http://www.webcitation.org/6p6alTeTc`.

Sutcliffe, K. M. and Vogus, T. J. Organizing for resilience. In Cameron, K. S., Dutton, J. E., and Quinn, R. E., editors, *Positive Organizational Scholarship: Foundations of a New Discipline*. Berrett-Koehler, San Francisco, CA, 2003.

Sydow, J., Schreyögg, G., and Koch, J. Organizational Paths: Path Dependency and Beyond. 2005.

Tesfatsion, L. Agent-Based Computational Economics. Growing Economies from the Bottom Up, 2012. URL `http://www2.econ.iastate.edu/tesfatsi/ace.htm`.

Thaler, R. *The Winner's Curse - Paradoxes and Anomalies of Economic Life*. Simon and Schuster, New York, 2012. ISBN 978-1-451-69787-2.

Theuvsen, L. Pfadabhängigkeit als Forschungsprogramm für die Agrarökonomie. *Agrarwirtschaft*, 53(3):111–122, 2004. URL `http://www.gjae-online.de/news/pdfstamps/freeoutputs/GJAE-307_2004.pdf.`

Thünen-Atlas. Thünen-Atlas zur landwirtschaftlichen Nutzung. Technical report, Johann Heinrich von Thünen-Institut, Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei, Braunschweig, 2015. URL `https://gdi.ti.bund.de/lr/agraratlas/`.

Tinbergen, J. *Shaping the World Economy: Suggestions for an International Economic Policy*. The Twentieth Century Fund, 1962.

Torres-Guevara, L. E. and Schlüter, A. External validity of artefactual field experiments: A study on cooperation, impatience and sustainability in an artisanal fishery in Colombia. *Ecological Economics*, 128:187–201, 2016. doi: https://doi.org/10.1016/j.ecolecon.2016.04.022. URL `http://www.sciencedirect.com/science/article/pii/S0921800915305310`.

Tweeten, L. *Causes and consequences of structural change in the farming industry -*. Food and Agriculture Committee, Washington, D.C., 1984. ISBN 978—0-8-90-68-0.

Uthes, S., Piorr, A., Zander, P., Bienkowski, J., Ungaro, F., Dalgaard, T., Stolze, M., Moschitz, H., Schader, C., Happe, K., Sahrbacher, A., Damgaard, M., Toussaint, V., Sattler, C., Reinhardt, F. J., Kjeldsen, C., Casini, L., and Müller, K. Regional impacts of abolishing direct payments: An integrated analysis in four European regions. *Agricultural Systems*, 104:110–121, 2011.

Viceisza, A. C. Treating the field as a lab: A basic guide to conducting economics experiments for policymaking. Technical report, International Food Policy Research Institute, 2012.

von Thünen, J. H. *Der isoli[e]rte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, oder Untersuchungen über den Einfluß, den die Getreidepreise, der Reichthum des Bodens und die Abgaben auf den Ackerbau ausüben*. Perthes, Hamburg.

Walker, B. and Salt, D. *Resilience Thinking - Sustaining Ecosystems and People in a Changing World*. Island Press, Washington, 2012. ISBN 978-1-597-26622-2.

Weick, K. E., Sutcliffe, K. M., and Obstfeld, D. Organizing for high reliability: processes of collective mindfulness. *Research in Organizational Behavior*, 21:81–124, 1999.

Weiss, C. R. Farm Growth and Survival: Econometric Evidence for Individual Farms in Upper Austria. *American Journal of Agricultural Economics*, 81:103–116, 1999. doi: 10.2307/1244454.

Wells, R. A. Management Games and Simulations in Mnagement Development: An Introduction. *Journal of Management Development*, 9(2):4–6, 1990.

Wildavsky, A. B. *Searching for Safety*. Transaction Publishers, New Brunswick, NJ, 1988. ISBN 978-1-412-83380-6. doi: 10.1002/pam.4050080329.