LAND MARKETS IN AGENT BASED MODELS OF STRUCTURAL CHANGE

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Abstract.
Land markets play a crucial role in agricultural structural change. The dynamics on land markets mainly depend on the interactions between individual farms. Agent-based modelling (ABM) provides one way to take the specific characteristics of land transactions into account, as it allows to model interactions between different agents as well as spatial relationships in a straightforward manner. However, reviewing the literature one can find only a few attempts of endogenized land markets in ABM. Furthermore, it seems that the allocation mechanisms of these endogenized land markets are chosen rather arbitrarily and not much attention is given to an intensive discussion of the impact of the respective allocation mechanisms to simulation results. To close this gap the aim of this paper is threefold: First we want to give a brief review of existing ABM with endogenized land allocation mechanisms and we identify a theoretical framework which serves as a guidance to develop a suitable and extendable land market (sub-) model. Second, we derive a number of relevant design considerations necessary to endogenize land transactions in an agent based modelling framework. Based on this we propose three different land market implementations which are based on auction mechanisms. In order to be able to evaluate the different implementations not only in relative but also in absolute terms we furthermore propose an approach to create a global optimal allocation in terms of the resulting economic land rent. For this we use a mathematical programming approach to solve the underlying allocation problem and the concept of average shadow prices to price the allocated plots.
In the third part we show the practical implications of different allocation mechanisms. This is done using the spatial and dynamic agent-based simulation model AgriPoliS as experimental laboratory. In that way we can analyse the properties of the respective allocation mechanisms in a realistic framework which is based on a detailed empirical calibration.

1. Introduction

Farm growth in agriculture is often binding to the availability of land, either as direct production input e.g. for crop production or indirect if e.g. animal production is tied to the availability of land as manure disposal area. The allocation of land is thereby realized over markets where the exchange of land is often quite informal and relies on bilateral negotiation instead of formal market places. Often markets for land are less developed (like in transition countries) or highly regulated (e.g. through actions of SAFER 'Société d'Aménagement Foncier et d'Etablissement Rural' programme in France). One can state, that there is much indication why specific land market characteristics take influence on structural change in a region. Consequently, any model which tries to analyze or predict structural change needs a proper representation of how land is exchanged between actors. In principal it is possible to incorporate these interactions between actors also in aggregated sector models; however, this would only be possible on the account of the goodness of fit of the individual decision making and its heterogeneity. To close this gap since the nineties ABM has been developed as an alternative approach (cf. BALMANN 1997, BERGER 2001). There is a broad range of applications within social sciences, mainly within game theory or institutional economics (c.f. AXELROD 1997, EPSTEIN 2001) as well as in financial economics (LEBARON2000) or environmental economics (JANSSEN 2002, BOUSQUET et al. 1998). Within agricultural economics, early work was done based on the CORMAS platform (BOUSQUET et al. 1998) in the field of common pool resources or by BALMANN (1997) in his work on path dependencies in structural change. The latter one serves still as basis for further models like the AgriPoliS model (HAPPE 2004, HAPPE et al. 2006, KELLERMANN et al. 2007) or the work of BERGER (2001). A literature review can also be found in PARKER et al. (2003) and BOUSQUET and LE PAGE (2004). Particularly PARKER et al. (2003) discuss several perspectives for the use of ABM approaches and carefully elaborate a number of open methodological questions which are still subject of ongoing research. Among others they especially pinpoint the role of land tenure systems and directly related to that the problem of a careful representation of individual decision making. Although ABM offers from a methodological point of view an ideal framework to deal with the named issues, corresponding attempts often lack a sound empirical or theoretical foundation (PARKER et al. 2003). Reviewing land allocation mechanisms of ABM for the analysis of land use and structural change leads to a diverse picture. To get an overview over the various land allocation mechanisms which are used in ABM, Table 1 summarizes the key features of those ABM which consider land transaction in some way. For each model we first give some information on the scope of the model, the general type of the implemented market and then we describe the chosen allocation mechanism.

Table 1: Overview of land allocation mechanism used in ABM

GOTTS et al. (2003)	FEARLUS (Framework for Evaluation and Assessment of Land Use Scenarios)
Model scope	ABM of land use change, dynamic. Abstract model to test the relative advantage of imitative versus non-imitative behaviour and factors influencing this relationship.
General	Land sales market
Land allocation	Fixed land parcel price (LPP), Each agent holds an account in which production yields are accumulated. If account is negative an agent sells its worst performing parcels at price LLP until the account is positive. Land is distributed to other agents randomly if a) their account covers LLP and b) they own at least one plot in the Moore neighbourhood[1] of the cell.
POLLHILL et al. (2005)	FEARLUS-ELMM (Endogenous land market model)
Model scope, general	see above, with extension for an endogenized land market model
Land allocation	If the account of a farm is negative it is regarded to be bankrupt and all land plots put up for sale. Farm with an account above a given threshold use a) a “Land parcel biding strategy” and b) a “Land Parcel Selection strategy” according to which they place bids on the available plots (simultaneously). The plots are then allocated according to a Vickery auction. Possible bidding strategies are: a) bid equals discounted average profit (same bid for all parcels) b) expected yield times a “Yield Coefficient” (only possible when yield information is available, which holds for neighbouring cells). Possible selection strategies are: i) “Buy cheapest” ii) “Buy dearest”, plots are sorted in ascending/descending order. There are as many plots selected as long as the total offer is smaller than a “Land offer threshold” iii) “Random selection”, as i) and ii) but plots are selected randomly.
KANTELHARDT et al. (2005)	
Model scope	ABM of land use change. Focus on social aspects and non-economic data.

[1] The Moore neighbourhood of a cell defines the eight orthogonal and diagonal cells, in contrast to the von Neumann neighbourhood which comprise of the four cells orthogonally surrounding a plot.

General	Equilibrium market. Heterogeneous land qualities (arable and grazing land). Farm models based on linear programming.
Land allocation	Land market is modelled as equilibrium market. There is a separate market for each land quality, whereas interdependencies between markets are considered. Equilibrium prices are determined via the Sequential Simplex Optimisation (SSO). For a given set of prices the demand of land is calculated. If demand is unequal to the supply in the region prices are changed due to the SSO and the demand is recalculated. This is repeated until demand is less or equal to supply of land.
FREEMAN (2005)	ABM of land use change
Model scope	Arbitrary number of soil qualities
General	Land sales and land rental market, heterogeneous soil quality
Land allocation	Based on BALMANN (1997). Land sales and rental market are modelled as two separate and iterative auctions. Supply from three sources: a) “Forced exit” → sales market, b) “Voluntary exit” → lease market, c) “Non renewed lease” → sales market. Restricted participation according to a credit scorecard. Farms bid in an iterative process on plots with respectively highest expected annual land rent. Bids are determined according the expected value of a plot. The auctioneer normalizes bids according to the mean soil quality and allocates the plot to the highest bidder in case the bid is greater than a reservation price (a weighted value of the current mean lease rate and the mean value of current period bids).
ALBISSER and LEHMAN (2006)	ABM of land use change
	Based on FREEMAN (2005), no description available.
BERGER (2001)	
Model scope	ABM of land use change with a focus on technology diffusion. The regional focus is Chile.
General	Pure land rental market.
Land allocation	The market is implemented via a double auction. Farm-agents rent out land when their shadow prices for a plot are below the sector average. The plots are then transferred to the farm with the highest shadow price for the specific parcel. Strategic behaviour is not taken into account and the individual level of rent is fixed at the average of the corresponding offer and request.
BALMANN (1997)	
Model scope	Proof of existence causes of path dependence in agricultural structural change.

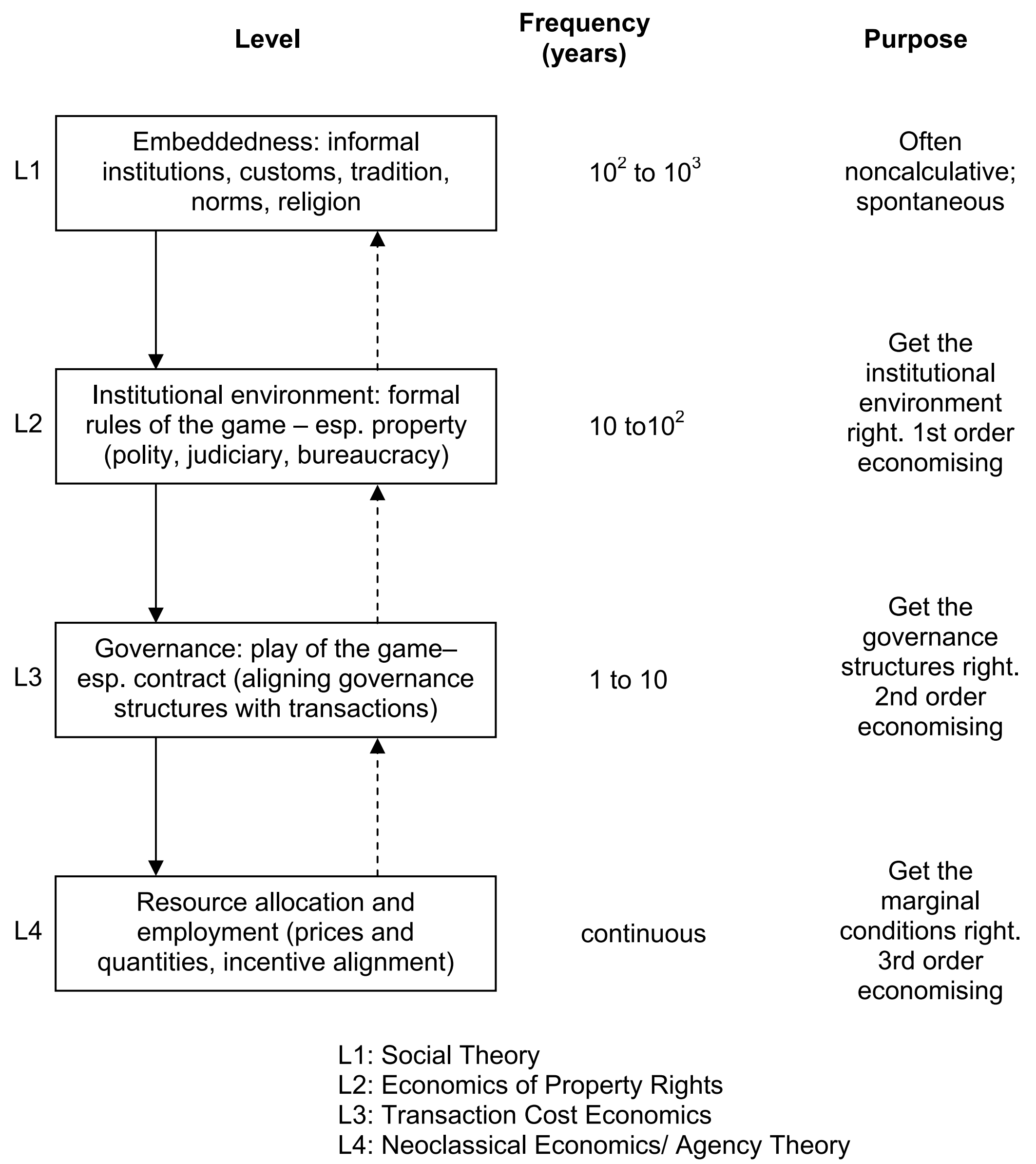
General	Homogenous soil quality.
Land allocation	The bidding strategy of the farms is implemented as follows: Any farm calculates the bid as the gross margin of an additional plot minus the transport cost to the nearest free plot. The farm with the highest offer gets the plot it has wanted. This is repeated until there are no further positive offers. The rents paid do not equal the bids and are set to equal the bid of the last plot offered.
Land release	Land is released a) when a farm quits and b) based on a decision rule a farm checks for every plot: A farm would give up a rented plot if the shadow price does not cover the plot's costs comprising of the paid rent and transport costs. The procedure is repeated until the shadow price of land is at least equal to the costs of a plot.
HAPPE et al. (2006)	AgriPoliS
Model scope	Scenario and policy analysis. Empirical calibration based on FADN datasets and regional characteristics. Calibrated to 12 regions in EU-25.
General	Heterogeneous soil quality (arable and grass land), land market is implemented as pure land rental market, although also owned land is considered. Farm models formulated as MIP.
Land allocation	Land market is based on BALMANN (1997). During an iterative auction free plots in a region are allocated to the farms. As in BALMANN (1997) every farm calculates the shadow price for an additional plot and formulates a bid for the nearest free plot that equal the shadow price minus the transportation costs times a rent transmission coefficient which reflects a security mark up. In contrast to BALMANN (1997) the shadow price for an additional plot is calculated as the maximal value of the marginal gross margin of an additional plot and the average additional gross margin of a fixed number of plots. This procedure is chosen to allow for a better approximation of discontinuities caused by the MIP approach. Also the price for an auctioned plot is determined via a first-price auction, i.e. the price a farm has to pay equals the bid for that plot. As two soil types are considered the auction alters between these two soil qualities.
Land release	See BALMANN (1997).
LAUBNER (2006)	
Model scope	Spatially explicit ABM of structural change for ex-ante simulation of policy changes. Focus is on land use and multifunctionality of agrarian production. The regional focus is on two mountains regions in Switzerland.

General	Comparative static model, although there is an iterative land allocation procedure, simultaneous transfer of several plots, heterogeneous land quality defined over four attributes each of three values (slope, altitude, potential yield, distance to farmstead). Farm models based on MIP model.
Land allocation	Land redistribution between farms is implemented as an iterative process. 1) All farms calculate the shadow price for every land quality with a relaxation of the MIP. If the shadow price for a certain quality is not available, the regional average is taken. Based on the individual shadow price the regional average is calculated for every quality. 2) A farm is randomly selected and tested if it is willing to release plots based on the regional average shadow price. 3) If yes, based on a given probability distribution one to five farms are randomly selected. The plots are distributed to these farms in a way that every farm receives at least one plot and the sum of the marginal gross margin of the plots is maximised. Based on this preliminary allocation the receiving farms check if they could increase their household income with this allocation. If yes, the plots are finally allocated; if no, the plots go back to the previous operator. This is repeated until every farm was selected. The individual shadow prices are not updated in between one iteration. After the allocation plots which are next to each other are put together and allow the farms to realize scale effects.
Land release	Land is released if individual shadow prices are below regional average shadow prices for a certain land quality, or when a farm is marked for quitting business.

Most approaches have in common that land allocation is modelled as some kind of auction, i.e. competition for land based on a defined bidding process and a set of rules for winner and price determination. There are some models which consider exclusively land rental activities. E.g. BALMANN (1997) uses a second-price auction where in an iterative process farmers place bids for plots which are most valuable for them. Nearly the same procedure is chosen in HAPPE et al. (2006) unless prices are determined via a first-price auction. Others, e.g. BERGER (2001), use a double auction to allocate free land in a region. Besides markets based on auction mechanisms there are other approaches where the allocation is derived form a set of exchange rules (e.g. GOTTS et al. 2003) or via mechanisms that try to calculate a market equilibrium (e.g. KANTELHARDT et al. 2005, LAUBNER 2006). What is missing in all cases is an intensive discussion of the chosen allocation mechanism and its effects on model results.

Another point which one has to keep in mind is the scope of the respective model. According to AXELRODT (1997b) there is a continuum between deductive and inductive approaches. AXELRODT even characterizes simulation approaches like ABM as a third way of doing science, i.e. ABM serve both as deductive tools, where through a simulation based on a set of explicit assumptions a data set is generated which itself is subject of a inductive analysis. Depending on how the model should be categorized, there are different requirements how e.g. a land tenure system should be modelled. On the one hand modelling can aim at a realistic representation of the target system coupled with a careful empirical calibration of model parameters. On the other hand modelling can be based on theory. This would be in line with what JUDD (1997) describes as the role for computational economics, namely the use of simulation models as complements to economic theory where the exploration of a set of assumptions is no longer tractable in an analytical way. We argue, that even in the first case, when one follows a positive approach, it is necessary to first build on theory in order to be able to separate and explain effects of changes in relevant model parameters. This would also provide an important step towards a proper model validation.

For developing a land market framework this means that we first need to identify a proper land market theory which is able to serve as a framework for our land market model. Unfortunately a comprehensive and unified theory of land markets is not available. A recent overview of land markets and land market related theories is given in HURRELMANN (2003) and in an updated version in HURRELMANN (2005). HURRELMANN suggests to define a land market with the help of the "Four levels of Social Analysis" proposed by WILLIAMSON (1998) and WILLIAMSON (2000).



Source: WILLIAMSON (1998)

Figure 1: Four levels of social analysis

WILLIAMSON distinguishes four levels describing the different influences on a working economy as displayed in Figure 1. Applied on land markets these levels can be according to HURRELMANN (2005) described as follows: Level 1 is the level of social embeddedness, where informal institutions, customs, traditions, norms and religion are located. The time frame for changes in this level is between 10^2 and 10^3 years. Level 2 describes the institutional environment. Regarding to land markets this level comprises three main issues: a) The historical development of property rights, b) the issue of land reforms and c) the issue of political interventions into private property rights. The time frame for changes in Level 2 is about 10 to 10^2 years. The third level then describes the governance form of land transactions. Issues on this level are mainly about contract choice and transaction costs influencing the decision. The time frame for this level is up to 10 years. Level 4 is then the level of resource allocation. This level describes the reasons for land transactions in terms of neoclassical theory from an efficiency point of view, i.e. the fact that a fixed amount of land is allocated to different users whereas marginal costs equal the price for the land and marginal cost are the same for all users in competitive equilibrium. At this level transaction and changes are taking place continuously. For creating a land market sub-model for an ABM like e.g. AgriPoliS obviously level 3 and 4 are of major interest. This is both because of the scope of influences affecting the market and the time frame considered in such a model which lies for AgriPoliS between 1 to 20 years. In this paper we concentrate on level four, however we like to mention that e.g. in KELLERMANN et al. (2006) we analyze the effect of transaction costs on farm restructuring, i.e. there the focus is on level 3 and partly on level 2.

The overall advantage of this concept as guidance for modelling of land markets is that it gives a structuring of the different scopes of possible influences. Moreover it allows, starting from the lowest level, to keep the "perfect market assumption" and a description of land markets according to neoclassical theory. On the higher levels parts of theses assumptions are then removed step by step. For our proposed land market model this means that in a first step we need to identify an allocation mechanism which should fulfil the following properties:

a) The allocation mechanism should be able to find a nearly optimal allocation given the underlying assumptions. This would be in line with level 4 of the WILLIAMSON framework.

b) It should be extensible to integrate influences and market impediments on higher levels like e.g. transaction costs. This leads necessarily to a decentralized coordination mechanism like an auction.

c) The computational complexity of the allocation mechanism should be within current technology.

2. Methodology

Of course land markets, as heterogeneous and spatially organized markets, are far away from the ideal assumption of a perfect competition where homogenous goods are traded on atomistic markets with equal access, free entry and perfect and complete information. As stated above, the developed land market model is tested within the agent-based model AgriPoliS (c.f. KELLERMANN et al. 2007, HAPPE et al. 2006 and HAPPE 2004). A detailed description of the model can be found in the given references. Based on the assumptions made in AgriPoliS there are some key points to be considered for the land market model:

a) Land is distributed in space, i.e. to use the land for production, transport costs occur. As for technical reasons the catchment area of a farm is limited we assume linear transport costs, perhaps neglecting the fact that for (super) large farming systems with different technologies perhaps a stepwise linear function is more realistic.

b) Land is assumed to be heterogeneous. For simplification we assume that we have a set of different land qualities, in this example we take arable, grazing and non-agricultural land.

c) Because of transport costs the number of market participants is limited.

d) Although farms are initialised with both owned and rented land, transactions on the land market take place exclusively via renting activities. Basically, there are two reasons for this decision: first, we assume that the capitalised rent equals the sales price of a unit of land. Even though this equivalence could not be observed in reality, the difference in capitalised rents and sales prices is often explained by determinants such as reliability, stability, eligibility for use as collateral or taxation reasons. As all of the mentioned determinants are beyond the scope of the model, this simplifying assumption seems acceptable.

e) We assume that land is traded once per production period. Hence, at the beginning of each period there is a number of free plots of different quality and location. These free plots come from two sources: Either a rental contract ended in the previous period or a farm quit.

f) Furthermore it is assumed that farms can exhibit scale effects and thus the initial factor endowment of a farm affects its efficiency. For the land market this means that plots can be complementary (due to increasing returns) to each other or substitutable (due to decreasing returns).

Within this framework we implement four different land market scenarios where we want to discuss three main characteristics: a) How the land is allocated to the farmers, b) how the allocated land is priced and c) what type of contractual arrangement is chosen. Regarding to the contract type we assume a fixed contract length which is drawn randomly from a uniform distribution between a given minimum and maximum contract length. This assumption holds for every scenario.

Regarding the allocation of the plots, in three of our four scenarios the allocation of free plots is done via an auction. This is inspired by the nature of land transaction on rental markets where there is some sort of a formal (e.g. through advertisement or real estate agent) or informal (direct/indirect conversation) announcement of the land owner who wants to offer land. Each farmer interested in the land plot communicates a bid to the land owner which is normally not public. Hence, to mimic this situation we use some kind of auction mechanisms where offers are not announced in public, i.e. a sealed bid auction. For all auctions we assume that farms do not have the possibility to bid for several plots simultaneously. Instead we assume that plots are traded in an iterative auction where one plot at the time is offered. In our first scenario called AUCTIONrandom, a virtual auctioneer picks one free plot randomly and offers this plot to all farms. Afterwards every farm formulates a sealed bid for the offered plot which is the true value of the plot minus the occurring transportation costs. The auctioneer collects all bids and the plot is allocated via a first-price auction. This means the bidder with the highest valuation receives the plot by the price of his bid. With this pricing mechanism we mimic a situation with perfect competition where we assume an unlimited number of market participants and free market entrance as this would mean that all land rents are shifted to the land owners.[2] This first allocation scheme could be considered as rather naive as it has an obvious disadvantage: By picking a plot randomly and calculating a bid for this specific plot we imply that a farm is not aware that there is perhaps a plot which is much closer to the farmstead and hence more valuable for the farm. This could lead perhaps to a situation that a farm, although it has not the highest valuation for a further plot, can achieve some kind of a first mover advantage.

To circumvent this problem we introduce a second scenario called AUCTIONnearest where we allow the bidders to search for the most valuable plot. As in our case the plots within a certain quality are only differentiated via the transport costs, this is the nearest free plot of a certain quality. The auction is organized as follows: Every farm searches for the nearest plot of certain quality and formulates a bid as above. The farm with the highest bid receives its most preferred plot. As we have two land qualities the auction alters between these two qualities to take into account complementarities between plots of different qualities.

As stated above the pricing mechanism (the first-price auction with bidders bidding their true value) assumes perfect competition and free market entrance. One further implicit assumption of this procedure is, that we should have perfect factor mobility as in equilibrium the price for land should equal its shadow price which should be the same for all farms. As in our model only a (small) part of the land is reallocated it is likely that shadow prices for land differ substantially between farms and it is also likely that farms are able to anticipate these differences at least to some extend. Therefore in contrast to the first two scenarios we implement a third scenario called AUCTIONsecond where the price is fixed according the last successful demander. In terms of an auction this means to use a second-price auction. As we allocate a series of *k* plots during one period this means that the price is fixed to the *k+1* highest bid, i.e. the highest unsuccessful bid of each land quality.

Because of the assumptions made under a-f) above one has to expect that the proposed land exchange mechanisms lead to a suboptimal allocation. In order to quantify these effects as fourth scenario we construct a benchmark allocation called GLOBAL which can be used to evaluate the alternative implementations of the land market model. One way to create such a benchmark would be to construct a suitable auction design and to use the resulting allocation and prices. However, this would be not straight forward both from the mechanism design and the bidding strategy point of view. E.g. KLEMPERER (2004) summarizes that it is very hard to achieve efficient outcomes in the multi unit case where units are complimentary or substitutable to each other. Besides efficiency considerations, a further problem which arises in such auctions is that of computational complexity. The algorithms proposed for the so called "Winner determination problem" in simultaneous auctions are NP-hard[3] (cf. CRAMTON et al. 2006).

Instead of using a decentralized market mechanism as a benchmark we use a centralized global optimization to construct an efficient allocation which can be described as follows. In AgriPoliS, for every production period, each farm is deciding about production activities and investment options

[2] This is in line with basic auction theory where e.g. the optimal bidding strategy in a first-price sealed bid auction is $b(v) = \underline{v} + (1 - \frac{1}{n})(v - \underline{v})$, given symmetric bidders with a private value v drawn independently from a common known uniform distribution $[\underline{v}, \bar{v}]$ and n bidders.

[3] There are no known algorithms which are able to solve the problem in polynomial time.

given its current factor endowment. As we assume that investments are indivisible this is specified as a mixed integer program. The production and investment mix is then defined by maximizing a farms total gross margin Y^e given a set of restrictions and the farms capacities. Assume that $a_i(S)$ means that a farm i receives a bundle of plots S, then an optimization problem which provides an efficient allocation can be defined as follows:

$$
\begin{aligned}
\max \quad & \sum_i Y_i^e(x_i, p^e, I, A_i, \ldots, a_i(S)) \\
s.t. \quad & x_i r_i \le b_i, \forall i \\
& \sum_S a_i(S) \le 1, \forall i \\
& \sum_{S \ni j} \sum_i a_i(S) \le 1, \forall j \\
& a_i(S) \in \{0,1\}, \forall i, S \\
& x_{i,j} \in Z_0^+, \forall j \in I \\
& x_{i,j} \in R_0^+, \forall j \notin I
\end{aligned}
\tag{1}
$$

This simply means that we simultaneously maximize the gross margins of all farms and thereby allocate the free plots in a region. The additional restrictions ensure that each plot is allocated only once[4].

Given an optimal allocation of plots in the next step we need to price the allocated plots. Naturally one would price the plots at their respective shadow prices. However, in a mixed integer program the calculation and interpretation of the dual value of a variable is not straightforward. The classical work dealing with dual values in integer programs is GOMORY and BAUMOL (1960). There they present an approach where additional cutting planes (restrictions) are introduced in the relaxation of the original MIP problem in a way that the integer solution is obtained. This augmented problem is then used to derive the dual values. However there are some problems related to this approach (cf. GOMORY and BAUMOL (1960, Williams 1981): First, the resulting shadow prices are not unique depending on the way the cutting planes are chosen. Secondly, the prices are themselves integer values. Third, there are possibly problems with the pricing of goods as "free goods" although they are binding as a result of their discrete nature and fourth the resulting dual price of a resource will not necessarily be equal to the marginal revenue product of this resource. As an alternative we utilize the concept of "average shadow prices" proposed by KIM and CHO (1988) and refined for mixed integer problems by CHO and KIM (1992), CREMA 1995). Given a mixed integer problem

$$\max \left\{ c^T x \mid Ax \le b; x \ge 0; x_i \in Z_0^+, \forall i \in I; x_i \in R_0^+, \forall i \notin I \right\}$$

where x is a vector of decision variables, b is the vector of resource constraints, c a vector of objective function coefficients, A a matrix of technical coefficients and I a index set of integer variables we first define a perturbation function

$$z_k(w) = \max \left\{ c^T x \mid a_i x \le b_i (i \ne k); a_k x \le b_k + w; x \ge 0; x_i \in Z_0^+, \forall i \in I; x_i \in R_0^+, \forall i \notin I \right\}.$$

The average shadow price y_k for a resource k is then defined by

[4] As we have raised the problem of computational complexity in the section about multi unit auctions, this is also an issue here. Given a dimension of a single farms matrix of e.g. 70 x 30 and 200 farms in a region and 200 free plots the corresponding optimization problem has a dimension of 28000 x 2300.

$$y_k = \sup_{w>0}\left\{\frac{z_k(w)-z_k(0)}{w}\right\}$$

In KIM and CHO (1988) it is shown that this price gives a meaningful economic interpretation that is a) if the price p_k for a resource k is greater than the average shadow price y_k for this resource, it is not profitable to buy further units of this resource, b) y_k is the maximum price a decision maker is willing to pay for a resource to gain a positive profit, c) the average shadow price reduces to the marginal shadow price in case a convex programming problem is considered and d) the resource k is a free good if and only if $y_k = 0$.

However, from a single farm's perspective the calculation of the average shadow price may be computationally intensive as a series of different instances of the optimization problem has to be solved. In the allocation problem described above instead w_i of a farm i can directly taken from the solution of the optimization problem and is given by the number of plots allocated to the farm in the optimal allocation. An additional property is that in contrast to a single farm optimization in the global optimization the shadow price considers implicitly the alternative use of the plot by other farms. By pricing the plots with there shadow prices we assume as in AUCTIONnearest and AUCTIONrandom that land rents are fully shifted to the land owners.

Data

To analyze the effects of the different land market implementations, AgriPoliS is calibrated to a sub region inside the federal state Saxony in the southern part of the former GDR. The study region is congruent to the so called "Wirtschaftsgebiet II" which consists of favorable and almost homogenous natural production conditions. The size of the region is 496,451 ha (86 % arable land and 14 % grassland). The number of farms adds up to 2,858. The average farm size results to 174 ha. Further information about the input data and the region Saxony can be found in SAHRBACHER et al. (2005).

The base year of the scenario is calibrated to the year 2001. The implemented policy starts with Agenda 2000 in the year 2001 and considers the actual implementation of the 2003 CAP reform in Germany starting in the year 2005. Germany decided for a hybrid dynamic decoupling scheme, which ends in 2013 in a regional payment. Payment entitlements are calculated in the following way.

- COP-payments (Cereals, Oilseeds and Protein plants) are transferred into a regional payment for arable land in each federal state.
- Slaughtering payments for cattle, additional payments for cattle and 50 % of extensification payments for cattle are distributed on the grassland of each federal state.
- Payments for milk, suckler cows, special payments for male cattle, slaughtering payments for calves, ewe payments and 50 % of the extensification payments for cattle are distributed on the agricultural land of individual farms.

Finally the farm specific payments and the hectare payment for arable land or grassland are put together in one payment entitlement per hectare.

Results

Looking at the structural change in terms of the average farm size in Figure 2a) we can observe that in the first nine periods the average farm sizes in the region are relatively similar throughout all scenarios. Only in 2009 the different scenarios start to diverge. Beginning with 2009 structural change is most radically in GLOBAL followed by AUCTIONnearest and AUCTIONrandom. The lowest structural change can be observed in AUCTIONsecond. One indicator for the efficiency of the allocation is the economic land rent displayed in Figure 2c) Here we can observe a similar picture. At the beginning of the simulation there are only minor differences which start to grow from a specific point in time. Overall we can say that all of the three auction based scenarios result in suboptimal allocation compared to GLOBAL. At least in the time horizon of the simulation we could not observe a “catching up”, i.e. successful farms are able to maintain advantages once gained. This means that the higher economic land rent of GLOBAL is of a substantial nature and not only caused by e.g. random effects.

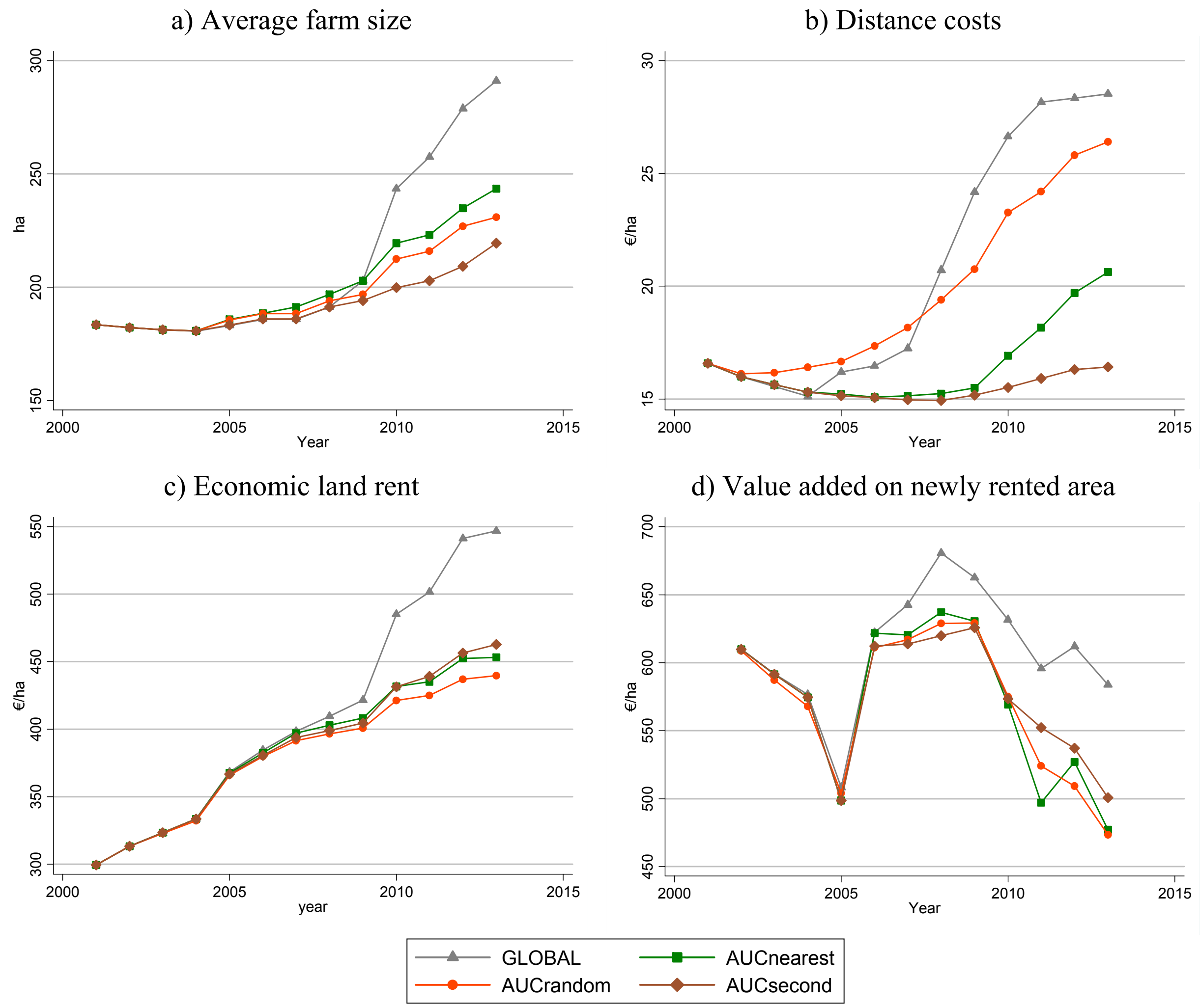


Figure 2: Effects on allocation and structural change

As said above, the average farm sizes start to diverge in 2009. The economic land rent displays a slight advantage of GLOBAL even before 2009. Looking more closely on the average farm sizes one can divide the simulation in three phases: 1) The period until 2004 where average farms sizes are the same between all four scenarios, 2) the period between 2004 and 2009 where slight differences can be observed and 3) the period between 2009 and 2013 where the four scenarios diverge. Although there are only small differences in structural change already till 2009, a reallocation between the existing farms takes place. This can be shown by looking at the distance costs and the value added as displayed in Figure 2b and d). Looking at scenario AUCTIONrandom we can see that this land market implementation immediately leads to an allocation where farms rent in plots which are obviously not their first choice resulting in increasing distance costs. The comparison of GLOBAL with AUCTIONnearest and AUCTIONsecond displays slightly lower distance costs. After 2005 distance costs increase in GLOBAL and exceed even those of AUCTIONrandom. However, whereas the increase in distance costs in AUCTIONrandom is caused by the fact the farms are not aware of their most valuable plot, in GLOBAL some farms are able to realise scale effects and are therefore able to rent in plots which are farer away. This can also be seen in Figure 2c) where the value added per newly rented ha is displayed. As there is a reallocation of land among farms although the number of farms is not differing between the scenarios at least until 2009 one may ask which farms are able to grow. At least a rough answer to this question can be given by analysing the share of different farm size classes as displayed in Figure 3. Comparing the scenario GLOBAL and AUCTIONnearest one can observe that at the beginning in both scenarios the acreages of farms between 1000 and 1500 ha is shrinking. This shrinking is even a bit more pronounced in GLOBAL. E.g. in 2006 in GLOBAL all land is occupied by farms smaller than 1000 ha. Almost 90% of the land is occupied by farms smaller than 750 ha whereas in AUCTIONnearest only 75% of the land is occupied by these farms. Looking again at the economic land rent and the value added on newly rented area this reallocation only slightly increases efficiency. After 2006 the situation changes. Obviously the higher farm size classes gain additional advantages which are of a more substantial nature as difference in additional value added is increasing. After 2009 a number of the shrinking farms even quit farming resulting in a strong increase of share of acreage of very large farms. This competition is obviously taking place between the larger farms as the share of farms smaller than 250 ha is approximately the same for both scenarios a least till 2009. After 2009 also these small farms shrink at the cost of much larger farms.

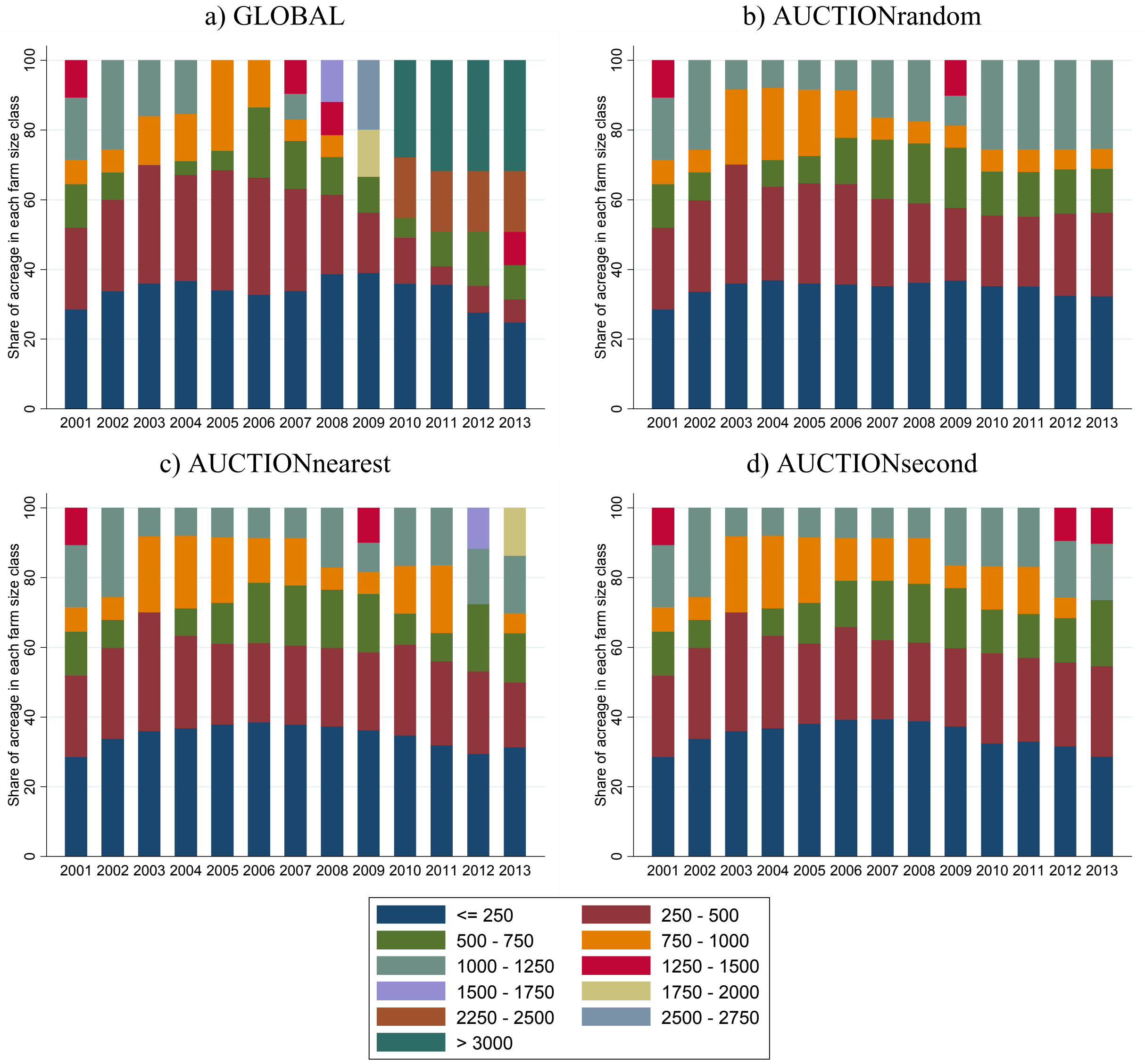


Figure 3: Change in farm size classes

So far we can conclude the following: Obviously the random selection of plots in AUCTIONrandom leads to very suboptimal allocations, i.e. it is necessary to equip the bidders with some kind of perception of the available land in the regions. Such a perception is implemented in the scenario AUCTIONnearest. Here we can say that over a longer period the scenario AUCTIONnearest is a good approximation of the optimal allocation. However in case of structural breaks the myopic bidding strategies are not able exploit the possible efficiency gains. However, e.g. in our case the CAP reform taking place in 2004 is not such a situation. Rather it is likely that the comparable small efficiency gains in the first periods sum up and in periods of stronger re-investments[5] in the region less efficient farms are pushed out of the sector.

Instead of just focussing on the allocation mechanism we furthermore want to analyze the effect of the different assumptions about the price building process. For this purpose we implement one scenario where we use a second-price auction (k+1 price auction as we have k plots) instead of a first-price auction. This would mean that the price is fixed according to the shadow price of the last demander

[5] Every production period farms have the possibility to choose out of a set of investment options with a predefined useful lifetime. This could lead to periods with increased re-investment activities.

and hence land rents are not fully shifted to the land owners. From an informational point of view this means that farmers are able to anticipate the shadow prices of their competitors. What we can observe is, that even in the optimum are still substantial differences in shadow prices between the first-price and second-price scenarios. This can be seen in Figure 4, in the difference between the rental prices on newly rented land. Whereas in the first-price scenarios the rental price reflects the "average" shadow price for land in AUCTIONsecond this figure reflects the shadow price of highest unsuccessful bidder. The differences in shadow prices itself are a result of the low factor mobility especially of land due to the rental contracts with a fixed contract length. One hypothesis which could be derived from that result is that the informational setting of farmers could be one explanation for the significant differences in rental prices as they could still be observed between large-scaled and small-scaled regions like in East and West Germany. Here one would argue that as the number of competitors is decreasing and crop farming is the prevailing farm type the technology set and the management capabilities of the competitors are easier observable. This would lead to a better estimation of the distribution of shadow prices which could be integrated in a more intelligent bidding strategy. Regarding structural change in our simulations this would lead to a reduction of structural effects as it can be seen in Figure 3.

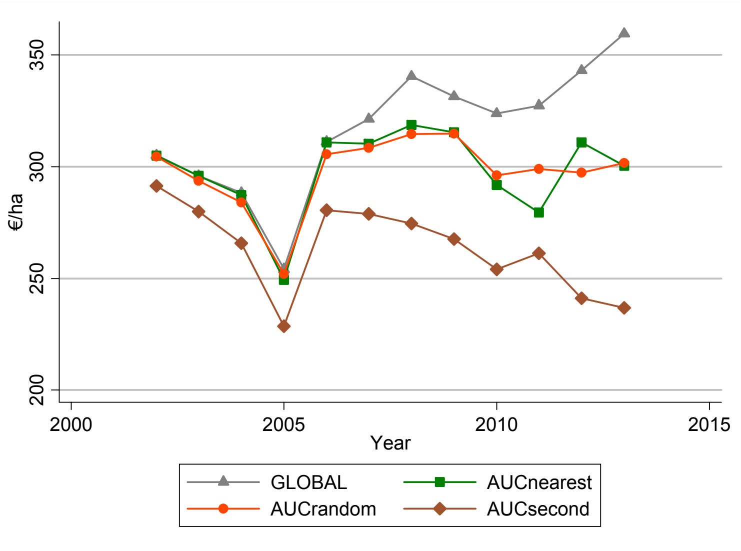


Figure 4: Rent per ha on newly rented land

Conclusions

The current work was driven by the fact that land markets and the dynamics on land markets play a crucial role in agricultural structural change. Although this is often highlighted, there are only a few (agent-based) models with an endogenous land market. Even in case an endogenous land market is considered there is hardly any intensive discussion of the underlying assumptions. The current paper tries to close this gap. With the four levels of social analysis of Williamson (1998 and 2000) we find a theoretical framework which guides our modelling. In order to be able to analyze the effects of market impediments on the governance or institutional level - like e.g. transaction costs taking place on land markets - we first must identify a proper allocation mechanism which leads within the given restriction to an at least approximately optimal allocation. Otherwise we would not be able to isolate the effect of market impediments and "build-in" failures of the chosen allocation mechanism. Based on these considerations we propose three different land market implementations which are based on some kind of auction mechanism. To be able to evaluate these land market implementations not only in relative but also in absolute terms we further use a mathematical programming approach to define an optimal allocation in a comparative static way. As result we can observe that for an approximation of the optimal allocation with an auction as decentralized coordination mechanism we need to give the farmers the possibility to percept there environment so that they can search for land plots which are most favourable for them. However in case of structural breaks the performance of the auction mechanism is rapidly decreasing and the naive bidding strategies of the farmers are not able to exploit the possible efficiency gains. Regarding the pricing of land we can observe that due to the low factor mobility even in optimum the shadow prices for land differ significantly between farms. In case farms are able to anticipate these differences in there bidding strategies this would result in substantial lower rental prices and a slightly reduced structural change. One hypothesis which could be derived from this result is that the informational setting of farmers could be one explanation for the significant differences in rental prices as they could still be observed between large-scaled and small-scaled regions like in East and West Germany.

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