Adjustment Costs of Agri-Environmental Policy Switchings

A Multi-Agent-Approach

by

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Abstract

More powerful computers, the better availability of micro-data, and the development of new modeling techniques, such as multi-agent systems, allows to analyze agricultural policies from the bottom up. We present such an approach that considers the spatial interaction of thousands of individually behaving heterogeneous farms and apply it to analyze agri-environmental policies for a selected intensive production region in the southwest of Germany.

Keywords: multi-agent systems, policy analysis, agricultural policy, environmental policy

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1 Introduction

At the end of 2000 it was revealed that BSE is much more prevalent in the European Union's agriculture than previously assumed. The public recognition of the widespread led to a major collapse of the beef market. For instance, in Germany, in a first reaction the demand for beef immediately declined by about 50 percent. Moreover, because of BSE many third countries banned EU beef imports. In response, the EU Commission initiated a program to destroy 500 000 tons of beef. This program was one of the impulses that led to severe discussions about the future of the Common Agricultural Policy (CAP). Apart from the ethical question of food destruction, severe doubts about the logic of the CAP arose. In particular, it was questioned how a situation could emerge in which enormous amounts of money have to be spend on destroying food that previously was produced by the payment of high subsidies.

Another major criticism concerned what is sometimes called the "industrialization" of agricultural production. The public, i.e. consumers and voters, realized that modern farmers do not feed their animals exclusively with crops grown on their own fields, but additionally with cheap fodder bought on the world market, with by-products of the food industry, and with meat and bonemeal. Since the latter, i.e. meat and bonemeal, is also held responsible for the widespread of BSE, the argument was brought up to create stronger incentives for farmers to grow their own food. Therefore, a number of politicians (among them the German Federal Minister of Consumer Protection, Food and Agriculture) proposed to subsidize grassland farming and to reduce direct transfer payments to those farmers who operate with animal densities that would require a higher fodder input than what can be supplied the farms' own crops. It is argued that these measures create incentives for farmers to reorganize production. In order to receive direct payments, farms with a high animal density are assumed to develop strategies to diversify and reduce their animal density by renting additional land or by reducing the number of animals. However, farms that are already very specialized in e.g. pig or poultry production may also respond inversely: If such a farm has no chance to increase its acreage because additional land is only available at enormous prices and if the reduction of animals is not attractive, it no longer may be interested in farming land at all because it would have to farm the land without subsidies. Instead of diversifying, the farm may reduce its acreage and become exclusively engaged in animal production.

Both strategies, i.e. diversification and specialization, affect the land market and, reciprocally, the relative attractiveness of these strategies will depend on other farms' behavior and thus on the existing farm structure. Hence, for regions with a low animal density, it can be expected that farms with intensive animal production will increase their acreage. Because in these regions only a few farms are concerned about the policy change, the adjustment has little impact on the land market. On the other hand, in regions with many farms specialized in pig or poultry production the situation will be much more complicated. For some regions in Germany - particularly in the north-west, and similar regions in The Netherlands -, the regional animal density is even higher than the proposed limit of two livestock units per hectare.[1] In such regions the policy impact on the land market is expected to be strong. Then only some farms will follow the strategy of diversification while others will have to specialize.

The intention of this paper is to analyze the effects of such a policy switching for a region with a large number of intensive livestock farms. The region of "Hohenlohe" located in the South-western German Federal State of Baden-Württemberg displays such characteristics. Apart from intensive hog finishing, and turkey production, there are also a number of dairy, farrowing, and crop farms present in the region. Farm sizes are relatively small and below the average in West Germany. The dominating organizational form is that of a family farm.

To tackle the problem of how farms interact, the study is based on multi-agent simulations. This means, we simulate the adjustment process with a spatial and dynamic model that considers approximately 2500 heterogeneous, individually behaving farms. These farms are spatially distributed in a region with a size of about 75000 ha of agricultural land. Since data for 2500 individual farms is not available, the model was fitted to the agricultural sector in Hohenlohe on the basis of data from a small number of real farms operating in the region. These selected farms can be considered typical for the region. The initial farm structure is determined by assigning a certain frequency to each of the selected typical farms. These frequencies are chosen in order to minimize quadratic differences between the model and the real region with regard to several key characteristics (cf. Balmann/Lotze/Noleppa 1998 a,b).

[1] A livestock unit (LU) is defined as an animal with a living weight of 500 kg, i.e. a cow is 1.2 LU and a sow is 0.3 LU.

In the remainder of this paper we present the idea of multi-agent modeling as well as the applied model's general structure, we inform about the region and how the model is calibrated. Thereafter, we present alternative policy scenarios and the simulation results with respect to structural change, efficiency, and farmers' incomes. Finally, we draw conclusions with regard to policy impacts as well as with regard to the applied approach.

2 Multi-agent systems

Multi-agent systems (MAS) (e.g. Ferber 1999, Franklin/Graesser 1996) consist of a number of interacting autonomous entities which are understood as agents. Russell/Norvig (1995, page 33) have defined agents as follows:

> *"An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors."*

This is a very general definition. Accordingly, agents may be persons, computer programs, or even thermostats. In a more differentiated way, Franklin/Graesser (1996) characterize agents according to their properties (table 1). Some properties are common to all agents. Agents are reactive, they act autonomously, are goal-oriented, and agents steadily sense certain parts of their environment. In addition, agents may have some particular properties, like the ability to communicate with other agents, learning, mobility, and flexibility. They may even have a particular personality and show emotions.

Table 1: Classification of agents (Franklin/Graesser 1996)

Property	**Meaning**
reactive	responds in a timely fashion to changes in the environment
autonomous	exercises control over its own actions
goal-oriented	does not simply act in response to the environment
temporally continuous	is a continuously running process
communicative	communicates with other agents, perhaps including people
learning (adaptive)	changes its behavior based on its previous experience
mobile	able to transport itself from one machine to another
flexible	actions are not scripted
character	believable "personality" and emotional state

To illustrate some instances of MAS in economics, table 2 presents a classification and examples of MAS. Accordingly, there are two main fields of applications: operations research and systems analysis. Regarding the first field of application, a number of techniques has been developed to solve complex optimization problems, like artificial neural nets and cellular automata. Because most of these techniques have become standard in operations research they will not be explained here in detail. We just want to point out, that these techniques are based on the interaction of numerous units that can be classified as agents.

Table 2: Classification and examples of multi-agent systems

Goal	**Problem solving / Optimization**		**Systems analysis**		
Agent characteristics	decentralization	competition of solutions	rule-based behavior	normative behavior	artificial intelligence
Examples	general: artificial neural nets cellular automata	general: ant systems genetic algorithms evolutionary strategies	special: Conway's 'Life' Schelling (1978) Axelrod (1984) Bousquet et al. (1998)	special: Day (1963) Balmann (1997) Berger (2001)	special: Arifovic (1994) Axelrod (1997) Balmann (1998) Balmann/ Happe (1999)

More interesting for the purpose of this paper is the use of MAS in applied systems analysis. Here a number of rather prominent examples can be found in the economics literature. They can be classified according to the behavioral foundation of the agents. For instance, Schelling (1978) studied the migration dynamics of a spatial neighborhood of individuals belonging to different social classes. In Schelling's model, individuals stay or move according to certain rules that represent particular preferences. The model is able to show how social clusters or even 'ghettos' may evolve as a result of segregation phenomena. Another prominent example of such rule-based MAS are Axelrod's (1984) computer tournaments. In these experiments a number of computer programs played an iterated Prisoner's Dilemma game against each other. These experiments led Axelrod to the famous result that a strategy called TIT FOR TAT which is mainly based on reciprocity is highly successful in repeated social dilemma games.

Although rule-based agents can have empirical and theoretical support, they often lack a direct economic rationale. More sophisticated are agents with a normative behavioral foundation. A very early example of a normative MAS in agricultural economics - even though in those days it was not called a MAS - can be seen in the recursive programming approach developed by Day (1963) that considers a number of interacting farms, each representing a particular farm type. A fundamental extension of this approach can be found in Balmann (1997). In this approach - which will be presented in some detail in the following section - an agricultural region is represented as a spatial grid with each cell representing a parcel of land. Farms are located on some of these parcels. The farms aim for income maximization and compete on a rental market for land. Each farm can engage in different production and investment activities, rent land, employ additional labor etc. Moreover, new farms can be founded and existing farms can close down. Originally, this approach was used to study endogenous structural change (Balmann 1997, 1999).

A further in theoretical applications very popular conception of a behavioral foundation of individuals in MAS is to derive individual behavior using methods of artificial intelligence. For instance, Arifovic (1994) studies the dynamics of a Cobweb model in which a number of producers (a population of agents) determines their output by using a genetic algorithm (GA), which can be described as a very simple MAS. In the search for solutions to a problem, GA employ the basic operators of biological evolution: selection, recombination (crossover) and mutation, which are applied repeatedly to a population of genomes, each representing a possible solution. These genetic operators not only determine how solutions are propagated into the next generation, they are also capable of generating new, possibly superior solutions. In Arifovic's study, the GA is able to successfully identify the Cobweb-equilibrium. Apart from market analyses, GA have also been used to study game theoretic problems (e.g. Dawid 1996, Axelrod 1997). Axelrod (1997) applied GA to study iterated Prisoner's Dilemma games. In Axelrod’s study GA generated strategies that show key elements of the famous TIT FOR TAT strategy which proved to be most successful in his 1984 computer tournaments. Balmann (1998) and Balmann/Happe (2000) apply GA to a spatial land market. Both studies come to the conclusion that (under comparative-static conditions) limited market access has some distributive effects if it is compared to situations with unlimited access to the land market. Oligopolistic behavior however is limited to very restrictive conditions.

Although a number of interesting applications of MAS exists, one may still ask, what is so particular about them. The first point is that these approaches are very flexible with regard to the parameter settings of a model. On the level of the individual agent it is possible to consider bounded rationality, heterogeneous goals and skills. Moreover, as for the model's framework, one can consider non-convex functions and imperfect markets. The main reason for the flexibility with respect to assumptions is that the use of relatively small decentralized decision making processes avoids that the required computing resources increase unacceptably with an increased model size and complexity, i.e. MAS reduce problems of NP-completeness. The disadvantage however is that such MAS do not ensure global optimization and hence they are, for instance, not in accordance with the conception of unbounded rationality. Rosser (1999) even argues that bounded rationality is inevitable in complex models. A second point is that MAS allow for self-organization phenomena such as particular emergent structures like flocking birds or a laser beam. These self-organization phenomena include not just complex structures but also complex dynamics; dynamics that may include for instance persistent states far from equilibrium and multiple-phase dynamics (cf. Day 1995, Day/Walters 1995). Last but not least MAS allow in a very direct way the consideration of space, and hence they are virtually predestinated for agricultural and environmental research.

3 The model

Imagine taking a bird's-eye view on an idealized agricultural region in which land is divided into parcels of a fixed size like on a chessboard. The region consists of about 30 000 quadratic plots of 2.5 ha each, i.e. the region's size is about 75 000 ha. To avoid border effects, the region is assumed to form a torus, i.e., plots at a border are assumed to be immediate neighbors of plots at the opposite side of the grid. Land is heterogeneous with respect to spatial ordering and quality. Two qualities are considered: land for arable farming and grassland. Initially, a total number of 2606 family farms operates in this region. The parcels on which the farmsteads are located are surrounded by a highlighted border. Each parcel managed by a particular farm has the same color as the interior of the farmstead. Then, this agricultural region may look similar to figure 1.[2]

[2] An earlier version of the model is presented in much more detail in Balmann (1997).

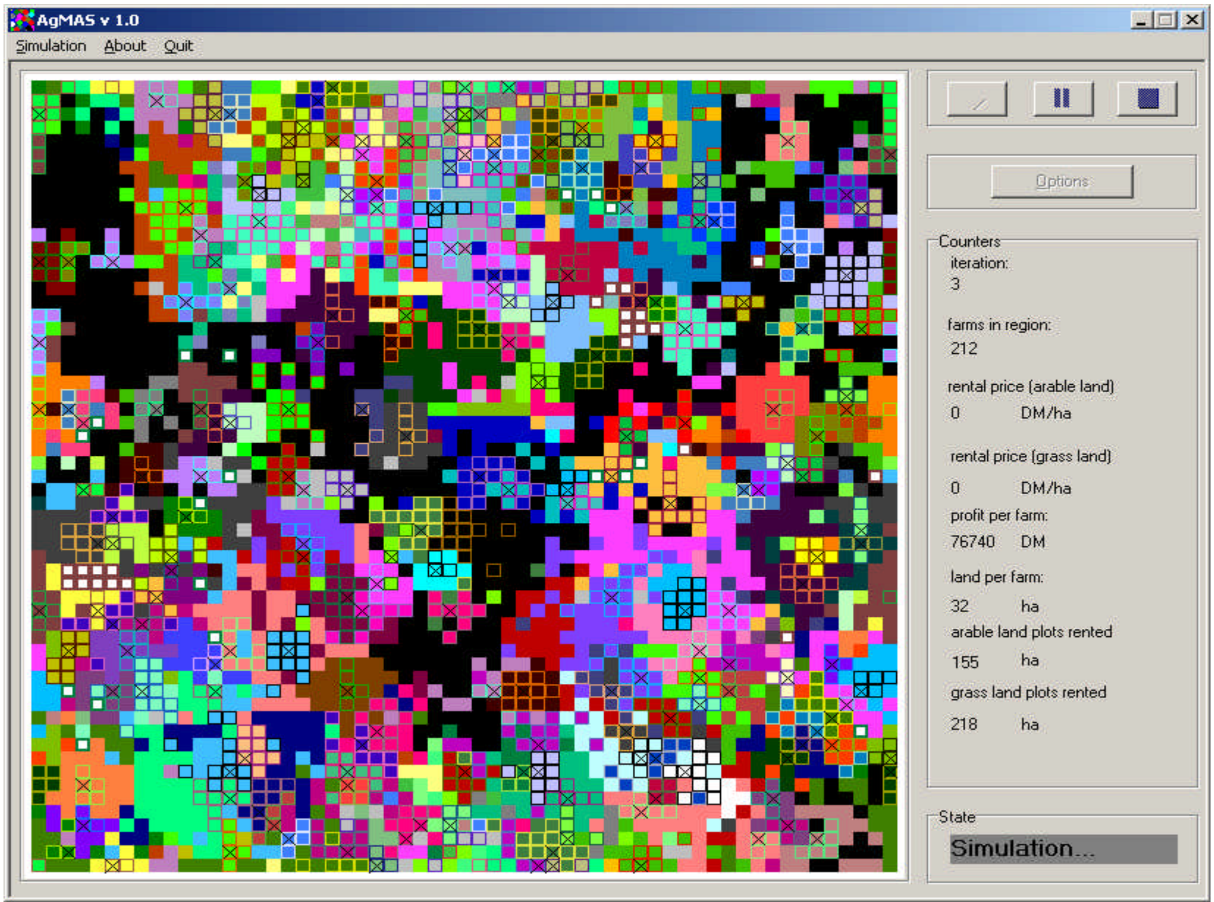

Figure 1: Usage structure[3]

The farms have to be understood as agents. Each of them acts autonomously in order to maximize the expected individual household income. They can engage in 13 different agricultural production activities (e.g. dairy, cattle, hogs, sows, arable farming, pasture land) and they can invest in 28 different assets (differently sized buildings for various activities, machinery of different sizes). These investment alternatives allow for some economies of size, i.e. with increasing size, labor can be used more effectively and average acquisition costs per unit decrease. For instance - and in accordance with a number of empirical studies (Kirschke et al. 1998, Helmcke 1995, Peter 1993) -, it is considered that in crop production, economies of scale exist up to a size of some 250 ha. In addition to the different production and investment activities, the farms can use their labor and capital for off-farm employment as well as they are allowed to hire in additional labor and to make debts. Additional land can be rented on a pure rental market and parcels can be disposed to the rental market. Farms can give up farming and, in principal, new farms can be founded.

[3] For display reasons only a tenth of the actual simulated region is shown here.

Although all farms act autonomously and can evolve heterogeneously in many variables (e.g. equity capital, liquidity, debts, asset structure, rental contracts) they all follow the same decision rules and expectations. All decision making routines are based on adaptive expectations. Production and investment activities are optimized by mixed-integer linear programming. If a farm invests, this has an impact on the farm's production capacities for the lifetime of the asset (machinery: 12 periods; buildings: 20 - 25 periods), i.e. the investment costs are considered to be sunk. The same holds for the capital stock that depends on previous investments as well as on previously gained profits. A farm closes down if it is either illiquid or if the farm's expected profit does not cover the opportunity costs of the factors owned by the farm-household.

Summarizing, on the micro level, each farm's decision making is defined in a way that can be called myopic or bounded rational. Although the farms are rather smart with regard to the applied optimizations techniques, the farmer's cognitive abilities are limited. For instance, farms are not able to communicate with their neighbors and hence they are not able to use machines jointly or to merge. Moreover, they are not able to behave strategically. On the aggregate level, the model can be understood as a complex distributed recursive programming approach that is simulated for a number of periods. In each period, all farms have to decide simultaneously on investments, renting land, and production activities. For computational reasons the farms' decision making routines are ordered and embedded in the program flow shown in figure 2.

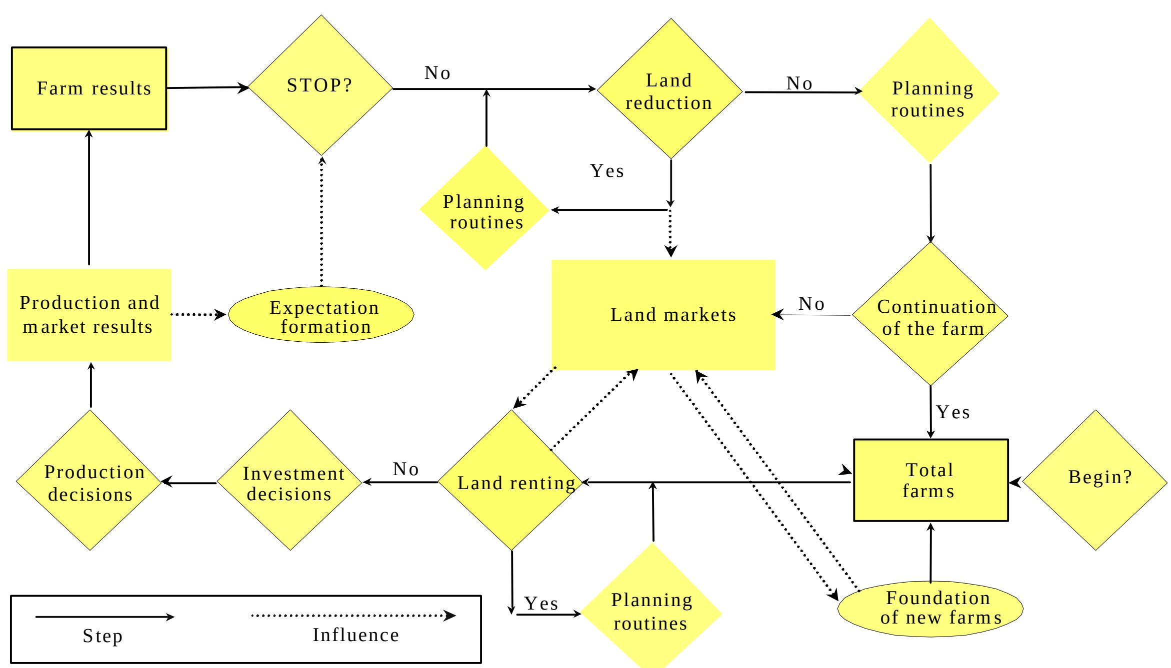

Figure 2: Flowchart of the program (according to Balmann, 1997)

The farms are linked together via product markets and several local markets for inputs: arable land and grassland, milk quotas, and manure. Particularly relevant are the land markets, since a farm can increase its acreage only if there either is idle land which is momentarily farmed by another farm or if other farms reduce their acreage and release land to the land market. The allocation of free land takes place in two iterative parallel auctions (arable land and pasture land) during which farms make offers according to their marginal productivity of land and their transportation costs to the next available parcel. All offers are compared and the farm with the highest bid receives the plot it wishes. Then all farms compute their offers again. These are compared again and so on. The auction stops when there is no more land available or if there are no positive offers. The actual rent paid for newly allocated plots in a particular period is determined on the basis of the offer given for this plot and the average offer for all other plots newly rented in that period. The rent paid for all other plots which were not newly rented in this period are iteratively adjusted towards the average price of newly rented plots.

The farms are also affected by developments on product markets. Product prices may change according to regional production activities. However, because only a small region is simulated, it is assumed that the gross margins of the main activities are fixed. For the simulations presented in the remainder, technical progress is ignored.[4]

As already mentioned, it is assumed that the acquisition costs of assets are totally sunk after an investment has been made, i.e. the opportunity costs of assets are zero. Furthermore, it is assumed that each farm is handed over randomly to the next generation every 25th period. Then, for the decision whether or not to continue farming, the opportunity costs of farm-household labor are considered to be 15% higher. If the farm continues, opportunity costs for off-farm use of labor remain at the lower level, since this is understood as an investment into agricultural training which reduces the chance of a profitable off-farm employment.

4 Calibration and data

Unlike the model approach presented in Balmann (1997, 1999, 2001) in which a fictitious, hypothetical region was modeled, the present approach models the agricultural structure of an existing region. In particular, the following simulations try to capture agri-environmental pol-

[4] A more realistic approach would probably be to consider increasing opportunity costs for labor and to incorporate technological progress. For an explicit consideration of technical progress cf. Berger (2001).

icy impacts on the selected region of Hohenlohe. For this, in a first step, the model is calibrated in order to consider the central characteristics of agricultural production in Hohenlohe. The calibration occurs on two levels: the farm level and the aggregate level.

On the farm level, 12 different basic farm types are defined. These are defined on the basis of data from 12 real farms in Hohenlohe, each of which takes part in the German Farm Accountancy Data Network (FADN). The main selection criterion was that the farms should be typical for the region, i.e. they should be able to cover Hohenlohe's range of farm types with respect to size, main production area, and whether it is a full-time or part-time farm. Table 1 gives an overview. Accordingly, 8 full-time and 4 part-time farms were chosen. Among them are dairy farms, pig farms, poultry farms, crop farms and mixed farms of different farm sizes. The farms operate with selected production techniques that are considered to be typical for the region. The required coefficients regarding investment alternatives, LP/MIP matrices, and the calculations of gross margins and profits are derived from standard farm management data samples published for the German agriculture (KTBL 1997, Landesanstalt fuer Landwirtschaft 2001, Regierungsbezirk Mittelfranken 2001).

Table 3: Characteristics and frequencies of the specified basic farms

Variable	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Organization												
crop					X	X					X	
dairy			X	X					X			
pig, poultry	X	X						X				X
mixed							X			X		
full-time	X	X	X	X	X	X	X	X				
part-time									X	X	X	X
Land												
total (ha)	22.5	72.5	67.5	30	37.5	60	50	112.5	12.5	17.5	10	20
arable (ha)	22.5	72.5	40	12.5	37.5	60	22.5	102.5	5	12.5	10	20
pasture (ha)	0	0	27.5	17.5			27.5	10	7.5	5	0	0
Animals												
cattle			90	52			63	25	28	5		
cows			39	26			28		12			
sows	40	128			40		64	170				128
hogs	300	600						0		100		
turkeys						20000						
Frequency	480	25	120	244	106	22	231	95	389	154	442	298

As the last row of table 3 shows, each of the specified typical farms is assigned a certain frequency. The frequencies are determined in order to receive a farm structure that reflects the main characteristics of the regional agriculture on the aggregate level. These aggregate characteristics are the number of farms (total and with respect to specialization and size), the amount of hectares of arable land and of pasture land, the land used by farms with a certain organization and specialization, and the number of animals (dairy cows, sows, hogs, turkeys). Table 4 shows the obtained adjustment with respect to the selected characteristics.

Table 4: Adjustment of the model with respect to main characteristics of Hohenlohe

Variable	Units	Hohenlohe	Model	Error
Farms				
total	farms	3013	2606	-14%
crops	farms	459	570	+ 24%
dairy	farms	906	753	-17%
pigs, poultry	farms	988	898	-9%
mixed	farms	516	385	-25%
full-time	farms	1578	1323	-16%
part-time	farms	1435	1283	-11%
Land				
total	ha	72448	73503	+1%
arable	ha	55043	54943	0
pasture	ha	17405	18560	+7%
Land farmed by				
crop farms	ha	9569	9715	+2%
dairy farms	ha	21683	20283	-6%
pig, poultry farms	ha	27766	29260	+5%
mixed farms	ha	14421	14245	-1%
full-time farms	ha	57464	55565	-3%
part-time farms	ha	16276	17938	+10%
Animals				
cattle	animals	60638	51903	+14%
cows	animals	21072	22361	+6%
sows	animals	99787	95718	-4%
hogs	animals	169901	174400	+3%
turkeys	animals	450000	440000	-2%

Since there is a certain trade-off in fitting the different characteristics, the frequencies have been chosen by minimizing the weighted quadratic deviations between the model and the region. A formal presentation of the calibration procedure can be found in Balmann/Lotze/Noleppa (1998a and b). According to table 2, the calibrated model fits the selected characteristics of the real region quite well. Strong differences only exist with respect to the number of farms. This is mainly due to the fact, that there is a sample error in the German FADN. Particularly small farms often are not willing to participate and often do not meet the respective criteria for participation. For instance, the smallest farm we found in the FADN for Hohenlohe which fulfilled the selection criteria had an acreage of some 10 ha. Thus, it was particularly difficult to represent the many part-time farms which are often smaller.

For the initialization of a simulation, each of the basic farms is established in the model region according to the determined frequency. However, before a simulation starts, the different basic farms are further individualized with respect to several variables. These variables are the location on the spatial grid and the age of the farms' machinery and buildings. These variables are determined randomly. Moreover each farm receives an individual management coefficient which affects the farm's variable costs and thus its profitability and competitiveness. For every calculation of gross margins, this coefficient (with a random value between 0.95 and 1.05) is multiplied with the relevant variable costs.

5 Policy scenarios

As already mentioned, this study aims to analyze the possible impacts of an agricultural policy switching towards a policy which favors environmentally friendly production methods, in the sense of a stronger link between animal production and land use. We have taken the Agenda 2000 as the reference scenario for the policy switching. The Agenda 2000 is a political action program of the European Union that has been agreed on in 1999 at the Berlin European Council Meeting by the heads of government of the respective memberstates. Starting in 2000, the program is being implemented successively and - apart from non-agricultural issues, such as to give the European Union a new financial framework for the period 2000-2006 - it also determines a general framework for the CAP.[5] Since the considered switching towards a more environmentally oriented agricultural policy will be based on the Agenda 2000, the actual regulations of the Agenda 2000 will have to be taken as the reference scenario. At present the first steps of the Agenda 2000, but not the whole program, have been implemented. Consequently, the farm structure and the considered farms' organization as they presently can be found in Hohenlohe are more the result of former CAP regulations, and not a direct result of Agenda 2000. In order to overcome this inconsistency, we first define and simulate a base scenario reflecting the pre-Agenda policy situation. This scenario is mainly used for calibration and vali-

[5] The contents of Agenda 2000 can be retrieved under http://europe.eu.int/comm/agenda2000/index_en.htm. Several studies analyzing its impacts on German agriculture can be found in Agrarwirtschaft, Vol. 47 (12).

dation purposes. During calibration and validation the assumptions of the base model are subject to adjustments in order to reflect the actual agricultural structure and the main trends of Hohenlohe in an acceptable way. After the model has been calibrated the reference scenario - the Agenda 2000 - is implemented into the calibrated model, as well as two alternative policy scenarios.

Reference scenario: Agenda 2000

To obtain an understanding of the policy scenarios to come, we will briefly discuss the key aspects of the reference scenario, the Agenda 2000. The central changes as compared to the pre-Agenda situation are a reduction of intervention prices for products like cereals, beef, and milk. In return farmers receive higher direct payments. With respect to crop farming the payments depend on the amount of land that is used for the production of cereals, oil seeds, and legumes. In dairy farming the payments depend on the milk quota and in beef production on the number of animals. Concerning arable crops, intervention prices for cereals are cut by altogether 15%. At the same time, direct payments are increased to 324 € per ha for cereals and oilseeds and 383 € per ha for protein seeds. The compulsory set-aside rate is reduced to 10%, but voluntary set-aside is possible, and it is compensated for with 324 € per ha. Arrangements for silage maize are maintained.

For beef products intervention prices are cut by 20%. The bull premium is increased to 283 € per animal and year. The annual premium for suckler cows is increased to 215 € per cow. All animals beyond an overall stocking density of two livestock units per hectare of forage area, including bulls, dairy and suckler cows, are not eligible for premia. For dairy products intervention prices are cut by 15 percent. Milk quotas are maintained at current levels. A new direct payment is introduced at 215 € per dairy "premium unit" per year, including the beef premium.[6]

Alternative scenario I: Limiting the livestock density

The first alternative scenario ("LU-Agenda") is directly based on the reference scenario of the Agenda 2000. The only modification is the assumption that a farm is only eligible to receive the full amount of direct payments if the farm's livestock density is below two livestock units

[6] A "premium unit" is defined as a dairy cow with an EU-average milk yield of 5 800 kg per year.

(LU) per ha of farmland.[7] If not, it is assumed that the payments are cut by 162 € for each LU that is above the farm's limit of 2 LU times the land which is farmed.

Alternative scenario II: Unitary premium for all grassland and limited livestock density

The second alternative scenario ("LU-Premium") also considers the limited livestock density. Moreover, instead of the rather differentiated payments for different crops, it is considered that the farms receive a unitary payment of 250 € per ha of land, regardless of how the land is farmed. The payments for animals are those of the reference scenario.

6 Results

6.1 Base scenario and Agenda 2000

Before, the policy scenarios will be analyzed, we will first look at the base scenario and the reference scenario, i.e. the Agenda 2000. In particular, we will illustrate the adjustment of the model with respect to structure and structural change. Figure 3 shows the evolution of the average farm size for the base scenario and the Agenda 2000. Accordingly farm sizes develop steadily and rather slowly. For the base run, the average annual growth rate is 2.9% which is similar to the real development in West Germany, where average farm sizes increased from 1991 to 2000 with a rate of 3.2% per year. The model growth rate is slightly lower because technical progress has not (yet) been considered in the model. Compared to the base run, the Agenda 2000 will slightly speed up structural change (3.2%). This can be explained by a reduction in subsidies, i.e. the higher direct payments do not fully compensate price reductions. As a consequence, more farms with a low productivity leave the sector, as compared to the base run.[8] This however does not mean that the Agenda causes persistently lower incomes. As figure 4 shows, profits develop closely together. After about 5 periods, the Agenda 2000 leads to equal profits. The explanation can be found in the faster structural change and – this is more relevant - in significantly lower rental prices for land which after period 5 compensate for the lower subsidies. This positive impact on incomes is also illustrated by figure 5 which shows the average rental prices and economic land rents. The economic land rent is computed as the household income plus rent expenditures minus long-run opportunity costs of the capital and

[7] One livestock unit (LU) is defined as an animal with a living weight of 500 kg
[8] Regarding a quantification of the effects cf. Balmann/Lotze/Noleppa (1998b).

family labor. Even though economic land rents are lower for the Agenda 2000, after some periods, the rental prices decline significantly and profits close up.

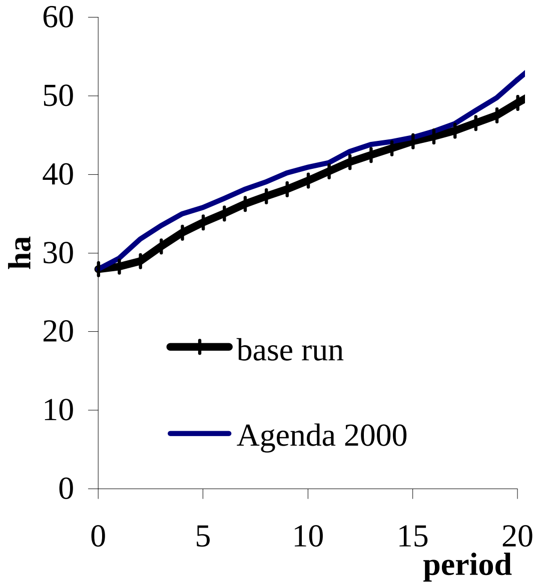

Figure 3: Evolution of average farm sizes

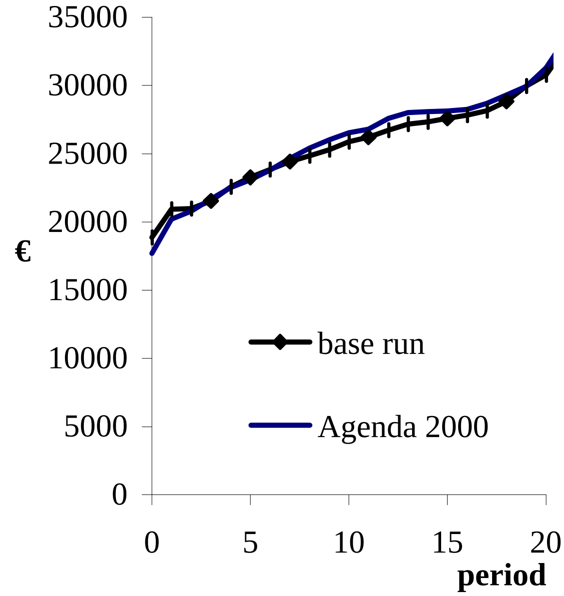

Figure 4: Evolution of average profits per farm

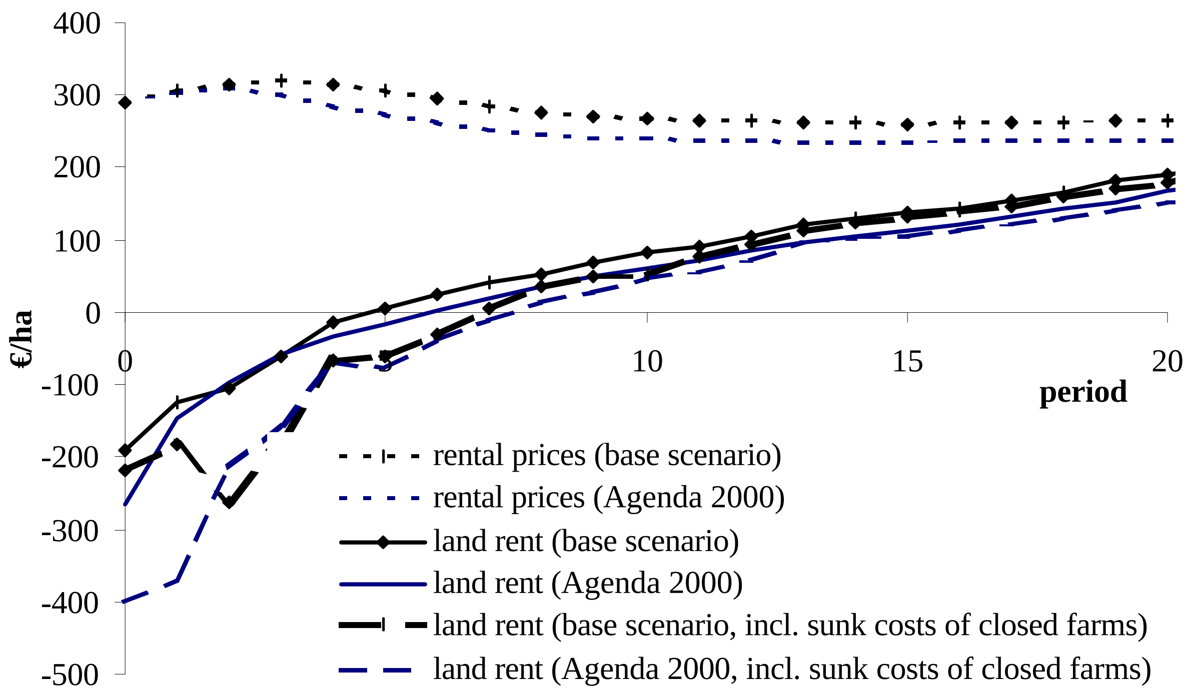

Figure 5: Evolution of rental prices for land and land rents

What is remarkable about figure 5 is the fact that for the entire time horizon of 20 periods economic land rents are below rental prices for land; for several periods they are even negative. On first glance this may surprise, because it implies a persistent disequilibrium. But, since initially farms are very small, hardly any farm is able to exploit increasing returns to scale. Many farms only continue farming because the costs of their assets are sunk and their opportunity costs of farm-household labor are low. If in figure 5 depreciation would be ignored, i.e. depreciations would be added to land rents, the sum would be above rental prices. Hence one can argue that even within a time horizon of two decades the sector is not able to adjust fully towards a state that fulfils central equilibrium conditions, in which prices cover long run costs.[9]

Summarizing, it can be concluded that in response to the Agenda 2000 farms have to adjust. But, the adjustment induced by Agenda 2000 policies turns out to be not much stronger than the adjustments that would happened in any case without the Agenda 2000 (base run). This is due to the fact that West German farms in general, and farms in Hohenlohe in particular, have to be considered as too small. Hence, adjustment pressure towards a larger farm structure is immanent to the farm structure. Concluding, it can be noted that the reference scenario defines a "state" that is far from equilibrium.

6.2 The switching costs of alternative policy scenarios

After having sketched the actual situation of the agricultural sector in Hohenlohe in the previous section, we will now focus on the two alternative policy scenarios defined above, both of which require farms to meet certain livestock densities in order to be eligible for direct payments. Results of these alternative scenarios will not only be analyzed on a sector level (which considers only averages), but a more detailed analyses on the farm level will be carried out to illustrate the policy response of different farm types as well as interactions between farms.

Unlike the base run and the Agenda 2000 scenario, on the aggregate level, the alternative policy scenarios show to have a strong effect on the structural adjustment process. For instance, the scenario Agenda 2000 with limited livestock density ("LU-Agenda 2000") fosters structural change with respect to average farm size. Obviously, farms initially exceeding the limit of 2 LU/ha with their existing production capacities, aim at increasing their acreage in order to further fully utilize their production capacities.

[9] A more detailed analysis of this equilibrium can be found in Balmann (1999).

This is somewhat different for the scenario with a fixed premium for land use ("LU-Premium") which shows to inhibit the increase in farm sizes. This can be explained by the fact that many small dairy farms benefit from fixed grassland premia, which were not granted as part of Agenda 2000. Thus the competitiveness of these dairy farms on the land market increases as compared to less grassland-dependent farms (pig and poultry farms, crop farms). Consequently, more farms survive and the average acreage remains smaller. This is supported by figure 7 which shows the land shares of different farm size classes. Accordingly, the scenario "LU-Premium" allows many small farms with 10 to 20 ha, the majority of which are small dairy farms, to survive at least during the first 15 periods of the simulation.

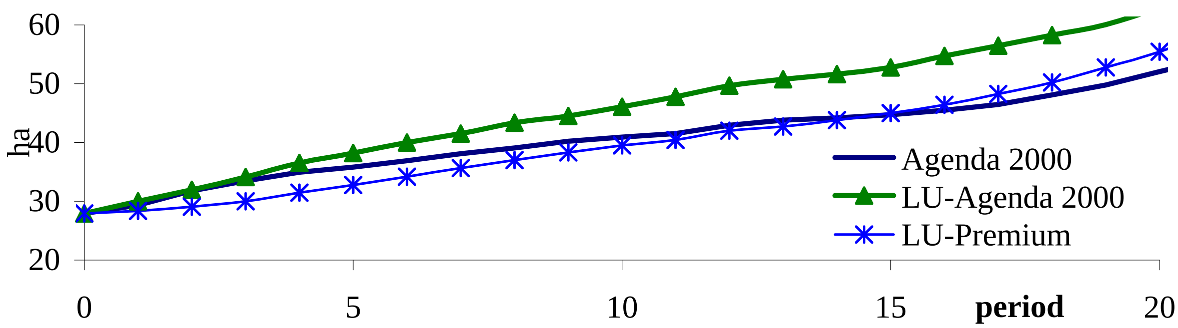

Figure 6: Evolution of average farm sizes

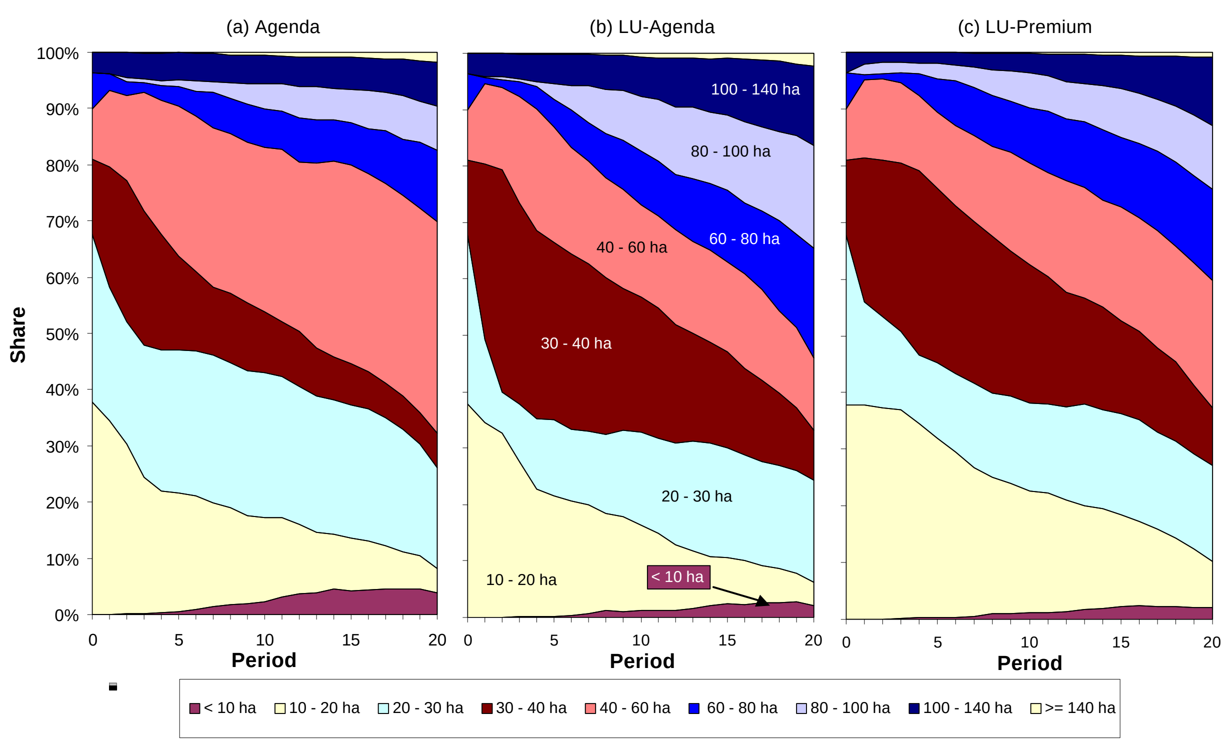

Figure 7: Evolution of farm size shares

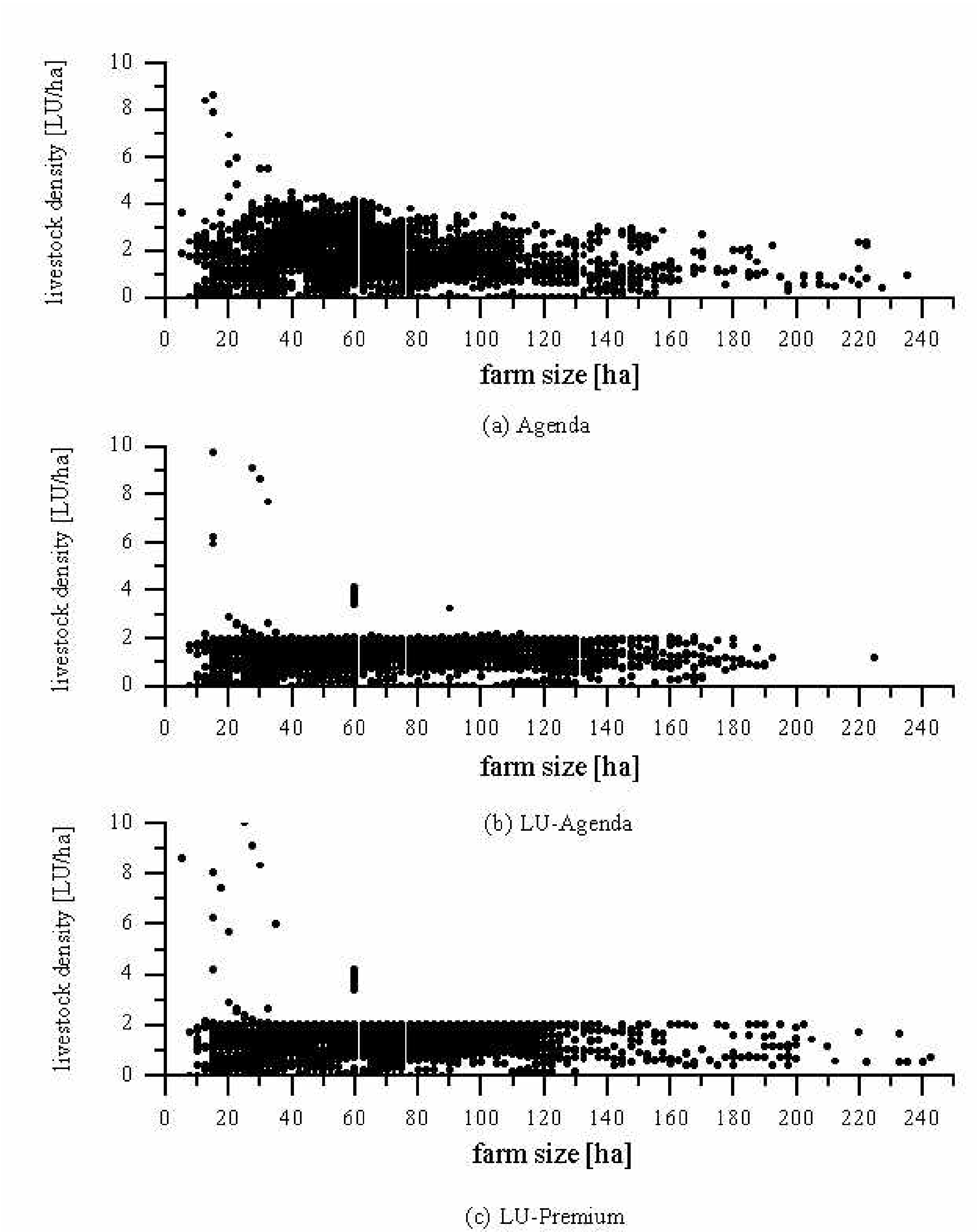

Figure 8: Livestock densities per farm and period

Nevertheless, the livestock limit on livestock density is very effective in both alternative scenarios. According to figure 8 the majority of farms chooses to actually limit their livestock density to a level below 2 LU/ha in all periods. There are only a few exceptions, where it is more profitable for the farm to accept the levy of 160 € per LU.

Thus the initial thesis that the limit may cause inverse responses by some farms is not confirmed, i.e. farms do not lay off all land and specialize exclusively on animal production. Moreover, the average livestock density on the regional level declines from about 1.8 LU/ha to 1.3 LU/ha. Thus, it can be concluded that such a policy will also reduce other environmental problems related to high local concentration of animal production, such as the intense use of manure.

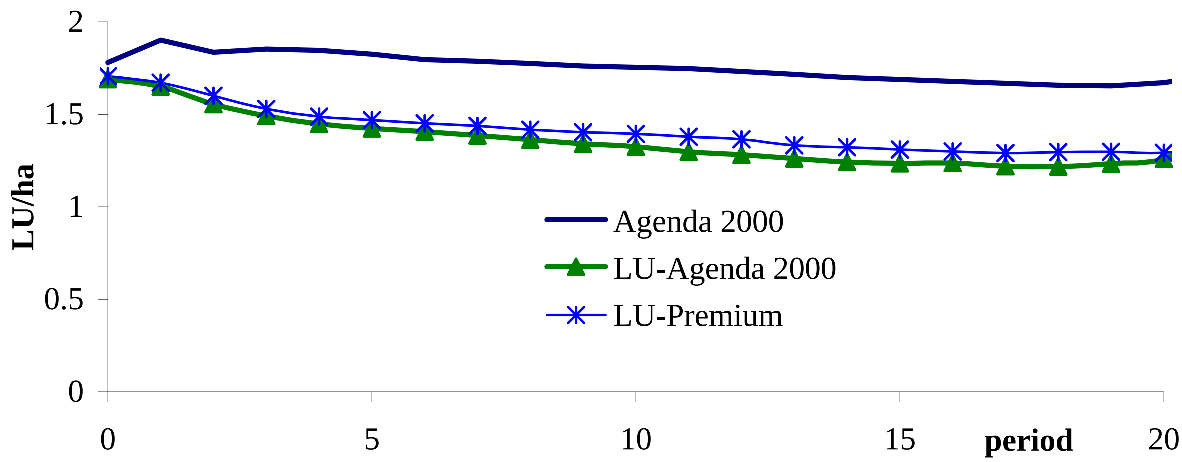

Figure 9: Evolution of livestock densities

After having shown that the alternative policy scenarios are indeed effective with respect to their aspired goal to reduce livestock density, it has to be asked at what costs this happens. A first point of interest is the impact on farm incomes. Figure 10 shows that for both scenarios incomes develop below the reference scenario "Agenda 2000". The income reduction of "LU-Agenda 2000" amounts to about 1200 € per year and farm, i.e. a reduction of 4.4%, and the income of "LU-Premium" is about 2200 € per year and farm lower, which corresponds to a reduction of 8%. On first glance this may not appear to be a strong income effect. Nevertheless, three aspects are worth mentioning: Firstly, it should be considered that in case of "LU-Agenda 2000" much more farms are driven out of the sector. Secondly, the average farm income is already rather low in the reference scenario, i.e. as figure 5 shows, the economic land rent is lower than the rental prices and thus there is a kind of functional income disparity (cf. Balmann 1999). And thirdly, one should consider that the farms are affected very heterogeneously by policy switchings. While some farms may even benefit, the profits of other farms may become even negative. This clearly supported by table 5.

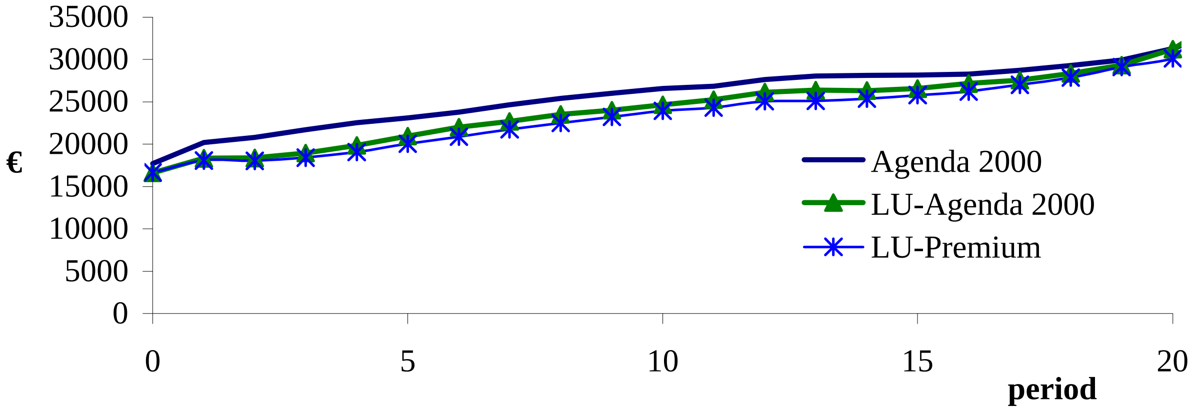

Figure 10: Evolution of average profits per farm

Table 5: Adjustment of the model with respect to main characteristics of Hohenlohe

		Dairy farms			Crop farms			Pig and Poultry farms			Mixed farms		
Initial farm types		I	D	C	K	F	E	B	A	L	G	H	J
Reference							**"Agenda 2000"**						
number	[%]	31%	44%	65%	57%	69%	91%	85%	95%	99%	85%	100%	78%
size	[ha]	28.80	33.05	59.99	23.81	87.15	45.21	71.71	30.95	24.44	58.94	110.28	28.67
income	[€]	32010	34287	38494	30737	24151	59016	33054	23843	45053	54437	85891	31923
profit	[€]	19895	27687	31699	13872	14632	38987	25293	14049	27141	43667	57134	13489
livestock	[LU/ha]	2.56	2.30	1.29	1.20	1.86	1.60	1.55	1.66	2.09	1.95	0.90	1.61
Scenario 1							**"LU_Agenda 2000"**						
number	[%]	23%	47%	62%	47%	54%	86%	71%	95%	78%	86%	100%	70%
size	[ha]	26.49	38.60	61.81	21.78	71.32	51.04	73.08	35.45	32.03	63.50	105.80	31.01
income	[€]	31723	34428	37401	30536	15844	58968	28217	22978	42823	53354	81991	30928
profit	[€]	14082	25945	31188	9206	3975	35051	21067	13417	26889	40888	51630	10986
rel. change	*[%]*	*-29%*	*-6%*	*-2%*	*-34%*	*-73%*	*-10%*	*-17%*	*-4%*	*-1%*	*-6%*	*-10%*	*-19%*
livestock	[LU/ha]	1.91	1.75	1.30	0.48	3.36	1.00	1.25	1.35	1.58	1.58	0.82	1.22
Scenario 2							**"LU_Premium"**						
number	[%]	*50%*	*74%*	*91%*	*50%*	*49%*	*85%*	*67%*	*94%*	*77%*	*94%*	*99%*	*89%*
size	[ha]	20.88	39.17	64.55	13.91	51.48	46.02	64.07	28.97	28.86	66.33	94.86	20.90
income	[€]	35135	38124	42221	30293	11358	57281	27273	22897	41524	58927	77991	32456
profit	[€]	13683	27681	35463	6464	-320	31453	19649	12019	25453	46152	49522	9441
rel. change	*[%]*	*-31%*	*0%*	*12%*	*-53%*	*-102%*	*-19%*	*-22%*	*-14%*	*-6%*	*6%*	*-13%*	*-30%*
livestock	[LU/ha]	1.71	1.68	1.36	0.33	4.64	0.91	2.70	1.36	1.69	1.68	1.09	1.11

The income effects for the two scenarios depend on several factors. One is the initial reduction of subsidies. But, as figure 11 shows, transfer payments in the alternative scenarios are only temporarily below the reference scenario. Whereas transfer payments in the reference scenario show a decreasing trend in the first periods, this is the reverse in the case of the alternative scenarios. There are different reasons for this development: As for the reference scenario the transfer payments are declining because of structural adjustments mainly by dairy farms that close down, sell their milk quotas, and leave the sector. Even though the assumed quota price with an annual opportunity costs of 0.05 € per kg is rather low, quota leaves the region and therefore direct payments for dairy cows decline. In the case of the alternative scenarios transfer payments initially are lower, but only after a few periods, farms have adjusted their farm organization such as to meet the payment criteria and hence there is no difference between the reference and the "LU-Agenda 2000" scenario. The scenario "LU-Premium" after 3 periods even leads to even higher transfer payments.

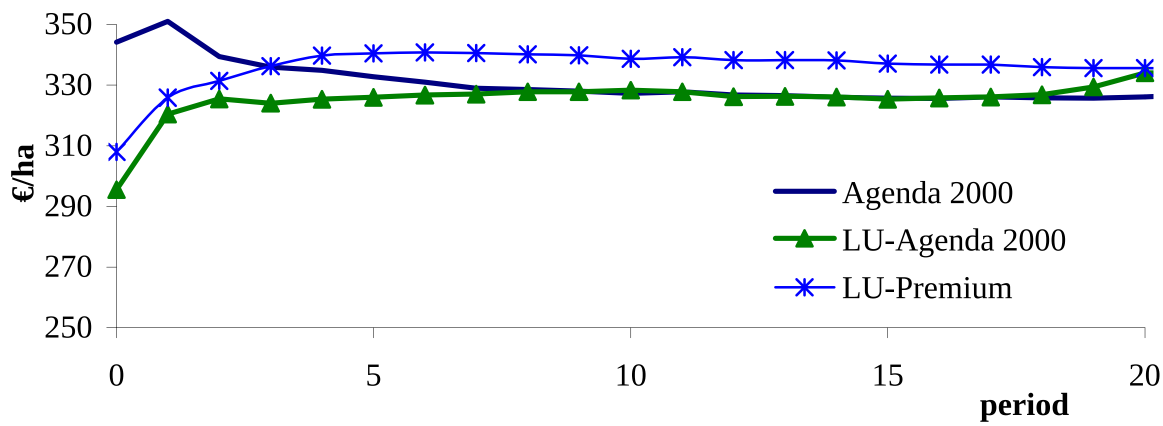

Figure 11: Evolution of average transfer payments per ha

Apart from the amount of transfer payments, the profits depend on the relation of productivity and land rents. According to figure 12, the policies affect both land rents and rental prices. Under Agenda 2000 conditions the limitation of the livestock density ("LU-Agenda") leads to a reduction of land rents during the first 10 periods as well as to an increase in rental prices. Because animal production capacities are fixed in the short run, the affected farms attempt to increase their acreage with the effect that rental prices increase irrespective of the fact that a number of farms receive lower transfer payments and thus have lower land rents. Since already in the starting situation about 50% of the agricultural land is rented land, this leads to smaller profits. What is remarkable about this situation is that after about 10 periods economic land rents are higher for the "LU-Agenda" scenario than for the reference scenario Agenda 2000 without livestock restrictions. A reasonable explanation for this is the productivity impact of a faster structural change. Since more farms with a low productivity leave the sector, the remaining farms perform better. However, this is not free of charge: Some farms close down despite of buildings that could still be used and and despite of low opportunity costs of their labor. If these adjustment costs are to be considered, the net effect is negative.

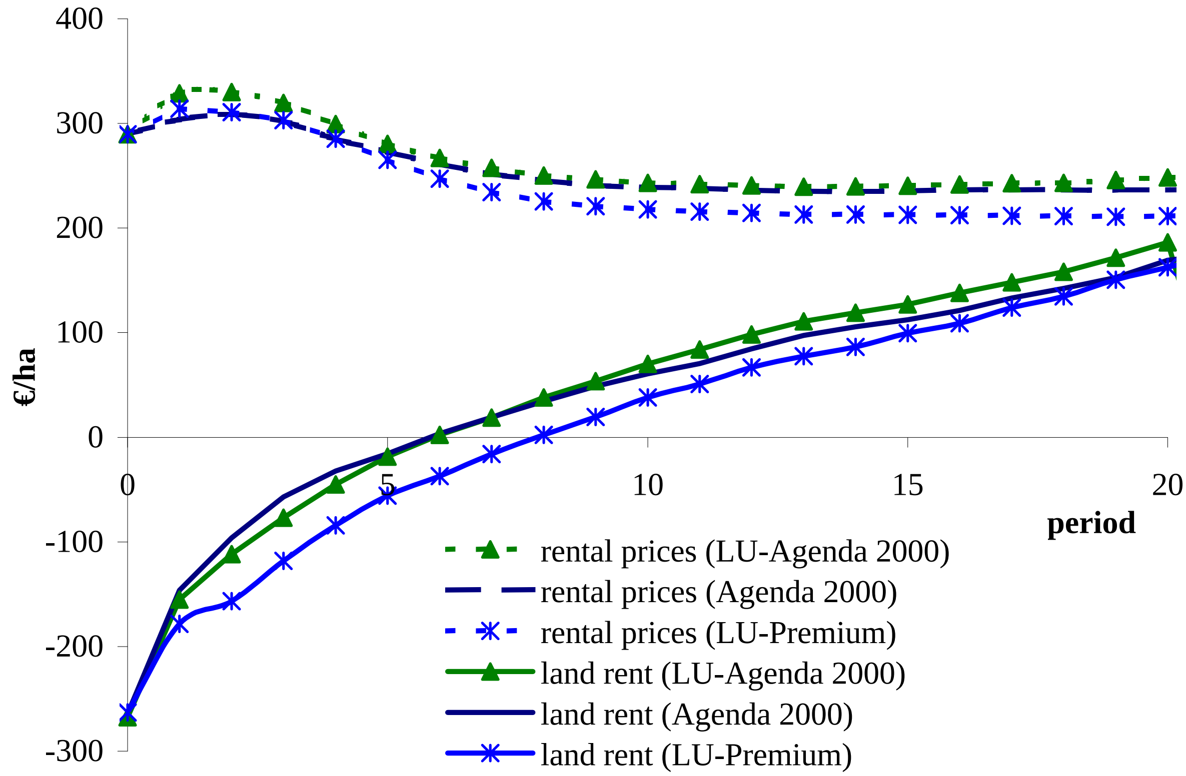

Figure 12: Evolution of rental prices for land and land rents

7 Summary and conclusions

Summarizing the results, one can conclude that the impacts of a main policy switching occurs on very different levels. If farms are heterogeneous they are affected individually and respond very differently. This can even mean that more restrictive policies may have positive impacts on some farms while other farms may suffer badly. The alternative policy scenarios presented above fall into this category. A policy that requires farms to meet certain animal density criteria in order to receive transfer payments can be quite effective because it creates the "right" incentives - provided that the requested animal densities follow the "right" goal. However, this is not free of charge. Particularly in livestock production, adjustment costs can be very high and adjustments occur slowly. On the one hand this is due to sunk costs, as illustrated above. On the other hand - and this has not been considered in this study - adjustments in livestock production often require farmers to learn about and quickly implement new and different production technologies. How time-consuming this may be can be seen from the transition of East German agriculture. Even 10 years after the fall of the Berlin wall, the successors of former collective farms increase their physical productivity in animal production at enormous rates which cannot reflect normal technological progress but still a catch-up process towards what is technologically possible (Balmann/Czasch/Odening 2001).

Thus, from a policy perspective, one has to conclude that policy switchings that affect animal production should either be introduced slowly or should be announced in due time such that farmers can respond without enormous adjustment costs. But, since policies often reflect spontaneous reactions to public concerns, this often is not the case. From a scientific and from a modeling perspective, one has to conclude that the simulations presented above give a starting point for further investigations. Even though the model is already very differentiated regarding individualization as well as regarding dynamic and spatial issues, many promising extensions are not yet implemented: One may additionally consider technological progress, more differentiated landscapes, heterogeneous preferences of farmers, etc. Moreover, the model may be applied to different regions and alternative market scenarios.

The presented simulations are based on a model approach that has been developed originally to analyze the particular dynamics of structural change. On the basis of this intention it allows to study long term policy effects. The obtained results shed some light on policy effects that often are ignored by conventional policy analysis, such as dynamical and distributional impacts on efficiency and incomes. From this point of view, policy modeling on the basis of multi-agent systems seems very promising. On the other hand, the question is, how valid and how convincing the model and its results are from the politicians' and economists' perspectives. And indeed, there are some critical points:

- Firstly, one has to concede that the validation of such models is difficult. Neither it is possible to recalculate all numbers, nor is it possible to compare the results directly with analytical and empirical results. Nevertheless - and this is demonstrated by earlier applications of the approach (Balmann 1999, 2000) -, the results are surprisingly robust and did not change significantly during many revisions the model was undergoing over the past eight years. Moreover, the results fit many empirical observations like slow structural change, persistently unexploited economies of scale, and income disparities very well.

- Secondly, several of the model's assumptions (like the existence of bounded rationality and economies of scale) and results (like path dependence and income disparities) are discussed very controversially in agricultural economics. Hence one may criticize that the model and its applications may only convince those people who are already persuaded of bounded rationality and increasing returns. A critic may argue that the model simulations just reflect what has been put into the model. But, this argument is too short-sighted. If the model's assumptions and results are in line with a particular economic argumentation this does not mean that it is trivial. Phenomena like bounded rationality, increasing returns, path dependence, and income disparities imply complexity and can often hardly be tackled analytically. Then the only opportunity is either numerical simulation or verbal and qualitative reasoning. The advantage of numerical simulations is that simulations allow to quantify the effects and to check the consistency of the argumentation. Herewith they enable to find inconsistencies of the argumentation and to improve the theoretical arguments. They may even allow to develop hypotheses which enable promising empirical tests.

- Thirdly, MAS are usually highly-dimensional and non-linear. Even for the user it is difficult to grasp the full structure of the results regarding their variability over the different agents and over time. Hence, it is far from trivial to mediate the model's assumptions and its results to third persons. Every presentation requires simplification and it may even occur that the more differentiated and sophisticated the presentation is, the more questions arise for the addressees. In the end, the analysis and presentation of the model results may require simplified models of the original model and its results. Sometimes it may even be useful to apply sophisticated statistical methods to study the simulations' results. For instance, Balmann/Hilbig (1998) applied a factor analysis and a cluster analysis to study conditions under which the presented model shows path dependent behavior.

Summarizing these points, it is clear that there are some problems with the use of complex MAS. But actually these problems should rather be understood as a matter of the research questions to which MAS are applied than one of the method itself. It is reality which is so complex. Models based on MAS allow just to consider and reflect this complexity. Hence, to renounce this method means often not to use a method that is able to grasp the complexity of the research question. Moreover, MAS have to be understood as a rather young field of research. The application of MAS allows to explore their opportunities and to learn about them. This is a valuable byproduct of a method which is a beneficiary of the increasing power of modern computers. The limits of such models are far from reached and they are steadily shifted further.

To conclude, MAS offer the opportunity to look at economic and social processes from new and different perspectives. They allow to study questions which otherwise cannot be tackled at all or which require rather strong assumptions. Hence, MAS appear to be a promising tool for policy research. Their limitations will depend on the progress in information technology and on the resourcefulness of its users. Thus they are also a promising field of future research.

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