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# FarmAgriPoliS – An Agricultural Business Management Game for Behavioral Experiments, Teaching, and Gaming

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# 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 platform. 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

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# 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 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; and 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.

# 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.

# 3 \ Objective, Design and Description

## 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 response 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 investments. 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, satisfying 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.

## 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.

## 3.3. | **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 1) 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.

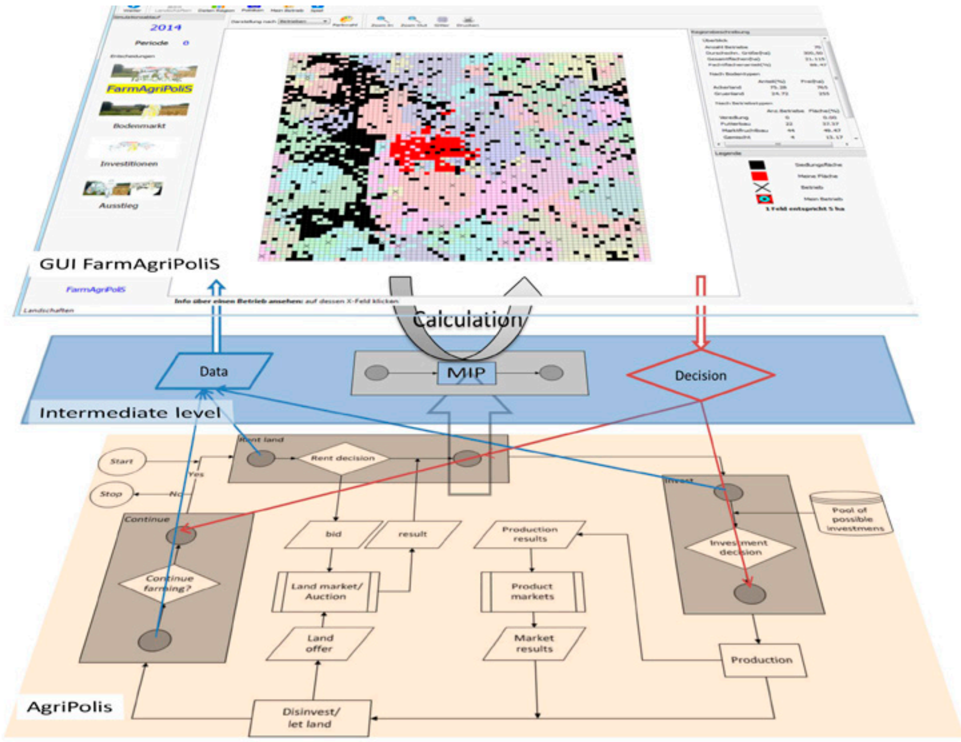


Figure 1 Interaction between AgriPoliS and FarmAgriPoliS

### 3.3.1 | **Structure and sequence of a game**

A typical experiment lasts twenty rounds (equivalent to twenty simulated years). Figure 2 illustrates the course of actions per year and highlights the situations in which a player has to decide with the gray boxes.

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. 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 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 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 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 2 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 2 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.

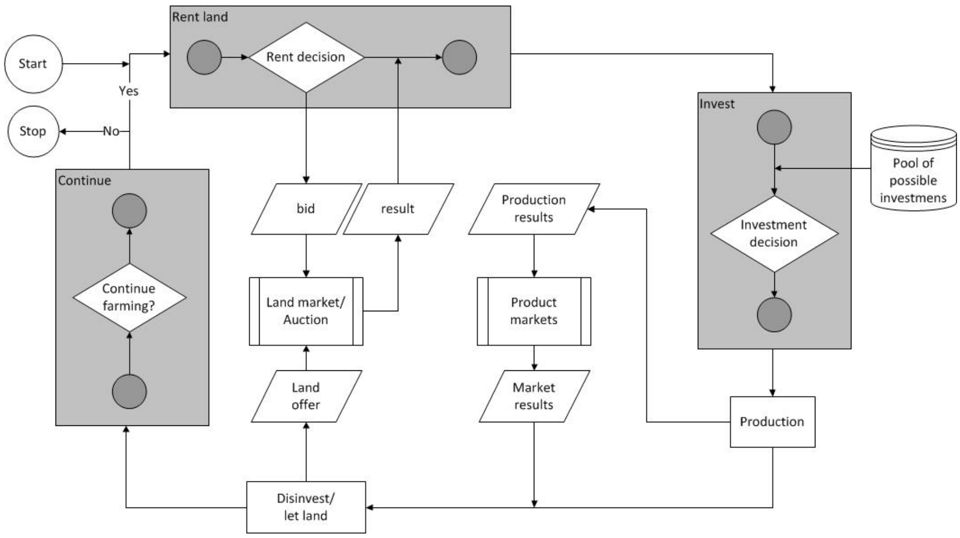


Figure 2 Flowchart of one iteration in AgriPoliS and FarmAgriPoliS
Source: Own figure based on BALMANN (1995)

### 3.3.2 | **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.

### 3.3.3 | **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 2008, 2014). In addition, the proportion of grassland is comparatively high (nearly 27%).

### 3.3.4 | **FarmAgriPoliS compared to other agricultural business management games**

Table 1 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 1 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** | www.farmagripolis.de | Farmers, students, interested stakeholders | Yes (with computer agents) | Teaching, research, entertainment |

# 4 \ Experiences from (previous) application

## 4.1. | 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 2. In total, data sets of 144 games were available for the analysis.

Table 2 Game scenarios

| Scenario | Milk price (trend) | Farm | Management skills* | Size |
|---|---|---|---|---|
| 1 | Stable | Farm 1 | Good (0.9) | Medium (665 ha) |
| 2 | Price 1 (fluctuating rising) | | | |
| 3 | Price 2 (failed expectations) | | | |
| 4 | Stable | Farm 2 | Normal (1) | Large (1,480 ha) |
| 5 | Price 1 (fluctuating rising) | | | |
| 6 | Price 2 (failed expectations) | | | |
| 7 | Stable | Farm 3 | Poor (1.15) | Medium (665 ha) |
| 8 | Price 1 (fluctuating rising) | | | |
| 9 | Price 2 (failed expectations) | | | |

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

## 4.2. | 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% 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 3 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 4 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 3 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 4 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 5). 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.

Table 5 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

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 6). 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 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 6 Rank correlation coefficient (Spearman)

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

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

## 4.3. | **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 2). 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 7). 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 for price movements to control for the two factors we manipulated in the scenario (cf. Table 2). 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 8, Model 1), as well as demographic variables such as university location, gender, and age (Table 8, Model 2). We further use a psychological decision-making-style scale (GDMS; SCOTT and BRUCE 1995), a maximization tendency scale (SCHWARTZ et al. 2002), and risk attitude (HLL; HOLT and LAURY 2002) (Table 8, Model 3). Finally, we control for players' evaluation of the game (i.e., perceived clarity, fun, and realism) (Table 8, Model 4). The following regression table includes all variables.

Table 7 Student's t-Test for selected financial indicators (at the end)

| | 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* |
| **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: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 8 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.** |
| **Farm 1** | **0.1135225*** | 0.0550257 | 0.1090029 | 0.0586362 | 0.101775 | 0.0593575 | 0.0926298 | 0.0614796 |
| **Farm 2** | **0.1609731*** | 0.0611642 | **0.1652611*** | 0.061756 | **0.168577**** | 0.0619598 | **0.1601302*** | 0.0632677 |
| Price 1 | 0.0186972 | 0.0295331 | 0.0269214 | 0.0298262 | 0.034615 | 0.0359003 | 0.0402323 | 0.0364208 |
| Price 2 | –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. Farm 2 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 2), 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. Older players also perform better (Table 8, 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.

### 4.4. | 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.

## 5 \ 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 shows, 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.

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