Studies on the Agricultural and Food Sector
in Central and Eastern Europe

Kathrin Happe

Agricultural policies and farm structures

Agent-based modelling and application to EU-policy reform

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Foreword

For a long time the agricultural sector in most industrialised countries has been – and still is – highly subsidised. The applied instruments and the amount of subsidies differ by country and change over time. Due to their strong impacts on farmers' incomes, on budgets, and on trade, it has become a routine for agricultural economists to regularly analyse policies and policy options to support policy makers and the various stakeholders. In general, the focus of the analyses was – and still is – either on the sectoral/regional, or on the farm level. Moreover, most analyses were and still are either highly aggregated (at least at the regional level) or disaggregated, but neglect interactions between farms. As a consequence, the policy analyses usually had little to say about interactions between farmers, the speed of farm adjustments, and the resulting structural impacts. The recently agreed reform of the EU's Common Agricultural Policy as well as the previous discussions made these deficits very obvious because topics such as policy impacts on land prices and structural change were intensely discussed, but methods to study them were largely lacking.

The present study by Kathrin Happe addresses these deficits and explicitly aims at giving insights on the impacts agricultural policies on structural change, land markets, and farm incomes in the short and in the long-run. In order to achieve this ambitious goal, Kathrin Happe develops and follows an even more ambitious research strategy: the development of an agent-based model of explicit structural change and its application to a real region to study actually relevant policy options. Although in some respects the outcome of this research strategy and its goals is based and inspired by previous work, the present outcome is unique: the spatial and dynamic agent-based model of agricultural structural change AgriPoliS is developed and documented, the model is adapted to the region of Hohenlohe in south-west Germany, the model and its adaptation are intensely tested and validated, sophisticated quantitative tools such as kernel density estimation and data envelopment analysis are utilised to identify high-dimensional structural policy impacts. Last but not least, several relevant policy options are intensely analysed and discussed. The results give a different view on the effects of agricultural policies, and particularly on some very specific distributional effects of different policies as well as the specific influence on structural change. Accordingly, many kinds of common types of subsidies show low transfer efficiency. Moreover, there is a danger of slowing down necessary adjustment processes and thus creating a dependency on subsidies. These findings were possible because the developed model AgriPoliS explicitly allows considering structural disequilibria and endogenous structural change. This is important to understand structural adjustments of the relatively small-scaled agriculture in the "old EU", as well as the often dualistic farm structures in the new EU member states and the new EU neighbour countries.

This study is relevant and important from a methodological, theoretical and from a practical perspective: it contributes to the development and testing of applied agent-based economic models, it delivers a new agricultural policy analysis tool, and it contributes to a better understanding of the role of agricultural policies with regard to structural change, farm incomes, and land prices. Although these contributions have a value in its own, the real value is their potential stimulus for discussions and future research. That is why I wish this book to become widespread among researchers.

Halle (Saale), December 2004 Alfons Balmann

Thank you

One day, during my third semester of Agricultural Economics at Hohenheim, I was sitting in the cafeteria and I was talking to some fellow students about what to do after graduation. Although it was only quite early on into my studies, I remember saying that I wanted – if possible – stay at the University. Why? I just loved the people and the atmosphere. After I had graduated in 1997, one more reason came up: Although I had a degree in Agricultural Economics, I had the feeling that I had not finished my studies. I simply had to go on. In particular, I wanted to know why and how things around me change.

So, I started to walk my PhD way. Many people have accompanied me on this way: some from beginning to end, others just on parts of the way. Nevertheless, each one of them has contributed to this work in one way or another, be it by trusting me to do this rather risky research, by listening, by showing interest, by making me laugh, by criticising me, or by something else. In the end, I feel that the time of my PhD has been a gift. It is difficult to express all my thanks in words. Thus, I just want to say a simple 'thank you' to Alfons Balmann, Jürgen Zeddies, Konrad Kellermann, Christoph Sahrbacher, Anne Kleingarn, Martin Damgaard, Jarmila Curtiss, Amanda Osuch, Martin Petrick, Valentyn Zelenyuk, Marten Graubner, Jörg Zimmermann, Frank-Michael Litzka, Michael Schäfer, Sorana Cernea, Olaf Heidelbach, Alfons Oude Lansink, Franz Heidhues, Noel Russell, Wilhelm Gamer, Beate Zimmermann, the many collegues with whom I had many inspiring discussions and conversations at conferences, workshops, and project meetings, the Federal State of Baden-Württemberg, the Deutsche Forschungsgemeinschaft (DFG) and the Institute of Agricultural Development in Central and Eastern Europe (IAMO), Erdentöne-Himmelwärts, Collegium Vocale Halle, Junger Kammerchor Baden-Württemberg, Unichor Hohenheim, Katrin, Maike, and Niklas Menzel, Martin Plothe, Justine Schuchardt, Elisabeth Angenendt, Nicole Schönleber, Agnes Bardoll-Scorl, Konrad and Ruth Sophie Scorl, Markus Pietzsch, Daniela and Burkhard Kreft, Christine, Gottfried, Daniel, Benjamin, and Sophie Kazenwadel, Steffen Krämer, Steffi Beinhorn, Paul Berentsen, my whole big family, and in particular Klaus, Elisabeth, Christoph and Norbert Happe. I am sure that each one of you knows how much I appreciate your trust, guidance, criticism, company, friendship and love.

Halle (Saale), December 2004 — Kathrin Happe

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1 General introduction

1.1 Problem assessment

1.1.1 The role of agricultural policies in structural adjustment

Agricultural structures have been shaped by a variety of factors including economic, cultural, historical, political, technological, and geographical conditions.[1] Hence, agricultural structures are not static but change. Structural change can be viewed as an evolutionary process, which is an integral part of any economy. It can be characterised – amongst other things – by a constant adjustment to changes in demand, supply, and technological progress (OECD 1994). This process is ideally guided by market signals, which convey information about social preferences and production possibilities. The degree to which agricultural structures can adjust to market signals depends on the extent to which production factors can move to areas where their productivity is highest. In this sense, the mobility of production factors is central to the competitiveness and efficiency of agriculture.

Market activity, however, also takes place within a policy framework. Policies set the rules for market activity, but they can directly interfere with the adjustment processes on markets, too. Regarding the latter, the role of agricultural policies is twofold. On the one hand, policies can alter the capacity of the agricultural sector - and thus of agricultural structures - to adjust and create incentives for adjustments. On the other hand, policies can also impede structural adjustment, for example, by (artificially) increasing the profitability of one production

[1] In the context of this study, the term 'structure' refers to the essential the composition of an entity made up of inter-related component parts (OECD 1994). Component parts of agricultural structures are farms, land, labour, and capital, which comprise the productive capacity of a region. OECD (1995) defines 'structural adjustment' as the movement of production factors among farm units, and between the agricultural sector and other sectors of the economy.

activity relative to others. This affects the allocation of the production factors land, labour and capital and thus creates market distortions, which are considered inefficient. Thus, interference of policies with the adjustment process is likely to create both costs and benefits in an economy (GODDARD et al. 1993).

The development of competitive and efficient agricultural structures has been one of the central goals of agricultural policy making in addition to ensuring a fair standard of living for farmers. To achieve these goals, the agricultural sector in most industrialised nations has long been the subject of government interventions. However, many agricultural policies have worked counteractively to these goals by creating distortions in the use and mobility of production factors (e.g. DEWBRE et al. 2001; OECD 1995, 1994; FENNELL 1999; VON URFF 1997; BALMANN 1995; WISSENSCHAFTLICHER BEIRAT BMVEL 1997). In principle, policies contributed to inhibit those structural adjustment processes, which would take place without support. Distortions emerge mainly because policies providing support to farming activity are considered to attract additional resources (in particular labour and capital) to farming activities than would be the case without support (OECD 1994). The result is that agricultural support policies may impede structural adjustment by providing incentive for marginal farms to remain in the sector and thus retard the development towards more efficient agricultural structures.

Regarding agricultural policies in the EU, in the past decades, two types of measures have been at the centre of interest: market price support and direct area and headage payments.[2] With regard to these measures, impediments to structural adjustment may particularly become evident in the following areas:

- *Production:* In general, agricultural support policies lead to increasing production while encouraging the maintenance of marginal farms. For example, market price support leads to higher returns on some products, which transfer into higher input prices for production factors. High prices encourage the expansion of production beyond market demand and often the use of capital-intensive production methods (OECD 1994). Direct area and headage payments coupled to production activities create also production incentives.

[2] Although in the agricultural reform of 1992 (and also in Agenda 2000) price support was successively reduced, it continued to be in place. Furthermore, to (partly) compensate for lower support prices, farmers were granted direct area and headage payments, which, however, were bound to production of certain crops and livestock.

Moreover, coupled direct payments impede structural adjustment because marginal farmers use parts of the payment to cover losses.

- *Specialisation vs. Diversification*: Guaranteed prices reduce uncertainties and therefore reduce the incentive for farms to diversify and spread production risk. Instead, farms (increasingly) specialise and intensify production to take advantage of other input subsidies such as investment programmes, and technological progress. Specialisation in combination with intensification may cause negative environmental effects (BEARD and SWINBANK 2001).
- *Land prices*: Agricultural support policies intensify competition for scarce resources and particularly for land because land supply is inelastic. In the case of land, a significant share of future support payments is capitalised into farmland prices and rental prices (e.g., WEERSINK et al. 1999; DAUGBJERG and SWINBANK 2004). High rental prices benefit land owners, but lead to lower profitability on the side of active farms (ISERMEYER 2002). In regions with a high share of intensive livestock production, competition on the land market intensifies additionally because of land required for manure disposal and limits on livestock density per hectare.
- *Farm size differences*: OECD (1994) and FENNELL (1997) argue that existing agricultural policies have contributed to the growing differentiation between larger and smaller farms since the former have generally been better placed to take advantage of agricultural support.

1.1.2 The scope for policy reform

Stimulated by the above considerations, throughout the past 30 years agricultural economists have argued repeatedly that agricultural policies could actually be defined and implemented in a way that lifts many impediments to the policy and promotes efficiency and competitiveness (e.g., KOESTER and TANGERMANN 1976; FENNELL 1997; WISSENSCHAFTLICHER BEIRAT BMVEL 1997; SWINBANK and TANGERMANN 2000).[3] The key reform principle behind these proposals has been to reduce market protection and to facilitate responsiveness to market conditions by agricultural producers through policy measures that result in lower support delivered in less distorting ways. In this way, a policy reform should be expected to positively influence the efficiency and competitiveness of agricultural structures.

3 FENNELL (1997) provides a detailed account of the EU Common Agricultural Policy after World War II.

Several policies have been envisaged to achieve these goals: Besides successive cuts in market support prices, policies going in this vein could be direct payments which are fully decoupled from production, a successive reduction of any kind of support, as well as incentive payments to remove surplus labour of all ages from farming.[4] What all of these policies have in common is that they exert adjustment pressure on existing producers and hence are expected to increase structural adjustment processes towards a more efficient allocation of factors. The actual nature of structural adjustment due to policy reform would depend on the pace and scope of the reform, structural and natural characteristics of affected regions, and in particular, on individual farmers' capacity to adjust.

The latter point requires special attention as it indicates that individual behaviour, local conditions, and thus, interactions and heterogeneity gain importance when studying the adjustment reactions to agricultural policy change. In other words, what matters are the specific conditions of individual farms. The degree to which individual farms can adjust is determined by a number of factors, such as a farm's technology, managerial ability, size, location, specialisation, factor endowment, opportunity costs of (human and asset) capital, etc. Depending on these factors, possible adjustment reactions may be manifold ranging from a change of the product mix, investment or disinvestment, to changing the income mix between on and off-farm income sources. Moreover, farms may also entirely withdraw from the sector. However, on the side of the farms, there may also be some factors that hinder adjustment such as low opportunity costs of production factors. Hence, sunk costs lead to the effect that farms may continue production although their long run opportunity costs are not covered (BALMANN et al. 1996).[5]

1.1.3 Consequences for modelling

Thus, when studying farms' and the agricultural sector's adjustment reactions in response to a policy change and its dynamics, the question arises, how well agricultural economics is equipped with tools to accompany such policy reforms

[4] The decoupling of direct payments is the major component of the new common agricultural policy (CAP) of the European Union in Council Regulation (EC) No 1782/2003 of 29 September 2003, in which the member states of the European Union agreed on a major policy shift. The new CAP is to replace the current one starting in 2005.

[5] BALMANN et al. (1996) define sunk costs as the discrepancy between the calculatory time value of an asset, i.e., the value it should have according to the expectation when it was installed, and the actual opportunity costs.

with quantitative analyses that explicitly take individual farms' adjustment processes as well as structural developments over time into account? From a modelling point of view, it is thus important to find appropriate ways of modelling adjustment reactions to policy change. Against this background, the emergence of new and innovative modelling methods such as agent-based modelling, in addition to ever-increasing computing capacities has offered new possibilities to model adjustment reactions and to quantify the impact of agricultural policies on a range of indicators. This opportunity shall be explored in this thesis.

1.2 Objectives of the study and methodological approach

This thesis takes up these new methodologies and applies them to model and gain more insight into the impact of agricultural policy measures on regional structural change. Moreover, the study shall contribute to a deeper understanding of farm-type specific adjustment reactions and the dynamics of structural change. This study applies an agent-based model to a selected region, which is the family-farm dominated region 'Hohenlohe' in southwest Germany. The starting point of the analysis is the hypothesis that Hohenlohe's agricultural structure displays structural inefficiencies because structural adjustment in the past has been impeded by existing agricultural policies and factor immobilities. Moreover, in this study, it is assumed that the impeding impact of policies has been aggravated in some regions by existing structural deficits, which can be attributed mainly to three phenomena. First, unexploited returns to scale leading to an inefficient use of production factors; second, adjustment costs were causing the immobility of production factors, and third, path dependencies meaning that a path, e.g., a specialisation or the emergence of a specific structure once taken, can only be left at high costs.

Based on these assumptions, it shall be studied whether and to what extent policy changes can facilitate structural adjustment towards a more efficient and competitive agricultural structure. Light will be shed in particular on farm size change, factor use, technical efficiency, and income aspects.

The approach taken in this study is to carry out a number of simulation experiments using the agent-based, spatial and dynamic model AgriPoliS (Agricultural Policy Simulator), which establishes a virtual model world on the computer, the rules of which can be fully controlled by the modeller. The particular feature of AgriPoliS is that it allows modelling a large number of individually acting farms operating in a region as well as farms' interactions with each other and with parts of their environment. Simulation experiments with AgriPoliS generate an extensive dataset of indicators for individual farms and the entire region based on which a host of questions can be analysed using different analysis techniques.

In this thesis, no formal theoretical discussion of agricultural policies is presented and no formal policy impact model is derived. This has been the focus of other studies (e.g., HENRICHSMEYER and WITZKE 1994; HECKELEI et al. 2001; BULLOCK and SALHOFER 2003; HOFER 2002, and the literature cited in these references). Simulated data are instead treated and analysed 'as if' they were derived from real empirical surveys of Hohenlohe's agriculture as it may evolve under certain conditions.

To achieve the general objective, three sub-goals are pursued in this thesis. The *first* is to discuss the scope of agent-based modelling in agricultural policy analysis and based on that to develop the model AgriPoliS drawing upon previous work by BALMANN (1995, 1997). The *second* goal is to adapt and to calibrate AgriPoliS to the agricultural structure of the region 'Hohenlohe' in south-west Germany. This goal includes the representation of Hohenlohe's agricultural structure based on regional statistics, farm accounting data and standard technical data. Finally, to answer the overall objective, the *third* goal is to analyse results of simulation experiments for different policy scenarios. The types of policies considered reflect the intention to lift impediment to structural adjustment. Two sets of policies are analysed. The first group comprises three fundamentally different policies, a retirement payment scheme, fully decoupled payments, and a stepwise phasing out of direct payments. Each of these policies aims at facilitating structural adjustment. The second set of policies is inspired by the policy debate on decoupling direct payments in the European Union. Three ways of decoupling direct payments are analysed with respect to their impact on structural adjustment. Key questions to be answered are: How do the policies affect structural change in the region? What is the pace of structural adjustment? How do policies compare with regard to their impact of factor use, farm size, incomes, efficiency, and government expenses?

1.3 Structure of the study

The thesis is organised in three parts, following the three sub-goals. *Part I* of the thesis introduces agent-based systems in general as well as the use of the approach as a tool for understanding and modelling regional agricultural structures. *Chapter 2* motivates agent-based models as a conceptual framework for modelling in (agricultural) economic research. The chapter furthermore provides a formal definition of agents and agent-based systems. Specific features of agent-based models relevant for modelling regional agricultural structures are discussed, and applications of agent-based models are presented. Particular focus is put on applications relevant in agricultural and resource economics. Finally, chapter 2 points out some theoretical and practical challenges of agent-based modelling. Having provided the theoretical background for agent-based modelling in chapter 2, *chapter 3* presents AgriPoliS. The agricultural structure created in AgriPoliS consists of a number of spatially arranged individual farms, called farm agents, that act individually and interact with each other subject to their actual state and to their individual environment consisting of other farms, factor and product markets, and the technological and political environment. Farm agents pursue the goal of household income maximisation, they can engage in a number of production activities, invest into buildings and machinery, operate as non-professional farms, or leave agriculture altogether.

Part II of the thesis presents an application of AgriPoliS and formal testing and sensitivity analysis to validate the model. In *chapter 4*, AgriPoliS is calibrated to the agricultural structure of the region 'Hohenlohe' in Baden-Württemberg in the financial year 2000/2001, which is taken as the reference year. The calibration aims to map key characteristics of Hohenlohe's farming structure as well as the variety of farms and production activities. In AgriPoliS, farm agents are defined based on farm accounting data of real farms in Hohenlohe. In addition, regional statistics, investment data, as well as data on technical coefficients (e.g. KTBL) are taken to represent the structure of agricultural production in the region.[6] The full implementation of the Agenda 2000 by the end of 2002 is taken as the reference policy scenario. *Chapter 5* further investigates and tests the behaviour of AgriPoliS under the reference policy. To shed some light on AgriPoliS from different points of view, three separate simulation experiments are conducted. It is aimed to learn more about specific characteristics of AgriPoliS and its behaviour. First, the impact of different parameter constellations for technological change, interest rates, the region's size, and managerial ability are analysed with respect to their impact on results. In particular, the statistical technique of Design of Experiments (DOE) is applied. This procedure involves the systematic variation of parameter values and the subsequent identification of result patterns. Second, repeated simulations with different random numbers aim to show that simulation outcomes are robust against variations of initial conditions. Finally,

[6] The Kuratorium Technik und Bauwesen in der Landwirtschaft (KTBL) is a German institute, which regularly identifies and publishes data, e.g., on technical coefficients of production, production technologies, gross margins.

an analysis of the impact of managerial ability on farm survival is conducted.

Part III of this study is devoted to the simulation of the mentioned agricultural policy scenarios with AgriPoliS and subsequent analyses. The study is based on an application of AgriPoliS to the Hohenlohe region. The analysis of simulation results aims at identifying the policy impacts from different perspectives: farm size, production, technical efficiency, economic efficiency, income, and government outlays. For all scenarios, the policies defined under the Agenda 2000 serve as the reference policy scenario. *Chapter 6* introduces different indicators and analysis techniques. A popular technique to investigate efficiency differences between different farms based on observed data is Data Envelopment Analysis (DEA). Chapter 6 introduces efficiency analysis and different efficiency concepts. It presents a DEA model to study differences in technical efficiency between farms as well as the structural efficiency of the region. The model uses simulated data from the policy experiments. Furthermore, analysis techniques such as Kernel density estimation, Gini coefficients, and Lorenz curves are introduced which are subsequently used to analyse indicators derived from the policy simulation experiments. *Chapter 7* shows results of policy experiments comparing the impact of a retirement payment with fully decoupled direct payments and a successive phasing out of direct payments. The approach followed is to contrast the impact of three policy alternatives, each of which is thought to have substantial impact on structural adjustment. Based on the simulation and the analyses of these policy scenarios, the goal is to identify some fundamental structural dynamics and adjustment patterns, which are discussed in the summary of the chapter. *Chapter 8* follows a different intention. Based on the elaboration of more fundamental adjustment patterns in chapter 7, different ways of decoupling direct payments are analysed. In particular, a fully decoupled single farm payment is analysed against a single area payment and partially decoupled payments. This set of policy experiments reflects, in a more general way, policy concepts that will be introduced in the European Union's common agricultural policy from 2005 onwards. At the end of this chapter, simulation results are summarised and discussed

Finally, *chapter 9* summarises the thesis. It places the obtained simulation results in the context of policy analysis as well as of the methodology of agent-based modelling. Future directions of research are pointed out as well as possible extensions of the current version of AgriPoliS.

Part I

Agent-based modelling of regional agricultural structures

2 Agent-based modelling: motivation, definition, and applications

2.1 Introduction

In this chapter, agent-based systems are introduced as an approach to understand and to model regional agricultural structures.[7] The chapter provides the theoretical background for the agent-based model AgriPoliS that will be presented in chapter 3. This chapter starts with a motivation for using an agent-based approach (section 2.2). The motivation is provided from the point of view of economics in general, and, more specifically, from the point of view of agricultural policy analysis. Thereafter, a more formal definition of agents and agent-based systems is given in section 2.3. Section 2.4 discusses three special features of agent-based systems in more detail. These features are particularly relevant in the context of modelling regional agricultural structures and structural dynamics. Section 2.5 presents a commented list of exemplary references to applications of agent-based models. Particular focus is put on applications relevant in agricultural and resource economics. Finally, section 2.6 points out some theoretical and practical challenges to agent-based modelling.

It is the aim of this chapter to argue in favour of agent-based models as a suitable approach for addressing problems related to regional structural change. Agent-based models provide an elegant way to blend concepts and methodologies from different fields of research. They provide one possibility to approach research questions, which would be difficult or even impossible to analyse exclusively with other, more well-known and established, methods. This concerns, for example, problems for which analytical solutions do not exist. Nevertheless, agent-based models should not be seen as a replacement of more standard economic modelling approaches.

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7 Parts of the chapter are based on BALMANN and HAPPE (2001b).

2.2 Motivation

2.2.1 General: agent-based modelling of economic systems

Ever since ADAM SMITH'S (1776) writings on the division of labour, economists have viewed economic processes as the result of parallel, local interactions between large numbers of individuals. Local interactions give rise to macroeconomic regularities such as the shared market protocols and behavioural norms that in turn feed back into the determination of local interactions. The resulting complex and dynamic system is one in which there are recurrent causal chains connecting individual behaviours, interacting networks, and social welfare outcomes (TESFATSION 2002). Economists have recognised this two-way feedback between microstructure and macrostructure as well as the dynamics of economic change for a long time, for example, by such prominent economists such as SMITH (1776), SHACKLE (1988), or SCHELLING (1978).

Despite of this long interest in complex phenomena, the economics profession, and also agricultural economics, have lacked the means of quantitatively modelling complex economic systems and the individual actors and their interdependencies within the system. Many quantitative economic models have followed, and still follow, a 'top-down' approach. A common feature of 'top-down'-models is their missing or a very limited foundation to the behaviour of individual economic agents and local interactions between agents (STOKER 1993). Instead, heavy reliance is put on exogenously given coordination devices such as fixed decision rules, representative agents, imposed market equilibrium constraints, common knowledge, and perfect foresight (TESFATSION 2002).

However, advances in information technology, and new modelling approaches such as agent-based modelling, have been enlarging the possibility set of researchers with regard to quantitative modelling. Agents may be used by researchers to more naturally understand and model complex systems (WOOLDRIDGE et al. 1999). Agent-based systems offer a possibility to explicitly introduce the mentioned feedback mechanism between the micro and the macro level, whereas agents at the micro level characterised by different actions and attributes.

The agent-based study of economic systems is one branch of what has come to be known as 'Agent-based Computational Economics' (ACE). ACE is the computational study of economies modelled as complex evolving systems of autonomous interacting agents (CONTE et al. 1997; EPSTEIN and AXTELL 1996; GILBERT and TROITZSCH 1999; AXELROD 1997). In particular, agent-based models permit researchers to extend existing research on the evolution of economies at least in five ways:[8]

1. Artificial economies can be constructed on the computer that are populated with a multitude of heterogeneous agents interacting and developing according to defined internal rules. Within this artificial model world, it is possible to carry out numerous simulation experiments.
2. A broad range of behaviours (e.g. profit maximisation or satisficing) and interactions between agents can be defined. There is also the possibility that agents adapt their behaviour, i.e. change their rules, in response to interactions with other agents. For example, self-organising structures can evolve because behavioural rules defined at the outset of a simulation can change at runtime.
3. Agents in these artificial economic worlds can co-evolve, i.e., the individual performance of an agent depends on the evolving behaviour of other agents.
4. Artificial economic systems can grow along a real time-line. This means that the modeller sets initial conditions and subsequently observes the development of the system without acting upon it. This is similar to growing bacteria cultures in a petri-dish.
5. Artificial economies, or agricultural structures, can explicitly be connected to space to analyse land use changes due to economic activity (VERBURG et al. 2002; PARKER et al. 2002).

Accordingly, the methodologies of agent-based computational economics offer a wide variety of possibilities to study a large number of questions in a controlled laboratory surrounding.

2.2.2 Specific: agent-based modelling in agricultural policy analysis and structural change analysis

The issue of quantitative modelling has been playing a key role in agricultural economics research, with a focus on policy impact analysis. The goal of agricultural policy analysis is to study the effect of agricultural policies on a range of indicators (e.g. income, efficiency, factor allocation, production, welfare, etc.) at different levels of scale (e.g. at the global, national, sector, regional or farm scale). Quantitative models typically used are partial or general equilibrium

8 The listing is adapted from TESFATSION (2001) and has been extended.

models, econometric models, and mathematical programming models.

The type of modelling approach chosen depends on the type of policy to be analysed and the question of interest. SALVATICI et al. (2001) discuss the advantages and disadvantages of different modelling approaches with respect to different types of policies. Accordingly, partial and general equilibrium models, for example, are primarily aimed at the evaluation of trade policies or the market impact of coupled domestic price support policies.[9] In particular, trade models take a highly aggregate look at agricultural production. With regard to individual types of farms, these models resort to the definition of a 'representative farm' to represent the behaviour and characteristics of a group of farms. However, if the goal is to analyse process-oriented policies, such as direct payments as implemented by the CAP reform in 1992, partial or general equilibrium models tend to run into difficulties because the level of aggregation in many models does not allow to model land allocation distortions, to give and example.

Process-oriented policies can more easily be analysed with econometric models (e.g. OUDE LANSINK and PEERLINGS 1996, 2001; GUYOMARD et al. 1996) or normative mathematical programming models (e.g., ANGENENDT 2003; KAZENWADEL 1999; HANF 1989; JACOBS 1998; SCHLEEF 1999; BALMANN et al. 1998a, b). With regard to policy analysis, econometric models face the specific problem that parameters are estimated for historical data (SALVATICI et al. 2001). This complicates the modelling of policies that have not existed in the past. Above all, structural breaks due to policy reform can hardly be considered. Mathematical programming models are, in fact, for the most farm-based models. Farm-based models such as individual farm models, representative farm models, group farm models, and farm sample models, explicitly view the problem from a micro-perspective, that is, the perspective of the individual farm or a group of farms. However, the individual farm perspective often creates an inconsistency between individual farm behaviour and resulting market effects at higher levels of scale. This aggregation problem can be eased by weighting individual farms to represent, for example, regional capacities (e.g., BALMANN et al. 1998a,b; KAZENWADEL 1999), or by creating group farms. The latter, however, neglect the structural heterogeneity of farms in a region. Moreover, normative models are 'closed' models in that farms are allowed to adjust within a given possibility

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9 A comprehensive list to references and applications for these types of models is given in HECKELEI et al. (2001) as well as SALVATICI et al. (2001). Examples are ESIM (MÜNCH 2002), GTAP (HERTEL 1997), SWOPSIM (e.g. RONINGEN et al. 1991), WATSIM-AMPS (KUHN 2003), and FAPRI (e.g. FAPRI 2003).

range; many times, these models also disregard changes in farming structure and changes in farming technology (BERGER and BRANDES 1998).

A criticism common to all modelling approaches discussed thus far is that they neglect a number of characteristic factors of the agricultural sector. In particular, aspects like the immobility of land, heterogeneity of farms, interactions between farms, space, dynamic adjustment processes as well as dynamics of structural change have not – or in a limited way – been taken into account. In brief, modelling the complexity of the system has not been at the centre of interest.

Nevertheless, agricultural economists have viewed (regional) agricultural structures as complex dynamic systems already since the early 1960s (e.g., BALMANN 1995; BERG 1980; BRANDES 1978, 1985; DAY 1963; FINKENSTÄDT 1995; HEIDHUES 1966; DE HAEN 1971; LENTZ 1993). With respect to agricultural structures, complexity mainly arises due to the following characteristics of agricultural structures:

- *Heterogeneity of farms:* An agricultural structure can be understood as a decentralised system with heterogeneous, individual farms. Among other things, farms differ with respect to their size, type, factor endowment, organisational form, managerial ability, and age.
- *Interdependencies:* Farms within an agricultural structure are not independent from each other. Rather, there are interdependencies between farms via institutions such as markets for land and quota, or by way of shared resource use. To give an example for local interdependencies, consider the fact that farms usually can only increase their acreage if other farms reduce acreage or close down.
- *Dynamic adjustment processes:* Farms within an agricultural structure constantly adjust to changing framework conditions set by markets, production location, policies, or external shocks. Farm factor endowments, the financial and personal situation determine the degree and pace of adjustment. Because of individual actions of farms, regional agricultural structures are subject to continuous change. Furthermore, macro results such as market prices or structural change are the combined effect of individual farm activities. They feed back into determining the behaviour of individual farms.
- *Path dependencies:* A system is path-dependent if its development is determined by its history; the system may be locked-in to a particular state or development path (cf. ARTHUR et al. 1997; ARTHUR 1989; BRANDES 1995, 1978; DAVID 1985). A path once taken can only be left at high costs. Path dependencies are often associated with technological change, and in particular,

with respect to technologies, with positive returns to scale (ARTHUR 1989; DOSI 1997). BALMANN (1995) and BALMANN et al. (1996) have shown agricultural structures to be path dependent without strong positive returns to scale. Regarding agricultural structures, path dependencies can be found both at the individual farm level as well as in agricultural policy making. At the farm level, path dependencies are caused, e.g. by quasi-fixed production factors which may hold up adjustment processes. At higher levels of scale, institutional arrangements as well as certain agricultural policies may cause path dependencies (cf. BALMANN et al. 1996).

In terms of modelling complex economic systems, in section 2.2.1 it was argued that agent-based models are a suitable approach to quantitatively model and understand such systems in a more natural way. In the same way, this applies to the modelling of agricultural structures. In particular, agent-based models of agricultural structures allow for carrying out computer experiments to support a better understanding of the complex dynamics of agricultural systems, structural change, and endogenous adjustment reactions in response to a policy change. With regard to structural change, BALMANN (1997) has pioneered this work in Germany by constructing a simulation model in which structural change takes place endogenously in response to the behaviour of individual farms.

This section aimed to provide some motivation and background for the use of agent-based models to quantitatively model economic systems. Up to this point, the term 'agent-based' was used implicitly, but a formal definition has not been given, yet. This is the objective of the next section.

2.3 Agents and agent-based systems

2.3.1 Definition

In the literature, there are a multitude of definitions of agents and agent-based systems. Currently, the term 'agent' is used in a rather vague way (FERBER 1999) and there is no generally agreed definition of what an agent is (GILBERT and TROITZSCH 1999).[10] RUSSEL and NORVIG (1995), for example, define agents as *"…anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors"*. According to this definition, an agent could equally be a computer programme, which produces output

[10] See ANDERIES (2002) for a discussion on agent definitions.

from input (cf. JENNINGS et al. 1998), or a gum machine that distributes a certain number of gums.

FRANKLIN and GRAESSER (1997) have compiled different agent definitions and based on them they defined agents in the following way: *"An autonomous agent is a system situated within a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to affect what it senses in the future."* Based on this definition, FRANKLIN and GRAESSER (1997) classify agents along a list of properties (Table 2-1).

Table 2-1: Agent Properties

Property	**Meaning**
reactive (sensing)	responds in a timely fashion to changes in the environment
autonomous	exercises control over its own actions
goal-oriented (purposeful)	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 behaviour based on previous experience
mobile	able to move in space
flexible	actions are not given exogenously
character	credible 'personality' and emotional state

Source: FRANKLIN and GRAESSER (1997), modified.

FRANKLIN and GRASSER (1997) consider the first four items in the above list to be the minimum requirements for an agent, i.e. an agent should be able to react autonomously and goal-directed to signals in their environment. Depending on the problem, one or more of the remaining items can augment the definition of an agent.[11] Agents are situated in environments in which they interact, co-operate, and exchange information with other agents that have possibly conflicting aims. Such environments are known as *agent-based systems* (ABS) or *multi-agent systems* (MAS).

There is, furthermore, no clear distinction whether the terms agent and agent-based systems refer only to virtual entities, or to any virtual (software component) or physical entity (human, robot, aircraft, organisation) fulfilling the criteria mentioned in Table 2-1. On the one hand, some authors (e.g. GILBERT and TROITZSCH 1999; LUCK et al. 2003; JENNINGS et al. 1998) associate agents with

[11] Other authors, e.g. FERBER 1999 or SYCARA 1998, have defined agents in a different way with slightly different properties.

computer programmes, i.e., with virtual entities. On the other hand, FERBER (1999) sees an agent as a kind of 'living organism'.

2.3.2 Origins of agent-based systems

Agent-based systems have their origins in information technology, and in particular, in the field of distributed artificial intelligence that started to form in the early 1980s. ABS have been one of the most important areas of research and development that emerged in information technology in the 1990s (LUCK et al. 2003). The motivation for an increasing interest in ABS research follows from the ability of ABS (cf. SYCARA 1999)

- to carry out certain tasks and to solve problems with computer systems and computer programmes that are complex themselves. This calls for breaking down large complex programmes into smaller parts;
- to provide solutions to problems where expertise and knowledge *"...is possessed by individuals who communicate within a group, exchange knowledge and collaborate in carrying out a common task."* (FERBER 1999);
- to provide solutions to problems or explanation of phenomena that can naturally be regarded as a society of autonomous interacting components, like air traffic, as well as an economy;
- to efficiently use information that is spatially distributed.

ABS, therefore, represent a reaction to these needs. FERBER (1999, p. 4) concludes: *"The approach takes into account the fact that simple or complex activities, such as problem solving, the establishment of a diagnostic system, the coordination of actions or the construction of systems, represent the fruits of interaction between relatively independent and autonomous entities called agents, which operate within communities in accordance with what are sometimes complex modes of cooperation, conflict and competition in order to survive and perpetuate themselves."*

2.3.3 Modelling procedure

Research studying economic systems in general, and agricultural structures in particular, using agent-based techniques relies on computational laboratories to study the evolution of agricultural structures under controlled experimental conditions. Accordingly, as in a culture-dish experiment, the researcher starts with creating an agricultural structure with an initial population of agents and the object which agents act upon. Depending on the agent definition chosen, agents can include both economic agents (e.g. farms, markets) and agents that can equally represent other social and environmental phenomena (e.g. politicians, non-farm agents, land). The modeller specifies the initial state of the agricultural structure by specifying the initial attributes of agents and objects. These initial attributes can include characteristics, behavioural rules, internally stored information about the agent itself and other agents. Finally, the artificial agricultural structure evolves over time without further intervention by the modeller. Accordingly, all events that subsequently occur must be the result of historical time, interactions between agents, or interactions between agents and the environment.

2.4 Selected features of ABS applied to economic systems

Three specific features of ABS appear to be of special importance when applying the agent-based approach to (agricultural) economic systems. The features are flexibility, the potential to represent complex emerging structures with heterogeneous und individual behaviour, and the integration of spatial aspects.

2.4.1 Flexibility with regard to assumptions

ABS models belong to the class of so-called 'bottom-up' modelling approaches. There is no central planner who controls the system as a whole and to that effect controls the behaviour of individual agents at the aggregate level. Instead, regularities at the macro level are the result of local individual actions and interactions between agents. To reflect this, modellers can choose to define agents along a broad range of different properties and behaviours.[12] This is in sharp contrast to more common 'top-down' approaches, where theory requires axiomatic assumptions to ensure consistency between the micro and the macro level. Examples for such assumptions are fixed decision rules, perfect rationality, representative agents, and market equilibrium constraints (TESFATSION 2002). In contrast, ABS models can be constructed in a way that makes them more flexible with regard to making assumptions. It is possible to implement axiomatic assumptions given by theory, but assumptions can also be made specific to the problem to be studied. Compared to 'top-down' modelling approaches, ABS

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12 It is not a necessary condition that each individual agent follows a different behavioural pattern. Nevertheless, ABS offers the possibility to do so.

models thus increase the spectrum of possible models.[13] In this regad, the flexibility of ABS also extends to the definition of the framework conditions in which agents act and interact. It is, for example, possible to define bilateral or multilateral exchange relationships.

To give an example for the flexibility with regard to assumptions consider the case of convex production functions. Many analytical models assume convexity to assure a unique analytical solution. However, as for ABS, convexity and the existence of perfect markets with perfect information are no necessary requirements to obtain a unique solution of the model. Non-convexity is less of a problem since behaviour at the agent level is commonly less complex than an adequate representation of behaviour at the aggregate level.[14]

As advantageous as the greater flexibility with respect to assumptions may be, it nevertheless requires the modeller to choose assumptions carefully. A possible guideline for making assumptions could be that they should be well founded, justified, reasonable, and documented. Although they do not provide a clear-cut quality criterion, assumptions, which do not comply with any of these criteria, will necessarily make the model and results less credible. The number of assumptions also appears to be a critical point. Because of the flexibility just mentioned, ABS potentially bear the danger of over-specification, i.e., of making models too particular. Over-specified models bear the danger of being more complex than the original target system. The more complex and specific a model, the more difficult it is to establish a connection between causes and effects within the model and between the model and the target system. Accordingly, when tracing back the computation for formal causes, the cause frequently spreads over the whole system and cannot be attributed to a single factor (EDMONDS 2000).

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13 Nevertheless, also ABS models require a certain degree of consistency between the micro and the macro level. Section 2.6.1 will deal with this issue.

14 Because of this aspect, the problem of NP-incompleteness is also less severe. NP-incompleteness means that with an increasing number of variables or restrictions the necessary computing time increases more than polynomial, i.e., exponentially or as a faculty. An example for this is the travelling salesman problem, where the necessary computing time for an optimisation for n locations to be visited increases by $n!$.

2.4.2 Complex structures and emergence

A particular feature, yet, of ABS is their ability to generate complex structures that change endogenously, or 'from within'. This particular property is known as self-organisation, examples of which are chaos, path dependence, or multi-phase dynamics (cf. BALMANN 1995; MANSON 2001). A system is called self-organising if the individual parts of the system interact in such a way that certain structures – and possibly even complex structures – arise without external influence (BRANDES et al. 1997). Self-organisation does not only apply to the structure of the system, but it extends to the speed of change, which is also determined from within and not set externally. If the speed of change is slow, then a system can potentially remain far away from equilibrium for a long time.[15]

Another property of ABS is what is called emergent structures. Emergence briefly describes the property that a system is not equal to the sum of its parts. Emergence appears, for example, where developments observable at the macro level cannot be explained by the properties and behaviours of the system's individual parts in isolation (EMMECHE 1994; SCHELLING 1978). In that case, patterns arising at the macro level are rather the result of a very large number of interactions and individual actions of the parts of the system. Examples of emerging phenomena are the 'invisible hand' that co-ordinates markets, a flock of birds, or living organisms in general. However, emergence is a concept which is theoretically and practically difficult to handle. AXELROD (1997, p. 4) notes: *"Emergent properties are often surprising because it can be hard to anticipate the full consequences of even simple forms of interaction. (…) Some complexity theorists consider surprise as a part of the definition of emergence, but this raises the question of surprising to whom?"*

2.4.3 Spatial representation

The (agricultural) economics profession has recognised the importance of the space and land-use ever since the work of VON THÜNEN and RICARDO. VERBURG et al. (2002) underline the potential of ABS in current land use change modelling in particular with respect to exploring dependencies between different levels

[15] The concept of self-organisation originally stems from the natural sciences (cf. e.g. HAKEN 1988; KAUFFMAN 1993) and it concerns elementary particles in the first place. Concerning this fact, LENTZ (1993) points out that the elements (humans) in social systems are not of a particle nature but complex themselves. Unlike elementary particles, they are intelligent in that they can 'plan' structures to a certain extent.

of scale by linking the behaviour of individuals to collective behaviour. Particularly in agriculture, land use takes a central position. Spatial aspects have a direct effect on farm decision making and on the economics of the farm. In addition to land value and transport conditions, the suitability of land for agricultural production is determined by non-economic factors like soil quality, climatic conditions, and inclination. What could hence make ABS particularly attractive is the possibility to link economic models with spatial models to support a better understanding of interdependencies between agent behaviour and space in land use systems.

2.5 Examples of applications of agent-based systems

Agent technologies and research span a range of specific techniques and algorithms for dealing with interactions and autonomous actions in dynamic and open environments. Researchers from different disciplines use ABS models to pursue a variety of objectives. Table 2-2 shows one such exemplary classification of applications, according to which applications of ABS models can be distinguished into problem solving, social systems analysis, and land-use/land-cover change analysis.

2.5.1 Problem solving

Using agents as problem solvers mainly concerns the solution of complex problems such as optimisation problems. For this, agents can either work together to solve problems that are beyond their individual problem-solving capabilities (distributed problem solving). Alternatively, each agent separately solves the complete problem (solution rivalry) and the best solution is taken.

2.5.1.1 Distributed problem solving

In distributed problem solving, a problem is decomposed into smaller sub-problems each of which is then solved by an individual agent. Tedious and time consuming in this context is the question how to decompose exactly a global problem into sub-problems and how to specify the relation between the sub-problem and the global problem. The same applies to the question of allocating tasks to agents. Exemplary applications of distributed problem solving are given by O'HARE and JENNINGS (1996) and by LESSER (1990). However, it should be noted that not all problems can efficiently be solved in a distributed way. With respect to some problems, the costs of communication between individual problem solvers may be higher than the benefits derived from distribution.

Table 2-2: Exemplary references to research using ABS models in problem solving, social systems analysis, and land-use change analysis

	General problem solving		**Social systems analysis**				**Land-use/land-cover change, integrated modelling**
Solution concept/ behavioural foundation	Distributed problem solving	Solution rivalry	Rule-based	Normative	Artificial intelligence	Human agents/ role-playing games	
References	O'HARE/ JENNINGS (1996) LESSER (1990)	HOLLAND (1975) GOLDBERG (1989) RECHENBERG (1973) SCHWEFEL (1977) KOZA (1992) DORIGO et al. (1996)	Conway's 'Life' SCHELLING (1978) AXELROD (1984)	DAY (1963)* BALMANN (1993,1997)* BERGER (2001)* HAPPE/ BALMANN (2002)*	ARIFOVIC (1994) AXELROD (1997) BALMANN (1998)* CACHO/SIMMONS (1999)* BALMANN/HAPPE (2001a)* BALMANN/ MUßHOFF (2001)* BALMANN/ MUßHOFF (2004)*	BOUSQUET et al. (1999)* BARRETEAU et al. (2001)*	PARKER et al. (2001)* BERGER/RINGLER (2002)* BARTH et al. (2003) JANSSEN (2002)* KRIMLY et al. (2003)*

Note: *References referring to applications in agricultural and resource economics.

2.5.1.2 Solution rivalry

Solution rivalry follows a different approach in that each agent in a population of heterogeneous agents solves the same problem. A central control agent then collects results and evaluates the individual agents' solutions. The procedure selects bad solutions and replaces them with better or new solution. This is, in very general terms, the procedure followed in approaches like genetic algorithms (HOLLAND 1975; MITCHELL 1998; GOLDBERG 1989), genetic programming (KOZA 1992), evolutionary strategies (RECHENBERG 1973; SCHWEFEL 1977), classifier systems (HOLLAND 1995) or ant systems (DORIGO et al. 1996).

2.5.2 Social systems analysis

Agent-based systems also find applications in the field of systems analysis where they are used to study the behaviour and development of systems of interacting individuals. Table 2-2 distinguishes four groups of exemplary applications by their solution concept: rule-based, normative, artificial intelligence, and role-playing games.

2.5.2.1 Rule-based behaviour

Conway's game of life is one of the simplest examples of the first group. The game generates 'emergent phenomena' based on simple rules. A cell located on a grid of cells changes its state according to the states of other cells. The player of the game can study how elaborate patterns and behaviours can emerge from very simple rules that the player defined beforehand. A second example is the work by SCHELLING (1978), who studies spatial segregation and aggregation phenomena in different societies. The behavioural foundation of Schelling's agents is also very simple and based on simple rules such as 'search for a new home if too many neighbours belong to another social class'.[16] Finally, another example of a simple rule-based ABS is AXELROD'S (1984) simulation of agents playing in a repeated Prisoner's Dilemma game, in which playing strategies are implemented in a simple simulation programme. The simulation results show that the well-known 'tit-for-tat' strategy (do whatever your opponent did last) was the most successful one. Although this was already proven in the 1950s, Axelrod's model nevertheless contributed significantly to the understanding of how social norms

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[16] Educative agent-based simulation environments, like StarLogo (RESNICK 1994), give many other examples. Users can easily run and modify pre-defined simulations, or create new simple applications.

evolve and to how they could be simulated on the computer (BINMORE 1998).

2.5.2.2 Normative agent behaviour

In most agricultural economic ABS applications, agents' behaviour is determined normatively. Early examples of an ABS model based on normative behaviour are recursive-programming models (DAY 1963; HEIDHUES 1966; DE HAEN 1971) which were applied to analyse and forecast dynamic developments in the agricultural sector. The models assume that farms agents representing farm types (group farms) or regions (regional farms) interact.[17] The farm agents are heterogeneous with respect to factor capacities, technical coefficients and the definition of the objective function in the set of linear equations underlying each farm agent. In each period, farm production capacities are updated based on previous experience, results of the last period, and external factors influencing the farm (HEIDHUES 1966). In principle, the models by BALMANN (1993, 1997), BERGER (2000) – further developments of which can be found in BALMANN et al. (2002) – and HAPPE and BALMANN (2002) follow a similar approach.[18] These latter models, however, are more complex and consider a multitude of individual farms instead of group farms to represent an agricultural region. Individual farms plan production using Linear (Mixed-Integer) Programming. The factor that differentiates these models most from the earlier models of the 1960s is their explicit consideration of space and heterogeneity.

2.5.2.3 Artificial intelligence

In the third group of models, agent behaviour is governed by an artificial intelligence. Axelrod, again, gives a nice example for agents with an artificial intelligence. Whereas in his 1984 tournaments, computer programmes competed for the best solution to the prisoner's dilemma, in 1997, Axelrod replaced the computer programmes in the 1984 tournaments with strategies generated by a genetic algorithm. For this, he defined a population of so-called genomes each

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[17] Although the field of agent-based systems and the respective terminology did not exist in the 1960s, the early recursive programming models of Day and De Haen actually already fulfil the criteria for simple agents.

[18] Berger's model approach extends and refines the ideas of Balmann's original approach in many respects. Farms follow heterogeneous decision models and they can communicate explicitly within communication networks. As water management played an important role in the study region, a hydrological module was added to the model in which water flows are considered in addition to a trade of water rights. The model was initially used to study the adoption of new technologies in a selected region in Chile.

of which is coded in a binary string consisting of '0's and '1's. If decoded, each binary string corresponds to a particular solution or strategy that competes with the other genomes for the best solution to the problem. Application of the genetic algorithm then replaces poorly performing strategies with better ones. This replacement property of a genetic algorithm is comparable to a simple type of learning.[19] Sample applications of genetic algorithms in agricultural economics are CACHO and SIMMONS (1999) who apply genetic algorithms to farm investment behaviour in risky environment, or BALMANN and HAPPE (2001a) who use a distributed genetic algorithm to determine equilibrium strategies on a rental market for land. In the latter model, a genetic algorithm determines the bidding behaviour of farms on the land market, and selects for better bidding strategies. BALMANN and MUßHOFF (2001) use genetic algorithms to derive equilibrium investment strategies for real options problems with competing agents. In another application, BALMANN and MUßHOFF (2004) use genetic algorithms to analyse whether a stronger vertical integration along the production chain allows reducing the investment reluctance due to the transmission of price fluctuations in a production chain.

2.5.2.4 Human agents and role-playing games

Another approach developed and applied by the CORMAS (Common Pool Resource Multi-Agent System) research group at the CIRAD (Centre de cooperation internationale en recherché agronomique pour le développement) is to define agent behaviour in the context of common pool resource use (BOUSQUET et al. 1999). The approach is based on field experiments in which researchers first survey users of a common pool resource about individual attitudes about the use of the resource and the way they use the resource. In a second step, the surveyed information is then transferred into a simulation model developed using CORMAS (BOUSQUET et al. 1998), which is then simulated. A specific way of carrying out field-work to obtain information on individuals' behaviour is to conduct role-playing games with real agents (BARRETEAU et al. 2001). Results of role-playing games may give information about the potential behaviour of agents in computer programmes.

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[19] CHATTOE (1998), however, notes that 'learning' in this type of models does not correspond to human learning. Humans learn at a different speed and according to different rules. It is less problematic, though, to view this approach as a way to identify Nash equilibria and evolutionary stable strategies (cf. DAWID 1999).

2.5.3 Land-use/land-cover change and integrated modelling

In recent years, the use of agent-based models has become increasingly popular in the fields of land-use/land-cover change analysis, as well as in integrated modelling. ABS models in these fields are particularly suitable because in most cases they aim to integrate spatial models of land use change with economic, social, and environmental models (e.g. PARKER et al. 2002; BERGER and RINGLER 2002; JANSSEN 2002; BARTH et al. 2003; KRIMLY et al. 2003).

2.6 Potential challenges to agent-based modelling

2.6.1 Modelling the co-ordination of agents

Co-ordination of agents is central to ABS. The allocation of scarce resources and the communication of intermediate results are two fundamental components of a co-ordination problem (MALONE 1990). These components are equally central to economic systems, in which a number of actors compete for scarce resources. Without co-ordination, individual agent actions may interfere with each other because agents have only a limited and imprecise view of the overall system. That is, agents are boundedly rational. For instance, if – like in a production process – one activity requires as inputs the results of other activities, and then co-ordinating the communication of intermediate results is required (MALONE 1990). Thus, individual behaviour needs to be compatible and coherent. In other words, nothing can be consumed that was not produced beforehand. Consequently, ABS models require mechanisms that control for the compatibility and consistency of individual agents' actions.

In practice, modelling co-ordination requires the definition of interdependencies between agents. However, the definition of interdependence and its degree is not all that easy. In particular, the degree of interdependence needs to be defined. At the one end of the spectrum, there are no interdependencies between individual agents, i.e., agents base their decisions and actions exclusively on their own situation. In economic systems, where resources are scarce this would not be possible and lead to the mentioned problem of interference between agent behaviour. At the other end of the spectrum, there is the case of strategic decision making. Strategic decision making represents the highest degree of interdependency because it requires each agent to have a complete model of all other agent's decision situations in all future time periods. This is only the case if agents are perfectly rational and have complete information about the system.

Modelling strategic behaviour is not trivial, though, as it requires each agent to have a model of all other agents and their environment in which agents have an agent-based model of their environment and so on. Whereas in the case of no interdependencies the co-ordination problem is easily solved, a solution in the case of strategic interaction – if it exists – is not trivial to find and computationally very costly. Potentially, in the latter case computational limits will be reached rather quickly.

As regards the rationality of agents in real economic system, it is most likely that neither end of the spectrum provides a feasible and realistic co-ordination solution. Rather, real economic agents as well as agents in agent-based models of economic systems can be considered boundedly rational (SIMON 1955, 1956, 1996), that is, agents make decisions based on the information available to them, which can possibly even be wrong.[20] As SIMON (1955) writes: *"Broadly stated, the task is to replace the global rationality of economic man with a kind of rational behaviour that is compatible with the access to information and the computational capacities that are actually possessed by organisms, including man, in the kinds of environments in which such organisations exist."* Accordingly, the rational decision-making of agents is strongly related to the availability of information in the environment of agents and the capacity of agents to process this information adequately. The concept of bounded rationality can also be transferred to agent-based modelling in that agents are explicitly endowed with a limited knowledge about other agents and their environment.

Consequently, two solutions to the co-ordination problem appear to be reasonable both of which ensure a coherent behaviour of agents. One is to define ad-hoc rules of interaction which consider some strategic aspects. The second is to introduce intermediate co-ordination institutions, such as markets, standards, or direct supervision (MINTZBERG 1979). This could be implemented by providing the group of agents with another agent – e.g., a market agent – that has a wider perspective of the system. This intermediate agent could gather selected information from individual agents and co-ordinate their activities. For example, with regard to an agricultural land market, the agent could organise a land rental market by way of an auction (chapter 3).

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20 See, e.g., RUBINSTEIN (1998) and SIMON (1996) for a discussion on bounded rationality and the applicability of the concept.

2.6.2 Verification and validation

ABS modelling efforts have to cope with a number of practical problems that range from model design, the required labour and time input, the dissemination of results, to acceptance with an audience. In the end, the way to solve these practical problems may contribute significantly to the success and meaningfulness of the model approach. Validation and verification aspects are particularly relevant in the context complex models of social or economic systems, which do not provide many hard and measurable facts. In this respect, the general question to be asked of all models is how well the model represents the underlying target system in its structure and behaviour.

Verification is generally associated with the process of testing the software model to ensure the proper functioning of the programme (GILBERT and TROITZSCH 1999; KLEIJNEN 1995; MANSON 2001). Possible sources of errors are the programme syntax but also the programme logic. Powerful debugging environments, graphical interfaces, or the application of standardised data analysis methods such as regression analysis help in detecting logical errors is. But most of all, it is experience and familiarity with the subject itself, which avoids most logical errors. The verification process is similar to sensitivity analysis in that the programme is tested for different parameter constellations.

Validation, on the one hand, is concerned with the question whether the simulation is a good and suitable representation of the target system (GILBERT and TROITZSCH 1999). On the other hand, there is the view that a model's validity can be measured by the model's ability to make good predictions and retrodictions (MOSS 2000). Regarding ABS models, the need for validation depends on the degree to which the model is to be used for theoretical reasoning or in applied research. For example, if an ABS model is of conceptual, theoretical, or didactic nature it is difficult to validate such an artificial model against real systems or real data. Hence, the more applied the ABS model, the higher is the need for thorough validation. But, there is also no single straightforward validation procedure available as the validation of complex simulation systems generally is a difficult task (cf. WEINSCHENCK 1977; ODENING and BALMANN 1997; BRANDES 1985). Following MANSON (2002), the key caveat is the effect of complexity or non-linear relationships. This is because complex models can generate complex and often surprising model results. Outcomes in any case must be validated along the greatest possible number of benchmarks. Hence, complexity is not an excuse for results that cannot be explained. Unfortunately, there is no standardised validation procedure for ABS models. Currently, validation of ABS-models requires use of multiple, complementary methods. MANSON (2002) presents different validation and verification techniques such as statistical methods, comparison of model patterns to patterns of real systems, or spatial validation techniques. In fact, the general question asked of all models is: how well does a model characterise the system to be modelled? In this regard, KWAŚNICKI (1999) proposes a list of (subjective) criteria along which to evaluate a simulation model:

- Correctness – consequences of the model ought to be very close to the results of experiments and/or observations;
- Consistency – the model ought to be consistent not only internally, but also with other commonly accepted theories used to describe similar or related phenomena;
- Universality – consequences of the model ought not to be confined to individual cases;
- Simplicity;
- Fecundity – the model ought to throw new light on well-known phenomena;
- Usefulness.

As written in KWAŚNICKI (1999), the 'Turing Test', which was originally established to test for intelligent behaviour of a computer algorithm, can also be applied in the context of ABS and complex simulation models. This test evaluates the level of similarity between simulation results and real systems (LAW and KELTON 1991). For example, people with a deep knowledge and understanding of a system (i.e., regarding agricultural structures these are researchers, farmers, and administrators) are asked if the results they are shown correspond to phenomena known from their experience. However, the experts do not know whether the presented results are real or simulated. In this way, it is not only possible to derive valuable insights for improving a model but also to evaluate the degree of similarity between a model and reality.

3 The Agricultural Policy Simulator (AgriPoliS)

3.1 Introduction

This chapter presents AgriPoliS (Agricultural Policy Simulator), which is a spatial and dynamic agent-based model of regional agricultural structures, developed in collaboration with Konrad Kellermann and Alfons Balmann. Central elements of AgriPoliS such as the conceptual framework, the data structure, and the variables build upon previous work by BALMANN (1995, 1997). The model's name, AgriPoliS, refers to its main application, the impact analysis of agricultural policies on structural change.[21] The chapter is structured as follows: Section 3.2 introduces a conceptual framework of an agent-based model of regional agricultural structures. Following this, section 3.3 presents the implementation of the conceptual framework as an object-oriented computer programme. The computer programme mainly consists of three types of objects: general purpose objects, agents and data management objects. These objects will be described in detail in sections 3.4 through 3.6. Finally, in section 3.7, data output is described.

3.2 Conceptual framework

The core of AgriPoliS is the understanding of a regional agricultural structure as a complex evolving system. This regional agricultural system is shown schematically in Figure 3-1. The figure shows the interactions between the three central components of agricultural structures: farms, markets, and land. This representation can be considered typical for family-farm dominated regions in Germany where production cannot take place entirely independent of land. A number of individual farms evolve subject to their actual state and to changes in their

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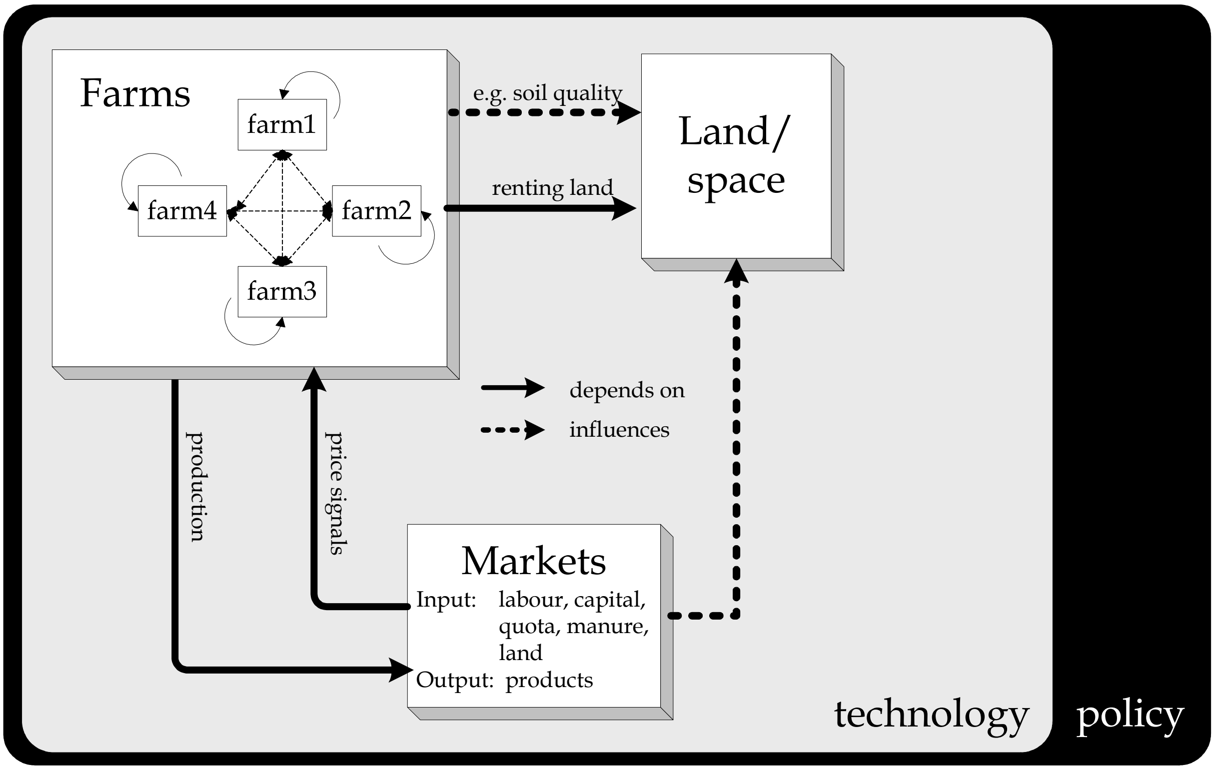
[21] Based on AgriPoliS, KELLERMANN (2002) has developed the interactive policy simulation game 'PlayAgriPoliS'. The game can be used, for example, for instructive purposes in the classroom. It allows the player to take the position of an agricultural minister and to set a variety of policies and policy combinations.

environment. This environment consists of other farms, factor and product markets, and space, which are again all embedded within the technological and political environment. Farms, land, and markets either directly depend on each other or they exert influence on each other. A direct dependence implies that one component cannot exist without another. The mutual dependence between farms, land, and markets results from the fact that farms require land to produce on the on hand. Farm management practices in return influence the state of the land the quality of which is characterised, for example, by soil fertility. On the other hand, the mutual interdependence between farms and markets takes place because farms can purchase production inputs on factor markets and sell products to product markets.

Figure 3-1: A static conceptual model of a regional agricultural system



Source: Own figure.

Representing this system using the abstraction of an agent-based system it is appealing to interpret farms as individual agents, not only because the description in Figure 3-1 suggests this. Also markets – be it product or factor markets, and in particular the land market – can be interpreted as agents that bring together and co-ordinate market activity. Before translating the conceptual model into a computer simulation programme in the following, the core contents will be sketched in more detail along the following questions:

- What are the agents involved and what makes them heterogeneous?
- How do agents behave and what actions are driving the system?
- Which factors comprise the individual agent's spatial, technical, and political environment?
- How do interactions between agents, and agents and the environment take place in the model?

3.2.1 Agents involved

For the purpose of AgriPoliS, an agent is defined as an entity that acts individually, senses parts of its environment and acts upon it.[22] In the context of regional agricultural structures, it is useful to differentiate between two kinds of agents: the farm agent and the market agent.[23] The agents in AgriPoliS are acting entities that actively carry out defined actions.

There are two types of agents in AgriPoliS, farm agents, and market agents. Of the two kinds of agents considered, the farm agent is the most important one. In the context of AgriPoliS, one farm agent corresponds to one farm or agricultural holding. In accordance with the above agent definition, a farm agent is an independently acting entity that decides autonomously on its organisation and production to pursue a defined goal (e.g. farm household income maximisation). Furthermore, a farm agent reacts to changes in its environment and its own state by adjusting its organisation in response to available factors endowments and observable actions of other farm agents.

The second kind of agent, the market agent, coordinates the working of markets. It is the responsibility of the market agent to bring together supply and demand of goods (products, production factors) and to determine a price of the good. More specifically, in AgriPoliS, there is a land market agent, the auctioneer, and a product market agent. Unlike the farm agent that meets all the criteria mentioned in the agent definition given in Table 2.1 in chapter 2, the market agents can only be considered as very basic agents, whose sole objective is to co-ordinate the actions of farm agents on the markets for products, land, capital and labour.

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[22] See chapter 2 for a detailed discussion of agents and agent-based systems.

[23] In fact, there is also a third kind of agent that manages the course of actions of the other agents in the actual simulation programme. This management agent is responsible for initiating the actions carried out be the other two kinds of agents.

3.2.2 Farm agent actions and behaviour

Farm agents can produce a selection of goods. In order to produce, farm agents utilise buildings, machinery, and facilities of different types and capacities. With respect to this, AgriPoliS implements economies of size as with increasing size of production, unit investments costs decrease. Moreover, labour is assumed to be used more effectively with increasing size. AgriPoliS also aims to mimic the effect of technological progress. More specifically, it is assumed that with every new investment, unit costs of the product produced with this investment decrease by a certain percentage.

Farms can engage in rental activities for land, production quotas, and manure disposal rights. Labour can be hired on a fixed or on a per-hour basis; vice versa farm family labour can be offered for off-farm employment. To finance farm activities and to balance short-term liquidity shortages, farm agents can take up long-term and/or short-term credit. Liquid assets not used within the farm can be invested with a bank. Farm agents quit production and withdraw from the sector if equity capital is zero, the farm is illiquid, or if opportunity costs of farm-owned production factors are not covered.[24]

Farm agents are assumed to act autonomously and to maximise farm household income. For this, production and investment decisions are made simultaneously based on a recursive linear programme including integer activities (cf. HAZELL and NORTON 1986). From the solution of the linear programme, shadow prices of production factors can be derived. Farm decision making is myopic or boundedly rational (SIMON 1955, 1956, 1996), that is, agents make decisions based on the information available to them, which can possibly even be wrong. Because of this, the decision problem of the model farms is highly simplified compared to that of real farmers in that strategic aspects are not included. Except for the price information on rents as well as product and input prices, individual farms in AgriPoliS do not know about other farms' production decisions, factor endowments, size, etc. On the contrary, unbounded rationality would imply that farms take account of all interactions between farms, and the technical and political framework conditions now and in future periods and that would include these into the individual decision problem.[25] Farm agents are also boundedly

[24] As investment costs are assumed to be sunk, only opportunity costs for land and labour are considered.

[25] For a discussion, see also chapter 2. Currently, this cannot be implemented because of computational and methodological problems, such as a unique analytical solution.

rational with respect to expectations. In the majority of cases, farm agents follow adaptive expectations. Merely policy changes are anticipated one period in advance and included into the decision making process.

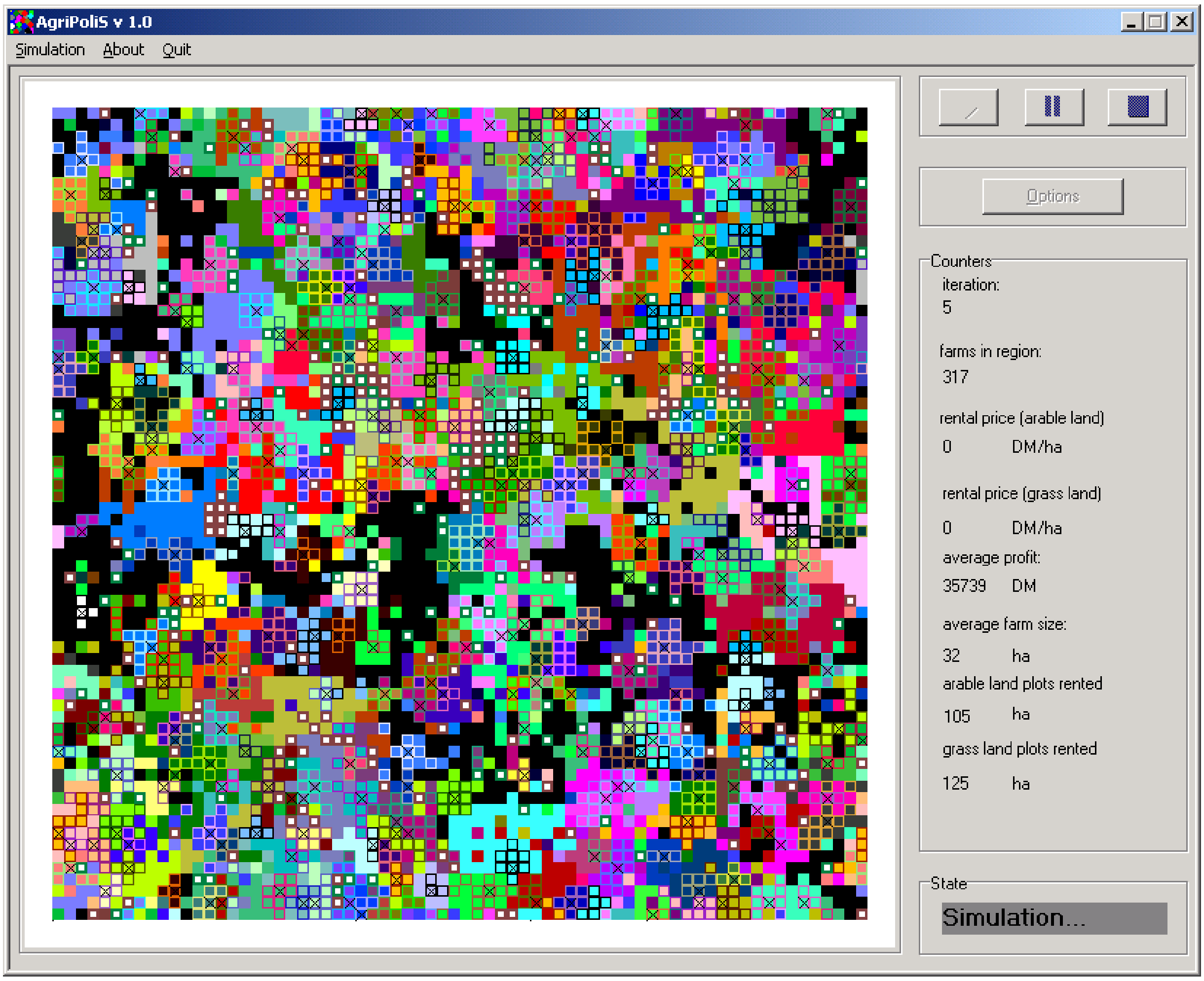
New investments affect production capacities for the operating lifetime of the investment. This implies investment costs to be sunk. A farm agent is handed over to the generation after a given number of periods. In case of such a generation change, opportunity costs of labour increase. Accordingly, continuation of farming can be interpreted as an investment into either agricultural or non-agricultural training. Finally, farm agents differ not only with respect to their specialisation, farm size, factor endowment and production technology, but also with respect to the person of the farmer, and with respect to managerial ability.

3.2.3 The spatial, technological and political environment

Land is an essential input for most kinds of agricultural production activities, be it for plant production, as fodder ground, or as manure disposal area. Hence, space is a factor that cannot be neglected if agriculture is concerned. Geographic Information Systems (GIS) provide a way for organising spatial data and assigning certain properties to space. A common way to organise space in GIS is to define a grid of cells. A grid, or layer, categorises land with respect to attributes of the cells. For example, this could be the soil type, ownership, or ecological parameters like the nitrogen load. A GIS-like representation could also be used in the context of an agent-based model of agriculture to achieve an explicit spatial representation as some recent examples show (e.g., BERGER 2004; PARKER et al. 2002). AgriPoliS, follows a more basic approach in that it does not implement a spatially explicit GIS in which the exact location of farms and land as found in a real region is modelled. AgriPoliS models space in a stylistic way to implement some, but not explicit, spatial relationships. In the current version of AgriPoliS, space is represented by a set of cells/plots assembled into a grid to form a kind of cellular automaton (Figure 3-2).

One individual plot represents a standardised spatial entity of a specific size that can take different states. In this idealised representation, all factors not directly relating to agriculture and land use (roads, rivers, etc.) were eliminated. The coloured cells represent agricultural land that is either grassland or arable land. Plots not used in agriculture are black. On some of the cells, farmsteads are located. They are marked with an X. The total land of a farm agent consists of both owned and rented land. All plots of land belonging to one farm agent are marked with the same colour; cells, which are owned, are surrounded by a box.

Figure 3-2: An idealised grid representation of an agricultural region



Source: Own figure.

The technological environment is given by technologies of different vintages and technological standards. Over time, technology is assumed to underlie a constant technological progress created in the up-stream sector, but not on the farms themselves. Farm agents are assumed to benefit from technological progress by way of realising additional cost savings when adapting new technologies. The political environment represents the third building block of a farm agent's external environment besides space and technology. Agricultural (and environmental) policies affect the farm at different instances such as prices, stocking density, direct payments, or interest rates.

3.2.4 Agent interactions

The concept of interaction between agents is central to agent-based systems. Interaction takes place when two or more agents are brought into a dynamic relationship through a set of reciprocal actions. Interactions develop out of a series of actions of agents whose consequences in return effect the future behaviour of agents (FERBER 1999). Interactions between agents take place either directly or indirectly, whereby an indirect interaction occurs through another agent (see chapter 2).

At this development stage, agents in AgriPoliS interact indirectly by competing on factor and product markets. Interaction is organised by market agents that explicitly coordinate the allocation of scarce resources such as land or the transaction of products. Direct interactions between agents, for example for directly negotiating on rental contracts, are not considered at this stage of the model development.

In AgriPoliS, the land market is the central interaction institution between agents. In reality, the land market is of particular relevance, as farms very often cannot develop independently of land. In the case of Germany, livestock production is directly linked to the provision of land for fodder production or manure disposal. In this sense, land is a central prerequisite for farm growth. In Germany, farms predominantly grow by renting land additional. Because of this, AgriPoliS considers a land rental market, but does exclude a sales market for land. With regard to land, the ownership structure consists of family farms owning some land and external land owners. The latter are not modelled explicitly but farm agents rent their land. When AgriPoliS is run, land available for rent on the rental market stems from two sources: one is farms that have quit production and withdrawn from the sector, the other is land released to the market due to the termination of rental contracts.

In brief, the land allocation process works as follows.[26] To allocate this free land to farms, in AgriPoliS an iterative auction is implemented in which an auctioneer (market agent) allocates free plots to farm agents intending to rent additional plots of land. Farm agents' bids for particular plots of land depend on the shadow price for land, the number of adjacent farm plots and the distance-dependent transport costs between the farmstead and the plot. The auctioneer collects bids, compares them, and allocates free plots to farm agents. The auction terminates when all free land is allocated or if bids are zero. As both arable land and grassland are considered, the auction process alternates between these two land qualities.

[26] Details of this process are presented in section 3.5.2 and section 3.6.1.

3.2.5 Central modelling assumptions

As with every model, AgriPoliS rests on a number of assumptions. Two kinds of assumptions can be differentiated. On the hand, there are assumptions that represent central characteristics of an agricultural system. These form the corner stones of the model. BALMANN (1995) has listed the central characteristics of agricultural systems and structures, which shall be mentioned here again.

- The evolution of agricultural structures follows a dynamic process;
- Agricultural structures are path dependent, i.e. the history of the system determines its present state significantly and certain events are irreversible;
- For the most, decision making follows goal-oriented economic considerations;
- Certain activities, decisions and actions are indivisible;
- There are feedback mechanisms, particularly on the local scale, between the actions of individuals and between the results of individual actions.

On the other hand, there are assumptions that are model specific and are necessary to make the model operational and to keep it tractable and clear. Assumptions in particular concern farm behaviour, expectation formation, the definition of the planning period, and the representation of markets and the interaction with other sectors. These assumptions will be mentioned and discussed in this and later chapters where applicable.

3.3 Implementation of the conceptual model

3.3.1 Object-oriented structure and design

A natural way of transferring the conceptual framework presented in section 3.2 into a computer programme is to use an object-oriented programming language such as C++, Java, or Smalltalk.[27] Object-orientation provides away to break a problem into components. In brief, object-orientation describes a system of entities in terms of elements called *objects*. Objects consist of data (or attributes) and actions (or methods). The data represent the state of the object. The actions operate on an object's data and change it. For example, a farm agent's investment

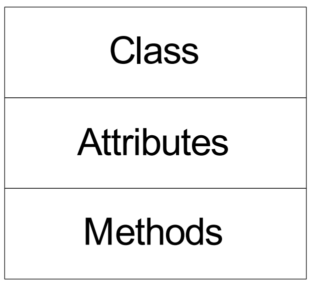
[27] This section on object-oriented design is largely based on REISS (1999) who gives an intuitive introduction to object-oriented programming and design.

activity (action) changes the agent's capital endowment (data). In other words, an object provides functionality in terms of data and actions.

A programme built using an object-oriented design usually contains a large number of objects, of which many are the same. For example, in an agricultural structure all objects representing farms will be treated in the same way. When designing a computer programme such as AgriPoliS using objects it is therefore sufficient to describe the behaviour of sets of similar farms as a whole. A group of objects with the same data and actions is called a *class*. Because of this, it is actually more common and useful to define the functionality of classes instead of individual objects in the design of object-oriented computer programmes. To summarise, object-oriented programmes thus consists of a set of classes, he data associated with these classes and the set of actions the classes can be asked to undertake.

One key to understanding object-oriented design is to view the objects as living, intelligent entities of various types (REISS 1999). They are living in the sense that their properties change over time. Objects are intelligent in that they can undertake actions and know how to perform them. To visualise and document the design of an object-oriented computer programme it is convenient to use a standardised language such as the 'Unified Modeling Language' UML (BOOCH et al. 1999). UML simplifies the representation of complex software design. Accordingly, a representation of a class based on UML is given in Figure 3-3. The upper part the class representation shows the class name. The middle and lower parts list the attributes and the methods that the class can be asked to undertake.

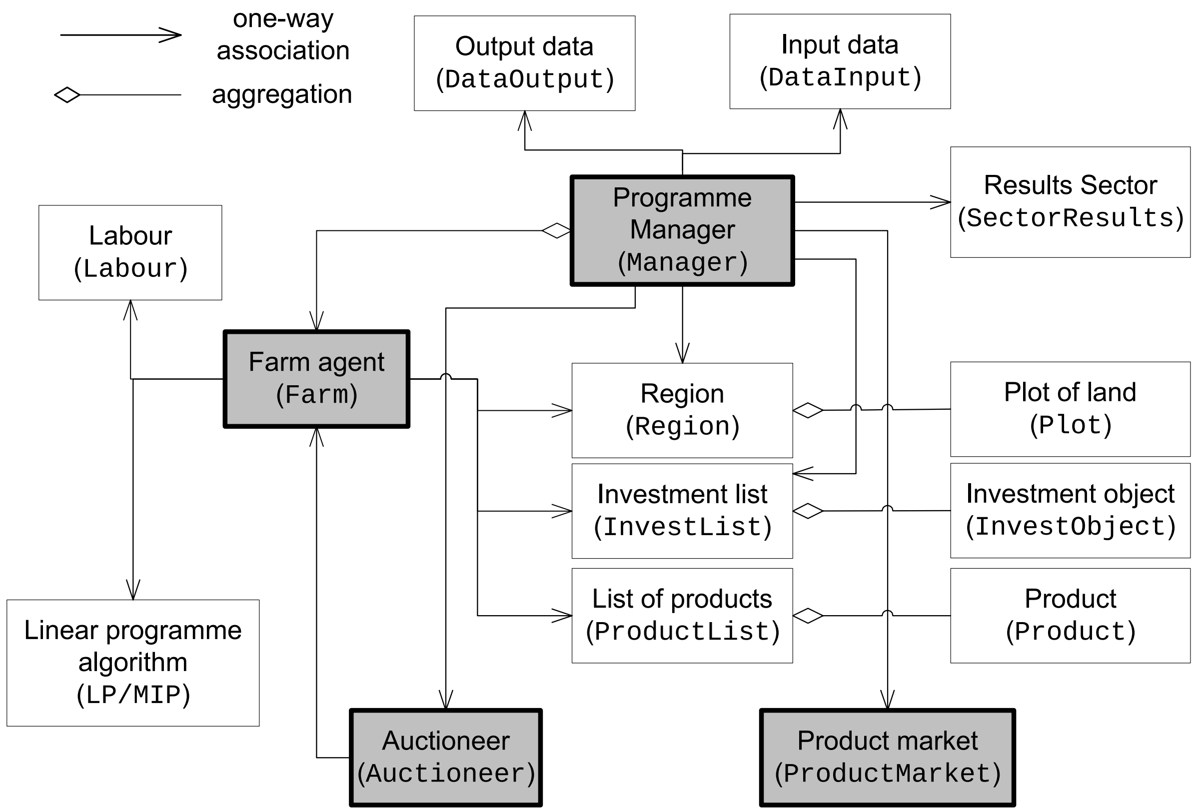
Figure 3-3: UML-representation of a class consisting of attributes and methods



Source: Own figure.

When building an object-oriented programme, one is first concerned with identifying the individual classes, then with defining the data and actions of these classes, and finally with describing the connection between classes. Figure 3-4 shows the object-oriented class design of AgriPoliS. Class names, as used in the C++ programme are in parentheses. The grey shaded classes are agent classes.

Figure 3-4: Object-oriented design of AgriPoliS



Note: Names in brackets denote the class names used AgriPoliS' C++ programme code. For reasons of clarity, the figure does not show attributes and methods. The complete model code can be provided by the author upon request.
Source: Own figure.

For the model to perform its task, it is not necessary that all classes are related with each other and can invoke each other's methods. In the figure, lines are used to express different kinds of relationships between classes. In general, a line between two classes denotes an *association* relationship. Properties of this line, such as the arrowhead, are used to specify the character of the association further. For example, the relationship between classes `Farm` and `LP/MIP` is implemented as a one-way association by using an arrow. This indicates that a `Farm` object can invoke the methods of the `LP/MIP` object, but not the other way around. Likewise, a `Farm` object determines its location by querying the `Region` object to return the position of the farm in the region, but the reverse is not possible. Another type of association is *aggregation*, denoted by a diamond. For example, the line from `Region` to `Plot` starts with a diamond, which denotes an aggregation. In this case, the region contains a set of plots. Similarly, each list of production contains a set of products.

From the classes shown in Figure 3-4, four kinds of objects can be derived: objects representing agents (`Farm, Auctioneer, ProductMarket`), objects representing production inputs and outputs (`Product`, `ProductList`, `Labour`, `InvestObject`, `InvestList`, `Plot`, `Region`), results and data management objects (`SectorResults`, `DataOutput`, `DataInput`, `LP/MIP`) and the `Manager` which controls the programme flow.[28] Accordingly, agent objects use the functionality embodied in input and output objects to achieve their respective goals. Results and data management objects offer some auxiliary functionality in that they provide optimisation methods on the one hand, and functions to summarise farm data on the other hand.

3.3.2 Model dynamics

Whereas Figure 3-4 presents the static structure of the AgriPoliS model, Figure 3-5 illustrates the dynamics which are implemented and controlled by the `Manager` objects. As can be seen, the `Manager` essentially includes two model phases, the initialisation phase, and the simulation phase. In the initialisation phase, the model structure, as described in section 3.2, is created. This includes the creation of objects based on the class definitions, and assigning values to the respective attributes of the various objects. The initialisation phase ends with further individualising farms with respect to attributes for which empirical data is not available or difficult to obtain.

Following the initialisation phase, the simulation phase starts with setting the political framework conditions that is valid during the subsequent simulation period. Following this, the `Manager` invokes the `Auctioneer` agent to carry out the land auction to allocate unused land to farm agents. After the land auction has finished, farm agents have the possibility to invest in new machinery, buildings, or equipment, and following this to produce using the available production factors. After production, the `Manager` invokes the `Market` agent to bring together production of all farm agents in the respective region and to determine a price for each type of product produced by the farm agents.

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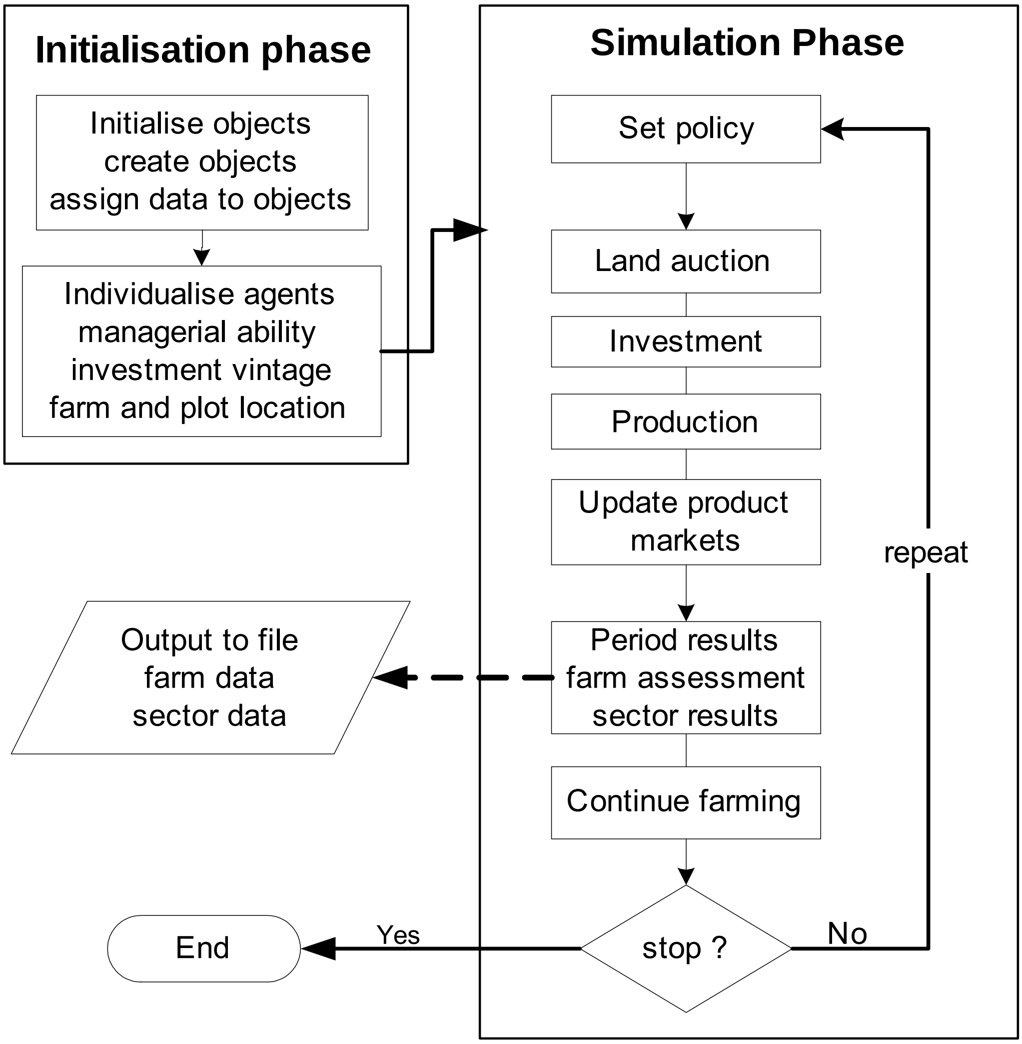
[28] As mentioned in section 3.2.1, the `Manager` can also be interpreted as an agent.

Figure 3-5: Model dynamics implemented in the `Manager` class



Source: Own figure.

At the end of each simulation period, farm agents assess their economic performance during that particular period. Based on this assessment and given prospective policy changes, the farm agents form expectations about the next production period to decide on whether to continue or stop farming. For this decision, farm agents take into account all possible adjustment options such as off-farm labour opportunities, selling excess quota, and terminating land rental contracts. Fixed assets cannot be disinvested due to the mentioned sunk cost assumption. Results for each individual farm agent and the sector as a whole are written to an output file. The simulation terminates when the number of specified simulation periods is reached.

3.4 Input and output objects

In AgriPoliS, input and output objects subsume all those objects that are necessary for agents to transfer inputs into outputs in the case of the farm agents or to organise a market. Each of these will be described in the following. Table 3-1 lists the AgriPoliS data structure and variable names used in the following.

Table 3-1: AgriPoliS data structure and variable names

Farm agent (k=1,…,K)		**Farm agent (continued)**	
Z	Utilised agricultural area of farm	TC	Transport costs
LU[a)]	Stocking density per farm	IC	Interest paid
MP	Manpower hours	HW	Wages paid
m	Managerial ability factor	W	Off-farm income
A (l=1,...,L)	Fixed assets	WD	Withdrawal for consumption
$\mathbf{A}_{\mathbf{ec}}$(l=1,...,L)	Equity financed share of assets		
n_c	Vintage of asset	WD_{min}	
LA	Land assets	ε	Additional consumption
L	Liquidity		
EC	Equity capital		
BC	Borrowed capital		
MR	Minimum equity capital reserve	**Investment I (h=1,…,H) to produce i**	
Y	Farm household income	d (d=1,…,D)	Investment type
Y^e	Expected farm household income	v	Equity-finance share
GMA	Gross margin agriculture	A	Investment costs
IR	Interest on working capital	AC	Average annual costs
$BID_{y,z}$	Bid for wanted plot $P_{y,z}$	N	Useful life
RE	Rent paid	MC	Maintenance costs p.a.
S	Support payments	l	Technical change factor machinery
MC	Current upkeep (maintenance)		
D	Depreciation	f	Technical change factor buildings and equipment
OV	Farming overheads	LS	Labour substitution
Capital		**Production activities**	
CRF	Capital return factor	**x** (i=1,...,I)	Production activity
i_{ec}	Interest on equity capital	**c** (i=1,...,I)	Variable prod. cost
i_{bc}	Interest on borrowed capital	$\mathbf{c}^{\mathbf{e}}$ (i=1,...,I)	Expected variable costs
i_{bcs}	Interest on short-term borrowed capital	$\mathbf{p}^{\mathbf{e}}$ (i=1,...,I)	Expected product price
Plot $\mathbf{P}_{\mathbf{y,z}}$	Plot at grid position y,z	γ	Price trend
β	Bid adjustment	**b** (j=1,...,J)	Factor capacities
$R_{y,z}$	Rent paid for plot $P_{y,z}$	**q** (j=1,…,J)	Shadow price of **b**
AP	Average number of adjacent plots per farm	**r** (j=1,...,J)	Factor demands
R	Average rent in region		
$TC_{y,z}$	Transport costs between farmstead and plot		
T	Number of adjacent plots		
$DI_{y,z}$	Distance between plots		

Note: Bold letters denote vectors; a) 1 LU corresponds to approximately 500 kg alive weight.

3.4.1 Production factors

Production factors in AgriPoliS primarily concern the classical production factors land, labour, and capital, whereby the factor capital includes both money and assets for production.

3.4.1.1 Land

The spatial representation in AgriPoliS is organised by way of cells (see Figure 3-2), called plots (class `Plot`) of equal size. Taken together, the plots make up the entire region (class `Region`). Plots differ with respect to three aspects: land quality, usage structure, and ownership. Regarding land quality, AgriPoliS considers two qualities: arable land and grassland. Land of either quality is assumed to be homogeneous. Regarding the usage structure, agricultural utilised area classifies as either managed land or abandoned land. And finally, at the outset of the model, agricultural utilised area is either owned by farm agents or rented. All land not owned by farm agents is assumed to belong to external land owners which are not explicitly modelled. The individual plots in AgriPoliS are characterised by a number of attributes defining the plot's state, its location on the grid of plots, and its location relative to the location of the farm interested in renting the plot or the farm agent managing the plot already. A plot of either land quality can take different states:

- no agricultural use
- abandoned land currently not managed
- grassland or arable land
- plot rented by farm agent k
- plot is farmstead
- plot is owned by farm agent k.

3.4.1.2 Labour

Labour is supplied in three forms (class `Labour`). The first is labour supplied by the farm family. The amount of farm family labour is derived from accountancy data; it is expressed in labour units.[29] Furthermore, farms can hire additional workers either on a fixed contract basis or on an hourly basis. Hiring fixed labour is treated as an investment for a period of one year. The total labour

29 One labour unit corresponds to the annual labour input in hour provided by one worker.

capacity is determined in the mixed-integer programme, where variable labour and fixed labour are activities.

In addition to hiring labour, farms can also offer their own farm family labour on the labour market. This offers the possibility for non-professional farming, on the one hand, and reducing the overall farm labour if necessary on the other. Corresponding to hiring labour, fixed and variable off-farm labour activities are introduced as activities in the mixed-integer programme.

3.4.1.3 Capital

To produce, a farm agent needs capital both in the form of liquid funds to pay running costs, and in the form of fixed asset capital (investments), which determine a farm agent's productive capacity.

Investments are introduced into AgriPoliS by way of an investment catalogue (class `InvestList`). This catalogue depicts a list of investment objects containing investment possibilities and production technologies typical for the region under investigation. The investment catalogue is available to all farm agents and it provides the basis for investment decisions by the farm agents. The individual objects in the catalogue differ with respect to the type of investment (e.g. dairy, fattening pigs, machinery), as well as the size of the investment reflected in the production capacity. For each type of investment, the catalogue contains a variety of sizes. Differently sized objects affect a farm agent in three ways: First, the effect of a larger scale of production is reflected in lower average annual unit costs compared to an object of the same type, but of smaller size. Second, larger investments are also considered to have lower labour requirements relative to smaller investments.

Third, over time, the technology underlying investment objects is assumed to improve, whereby larger investment objects are assumed to be technologically more advanced. Although technological change is not modelled explicitly by way of changing the technical coefficients of production, AgriPoliS nevertheless aims to mimic two effects of technically more advanced production technologies. On the one hand, AgriPoliS assumes that with every new investment, unit production costs of the product produced with this investment decrease. The extent of this cost-saving effect depends on the technical standard of the investment (see section on cost expectations).

Stated more formally, each investment object $I_{h,i,d}$ (h=1,…,H) to produce product i (i=1,…,I) is defined by the set of attributes in Table 3-2.

Table 3-2: Investment attributes

Investment attributes
- ID-number
- Type of investment (d)
- Investment costs (€)
- Production capacity (heads or hectares)
- Maximum useful life (periods)
- Labour substitution (hours)
- Maintenance cost (% of investment costs)
- Technological change factor (%)

In particular this is the investment's type d (d=1,…,D), investment costs, production capacity, maximum useful life, labour substitution in hours, maintenance costs, and a factor representing the impact of technological change.[30] Maintenance costs are expressed as a percentage of total investment costs.

The maximum time that an investment can be used in production is given by its useful life. Before any investment object has reached its maximum useful life, the object cannot be sold. Accordingly, an object's salvage value at the end of the useful life is zero such that it is non-tradable. This particular assumption has important consequences for the decision making of farm agents because it implies that investment costs are fully sunk once an investment is made. Because of this, depreciations not variable and treated as fixed costs in any case.

Capital required for production and investments is considered in three forms: short-term credit, long-term credit, and liquid equity capital.[31] Short-term credit is taken up by farms in the case of short-term liquidity shortages. The amount of short-term credit is not explicitly limited but interest is higher than for long-term credit, which therefore sets a kind of natural limit for borrowing in the short-term.

Long-term borrowed capital can be used to part-finance investments. It is assumed that a maximum share $(1-v)$ of investment costs is part-financed with borrowed capital with the remaining share v representing the equity financed share. Borrowed capital for investment is supplied by an annuity credit that runs for the entire useful life of the investment. The maximum amount of borrowed capital is also not directly restricted. Nevertheless, it is assumed that a farm only

30 For more clarity subscripts i, and d will be omitted in the following.

31 Liquid equity capital is defined as total equity minus land assets minus equity bound in asset capital.

invests if the equity financed share of total investment costs does not exceed a minimum equity reserve threshold MR value given by

$$\sum_{l=1}^{L}(v \cdot A_l) \leq L + 0.7 \cdot LA + 0.3 \cdot \sum_{l=1}^{L} A_{ec,l} \text{ with } L = EC_{t-1} - LA - \sum_{l=1}^{L} A_{ec,l} \,. \qquad (3.1)$$

That is, there is a limit on the maximum equity capital that can be used for investment. The limit is introduced to prevent putting the substance of the farm at risk.[32]

3.4.2 Production activities

Production activities in AgriPoliS are distinguished into livestock production (e.g. fattening pigs, turkeys), plant production activities (e.g. crops, sugar beets, grassland), short-term capital activities (e.g. short-term borrowing), short-term labour activities (e.g. short-term hiring), and 'additional' activities. Most livestock and plant production activities are consist of the production of marketable products. Exceptions are grassland production activities and silage maize, which serve as intermediate products for livestock production. Additional activities relate to those activities besides capital and labour which are needed to balance capacities in the short-run. This includes, for example, manure disposal, machinery contracting, or milk quota lease. Similar to investment objects, each individual production activity is characterised by a set of attributes (Table 3-3).

In the simulation, products are managed by the farm agents in a product list that keeps track of the total units produced as well as the gross margins associated with each product. Product prices change in response to developments on product markets (see section 3.6.2). Variable unit production costs are affected by technological change, on the one hand, and by the individual managerial ability of a farm agent.

[32] This means that 70% of land assets LA and 30% of total equity-financed fixed assets have to be covered by total equity capital EC_{t-1} at all times. The parameters 0.3 and 0.7 produced the most plausible results in a set of try-out simulations with AgriPoliS.

Table 3-3: Product attributes

Product attributes
ID-number
Production branch (e.g. sows for breeding, dairy production)
Product produced with investment Io of type d
Price (€/unit)
Variable unit production costs (€/unit)
Price flexibility
Price trend (% change per period)
Support payment (direct payment) (€/unit)

3.5 The farm agent[33]

To characterise the farm agent, it is useful to first describe why farm agents do what they do and based on what. That is, this section will first describe a farm agent's behaviour and the goal of its actions before describing the farm agent's actions.

3.5.1 Behavioural foundation

3.5.1.1 Farm planning

To model the behaviour of farms it is necessary to make assumptions about goals, expectations, managerial ability, and the variety of actions that a farm agent can pursue. AgriPoliS assumes each farm agent to maximise farm family household income in any one planning period. One planning period corresponds to one financial year. That is, a farm agent aims for maximising the total household income earned by farm family members either on or off the farm.[34] The action space given to farm family members is defined by on-farm factor endowments (land, labour, fixed assets, liquidity), the situation on markets for production factors and products, the vintage of existing fixed assets, technical

33 In this section, subscript *k* is omitted to increase clarity. All formulae concern one farm agent only.

34 The assumption of household income maximisation is reasonable in the current version of AgriPoliS as it is applied to a region with only family farms, where the majority of the workload is done by unpaid farm family labour. If other organisational forms such as corporate farms would be considered, this particular assumption would probably need to be reconsidered to reflect potentially different goals of corporate farms.

production conditions, overall economic framework conditions (work opportunities outside the farm, interest rate levels, access to credit), and the political framework conditions.

In order to maximise household income, farm factor endowments, production activities, investment possibilities, and other restrictions need to be brought together and optimised simultaneously. A suitable setting for this is a mixed-integer optimisation problem, the solution to which gives the optimal combination of action possibilities subject to the given framework conditions. Figure 3-6 shows matrix of the optimisation problem.

In this scheme, investments and fixed labour are considered non-divisible. They are therefore introduced as integer activities. The set of constraints consists of on-farm production capacities, but some constraints also reflect political framework conditions, such as the set-aside requirement, the limit on livestock density, or the nutrient balance. In more formal terms the mixed-integer optimisation problem is expressed as (abbreviations are given in Table 3-1)

$$\begin{aligned}
&\max\ Y^e(\mathbf{x},\mathbf{p^e},\mathbf{c},\mathbf{A},\mathbf{I},\mathbf{r},MP,D,RE,L,BC,IC,\ldots)\\
&\text{with}\\
&Y^e = \mathbf{x}'(\mathbf{p^e}-\mathbf{c}) + IR + S + W - RE - MC - D - OV - TC - IC - HW \qquad (3.2)\\
&\text{s.t.}\quad \mathbf{b} \geq \mathbf{x}'\mathbf{r} \qquad \text{with} \quad \mathbf{r} = (r_1,\ldots,r_I,\ldots,r_H,\ldots,r_J)\\
&\qquad\ \mathbf{x} \geq 0
\end{aligned}$$

This optimisation problem produces the vector q of shadow prices for scarce resources. Particularly the shadow price of land q_{Land} is of interest because it provides the basis for the production of bids in the land auction (see section 3.5.2).

Figure 3-6: Exemplary scheme of a mixed-integer programme matrix

Mixed-integer programme		Short term loans/saving	Buy/sell variable labour	Hire contractor	Plant production	Livestock production	Set-aside land	Buy/sell manure	Buy/sell milk quota	Investment activities	Buy/sell fixed labour
		c	c	c	c	c	c	c	c	i	i
	Objective function	*Gross margin*									
Factor capacities	Liquidity (€)	x		x	x	x	x			x	x
	Min. equity capital reserve (€)				x	x	x			x	x
	Labour (h)		x		x	x	x	x		x	x
	Utilised agricultural area (ha)				x			x			
	Winter fodder (ha)					x					
	Livestock capacities (places)					x				x	
	Machinery (ha)			x	x		x			x	
Other restrictions	Organic N-balance (kg N/ha)				x	x					
	Rape seed max. (% of UAA)				x		x				
	Sugar beet max. (% of UAA)				x						
	Set aside (% of UAA)				x		x				
	Milk quota (litres)					x			x		
	Direct payments (€)				x	x	x				
	Stocking density (LU/ha)				x	x	x				

Notes: c = continuous activities, i = integer activities.
Source: Own figure.[35]

3.5.1.2 General remarks about expectation formation

Production planning, investment, but also the decision to continue or quit farming is based on expectations about future developments of prices, costs, technologies, investment possibilities, and policies. In AgriPoliS, farm agents can form short-term expectations about the next planning period. However, farm agents are not capable of forming long-term expectations. With respect to all

[35] Compared to highly differentiated and detailed farm-based linear programming models (e.g., KAZENWADEL 1999; MÜLLER 2002), the optimisation model in AgriPoliS is aggregated. In view of a very detailed representation of the farm organisation the chosen aggregation can be considered to be a rather crude simplification compared to the actual planning situation and question faced by real farms. Yet, with respect to the objective of AgriPoliS it is not the specific farming system which is of interest in this study but rather a basic representation of central organisational characteristics as well as financial/economic considerations.

other future periods, they expect prices and costs to remain constant.[36] By doing so, dynamic effects resulting from expectations about the development of markets and demand developments are neglected. Farm agents also follow the same pattern of expectation formation, i.e. there is no differentiation between optimists and pessimists.

3.5.1.3 Price expectations

Regarding prices, a farm agent follows adaptive expectations defined in terms of the weighted geometric average of actual and expected prices.[37] A farm agent bases all planning decisions on expected prices because actual prices are only determined at the end of a production period as a result of farm activity. The expected price of production activity i in period $t+1$ is determined as

$$p_{i,t+1}^{e} = ({p_{i,t}}^{\alpha} \cdot {p_{i,t}^{e}}^{(1-\alpha)}) \cdot {\gamma_i}^{-1} \text{ with } 0 \le \alpha \le 1 \text{ and } p > 0 \text{ for i} = 1,\ldots,\text{I} \qquad (3.3)$$

The coefficient γ controls for a price trend of production activity i, whereby prices increase (decrease) if $\gamma < 1$ ($\gamma > 1$). In AgriPoliS the actual price and the expected price in period t are equally weighted, i.e., $\alpha = 0.5$.

3.5.1.4 Cost expectations

A farm agent also forms expectations about production costs. With regard to cost expectations, livestock and plant production activities defined in section 3.4.2 are treated differently from additional production activities.

For the group of additional production activities, a farm agent forms cost expectations in the same way than price expectation, however, without the price trend. Accordingly, expected costs of additional production activities are calculated as the weighted geometric average with equal weights

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36 This assumption has some implications in particular for investment activity because farm agents make long-term investment decisions on the basis of short-term expectations. If farm agents would be able to articulate medium or long-term expectations, some investments probably would not be made. The introduction of long-term expectations might be desirable but currently it is limited by practical problems. It appears to be particularly difficult to consider short-term and long-term expectations simultaneously. The problem would be even more complex if expectations would also be made with respect to the behaviour of other farm agents.

37 Unlike the more common definition as the weighted arithmetic mean, the chosen definition tones down expectations for period t+1 if expected prices and actual prices in period t differ (cf. BALMANN 1995).

$$c^e_{i,t+1} = c_{i,t}{}^{\alpha} \cdot c^e_{i,t}{}^{(1-\alpha)} \text{ with } 0 \le \alpha \le 1 \qquad \text{for } \mathrm{i} = 1,\ldots,\mathrm{I}. \tag{3.4}$$

Cost expectations for livestock and plant production activities are determined in a different way in order to introduce the cost-saving impact of technologically more advanced production technologies (see discussion on technological change). With respect to this, it is necessary to distinguish between plant production activities and livestock production activities.

As mentioned above, it is assumed that the technological standard of production technology improves with time. Thus, with every new investment into livestock production, the expected production costs $c^e_{i,t+1}$ of livestock production activity i produced with investment object I are computed as

$$c^e_{i,t+1} = c_{i,t} - f_{o,i} \cdot c_{i,t} \text{ with } 0 \le l < 1 \qquad \text{for } \mathrm{i} = 1,\ldots,\mathrm{I}, \tag{3.5}$$

whereby factor f represents the size of the investment. The factor is higher for larger investments.

On the subject of plant production activities, cost savings can only be realised as a combination of larger machinery together with larger field sizes.[38] Expected costs of plant production activities $c^e_{i,t+1}$ are thus a function

$$c^e_{i,t+1} = c_{i,0} - l \cdot c_{i,0} \text{ with } 0 \le l < 1 \qquad \text{for } \mathrm{i} = 1,\ldots,\mathrm{I} \tag{3.6}$$

of costs at the outset of the simulation in period t=0, adjusted by a factor l, which is a function of the average number of adjacent plots and the size of the farm. The factor l thus captures the effect of larger field sizes. It is defined as

$$l_t = \cdot \left[1 - \frac{0.15}{1 + 100/Z}\right] \cdot \left[1 - \frac{0.45}{1 + 100/(10 \cdot AP_t + 1)}\right]. \tag{3.7}$$

Figure 3-7 shows values of l for different farm sizes and average numbers of adjacent plots. Accordingly, a farm agent with initially little and scattered land can realise large cost savings if it considerably increase its acreage. The poten-

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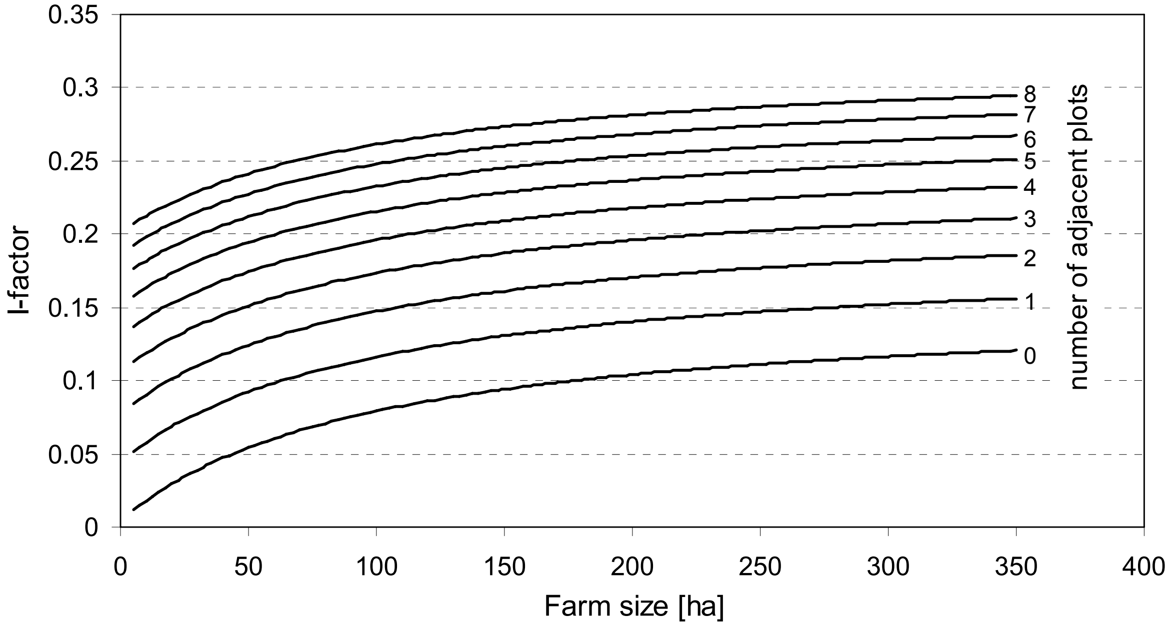
38 KUHLMANN and BERG (2002) quantify the cost difference between a 1 ha plot and one of 60 ha at 250 €/ha which corresponds to about a third of the current revenue for wheat.

tial cost effect is much lower if a farm agent's acreage is already high and if the plots are in the neighbourhood.

Figure 3-7: Expected cost savings for machinery investments depending on farm size and the average number of adjacent plots



Source: Own figure.

3.5.1.5 Expectations about policy changes

When forming expectations about the next planning period, policy changes have to be taken into account as well, particularly if changes are expected to be strong. It is assumed that a farm agent knows about major policy changes one period before the policy becomes effective. This influences decision making primarily when it comes to evaluating the farm agent's profitability at the end of a planning period (see section 3.5.2). In AgriPoliS, no general expectation formation with regard to policy changes is implemented. Rather, depending on the policy setting to be simulated, specific assumptions and expectations have to be formulated and introduced into the model.

3.5.1.6 Managerial ability

In real world agriculture, the economic performance of farmers can differ substantially even if they operate under more or less the same production conditions using the same production technologies. These differences in the economic performance of farmers are often attributed to differences in the managerial ability of farmers (NUTHALL 2001; ROUGOOR et al. 1998). Managerial ability can be understood as the ability of a farm agent to use its technology to realise all potential cost savings. Accordingly, production costs are lower if managerial ability is higher. In AgriPoliS, the managerial ability of a farm agent is introduced by a factor m, which is drawn randomly from a uniform distribution at start-up. The factor affects production costs of all products in the initial period according to

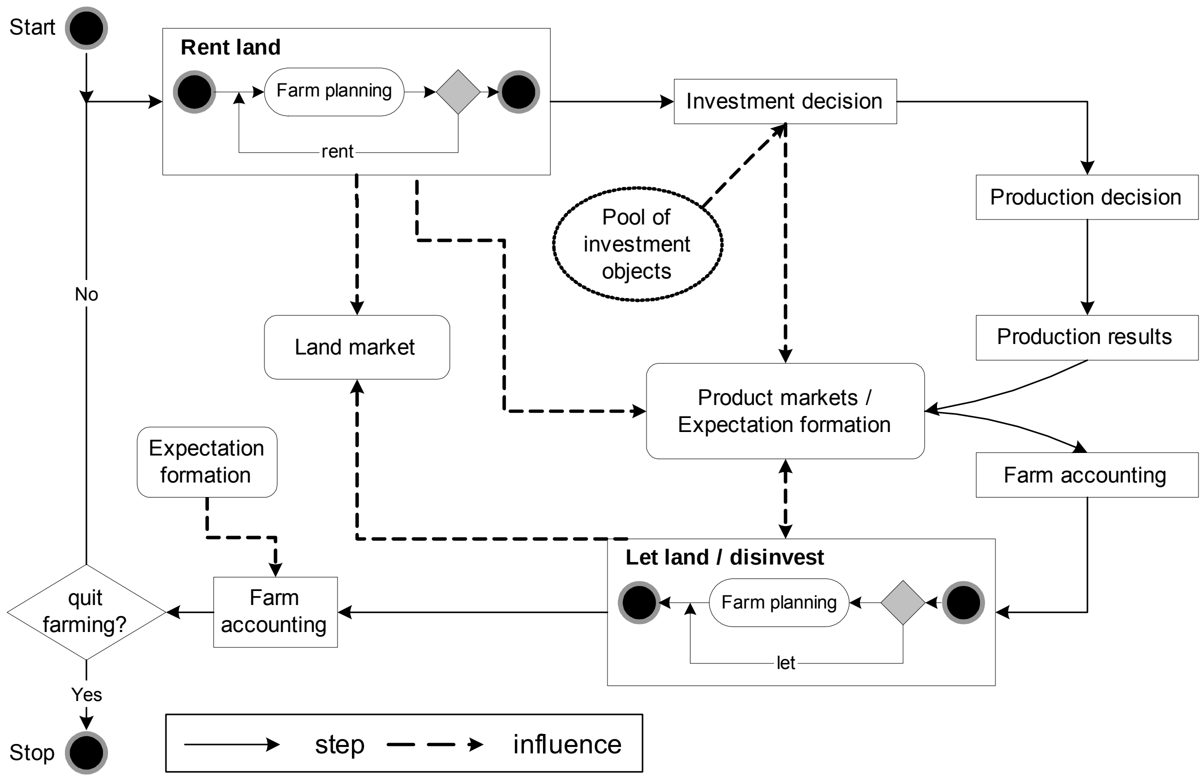
$$c_{i,0}^{new} = m \cdot c_{i,0} \quad . \tag{3.8}$$

In the current version of AgriPoliS, farm agents cannot learn to improve managerial ability.

3.5.2 Farm actions

During one planning period, a farm agent passes through a number of steps, shown in Figure 3-8. Each step describes an action.

Figure 3-8: Course of events in one planning period for one farm agent



Source: Own figure based on BALMANN (1995).

Based on the figure, the most important actions undertaken by a farm agent are renting land (renting additional land and disposing of unprofitable land), investment, production, farm accounting, and the decision whether to quit farming or stay in the sector.

3.5.2.1 Renting land

As mentioned at several points during this chapter, the land market is of particular relevance. As farms predominantly grow by renting land, AgriPoliS only considers a land rental market. As shown in Figure 3-2, in AgriPoliS, all farmland is categorised as plots of the same size. Plots are not divisible, and their size is fixed during one simulation run. Accordingly, the size of a plot defines the smallest unit by which farm acreage can change. Initially, each farm agents is endowed with a certain amount of land consisting of owned and rented land. Regarding the duration of a rental contract, no formal contract length is introduced in AgriPoliS. Instead, it is assumed that a farm agent can terminate unprofitable rental contracts at the end of each planning period. Rental contracts for profitable plots remain valid.[39] Accordingly, land is available for rent either because a farm agent withdraws entirely from agriculture or because rental contracts are terminated.

In each period, land available for rent is allocated to farms in an iterative auction. In order to be eligible for renting one additional plot a farm agent is asked by the auctioneer agent to make a bid for a particular plot in the region. Assuming that transport costs and the exploitation of economies of size for machinery (see section 3.5.1) influence the renting behaviour, a farm agent aims at renting a free plot which is closest to the farmstead and next to other plots belonging to the same farm agent. The maximum price, or bid, $BID_{y,z}$ for plot $P_{y,z}$ of either land quality is a function of both transport costs $TC_{y,z}$ between the farmstead and the plot, and the number of adjacent plots T. It is defined as:

$$
\begin{aligned}
BID_{y,z} &= (q_{Land} - TC_{y,z}) \cdot \beta + T \cdot \delta && \text{for} \quad 2 < T \le 8 \\
BID_{y,z} &= (q_{Land} - TC_{y,z}) \cdot \beta + \delta && \text{for} \quad 0 < T \le 2 \qquad (3.9) \\
BID_{y,z} &= (q_{Land} - TC_{y,z}) \cdot \beta - \delta && \text{for} \quad T = 0
\end{aligned}
$$

with $0 < \beta < 1$.

[39] This assumption is quite different from rental contracts in reality, which usually involve a long-term commitment for a number of years.

Parameter β reduces the bid to reflect other costs associated with leasing land such as taxes, administrative costs, labour costs and fees as well as the farm agent's additional rent derived from renting this plot. Accordingly, β represents the proportion of the shadow price of an additional plot remaining with the farm agent. The higher the value of β – and therefore the higher the bid – the larger the proportion of the shadow price of land that is eventually passed on to the land owner. A higher bid also increases the probability of a farm agent to receive the plot it wishes. In this respect, the difference $q_{Land} - \beta \cdot (q_{Land} - TC_{y,z})$ can also be interpreted as a kind of security mark-up. Moreover, if the desired plot is next to other farm plots, a surcharge δ is added to the bid. If the bid is highest compared to other farms, the farm agent receives the plot.

An obvious problem with this procedure is related to the fact that the shadow price of land is only determined for one additional plot at a time. In fact, because of the indivisibility of investment options, the shadow price for land derived from the optimisation model may potentially change rapidly if calculated for more than one plot at a time. For that reason, it would be reasonable if farm agents could bid for more than one plot at a time. This poses computational difficulties, though, as different bundles of plots would need to be tested to derive the maximum shadow price from a combination of plots. Therefore, in addition to the shadow price for only one plot the average shadow price for renting eight plots at a time is calculated. The maximum shadow price of one additional plot and of eight additional plots is then taken as the basis for the bid.

Similar considerations apply when a farm gives up rented land to increase its overall profitability (see section on farm accounting).[40] In this case, a farm would give up the rented plot $P_{y,z}$ if the shadow price does not cover the plot's costs consisting of the rent $R_{y,z}$ and transport costs $TC_{y,z}$, that is if

$$q_{Land} < \max_{y,z} (R_{y,z} + TC_{y,z}) .^{41} \tag{3.10}$$

After giving up a plot, the farm recalculates the shadow price of land. The procedure is repeated until the shadow price of land is at least equal to the costs of a plot. Unless a farm agent withdraws from agriculture altogether, it is not

40 Here, the number of adjacent plots is not taken into account.

41 Adjacent plots are not considered when rental contracts are terminated.

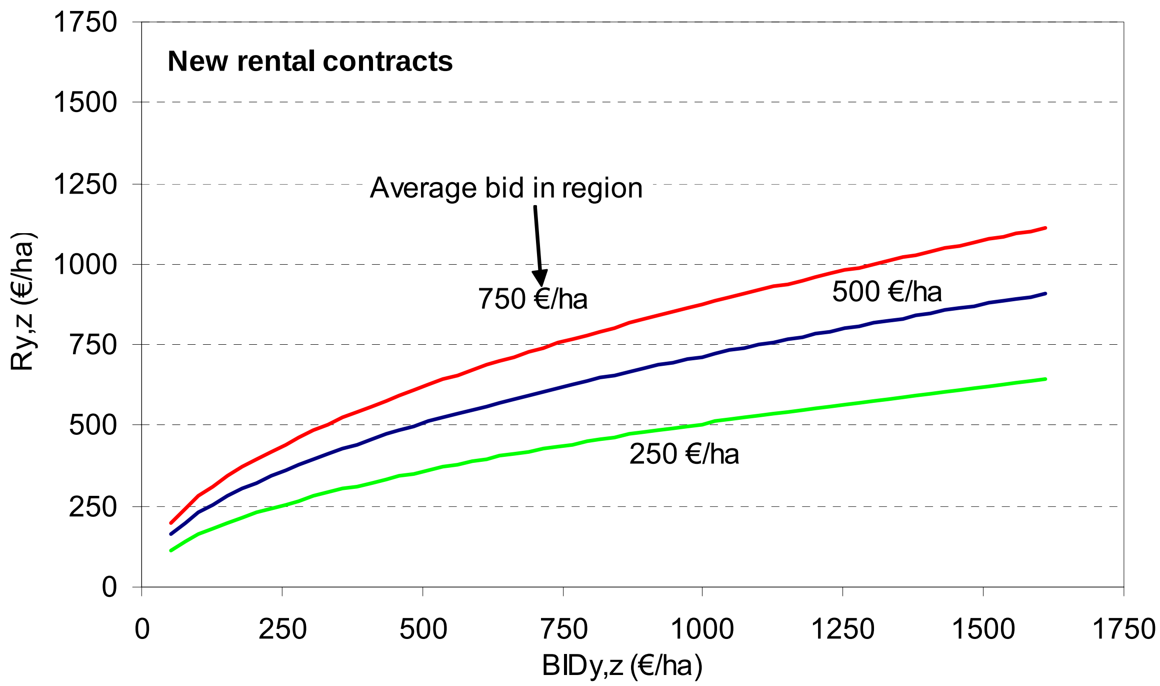
possible to let owned land in order to be rented by other farm agent.

In AgriPoliS, the rent paid for a plot is not equal to the bid given in the land auction. This has two reasons. The first is that shadow prices can vary significantly between farms. Hence, rents would differ significantly between farms, which would affect the farm agent's competitiveness. The second reason is that an equality of bids and rental prices is rather unrealistic. In reality, most new rental contracts include a passage that places rents in the context of an average regional rent. To reflect this, the actual rent paid for a newly rented plot is calculated as

$$R_{y,z} = \sqrt{BID_{y,z} \cdot \overline{R}}\ , \qquad (3.11)$$

i.e., is it derived from the weighted geometric average of the bid $BID_{y,z}$ given in the auction and the average regional rent $\overline{R}$ with equal weights. Figure 3-9 shows this relationship graphically.

Figure 3-9: Rent adjustment for new rental contracts



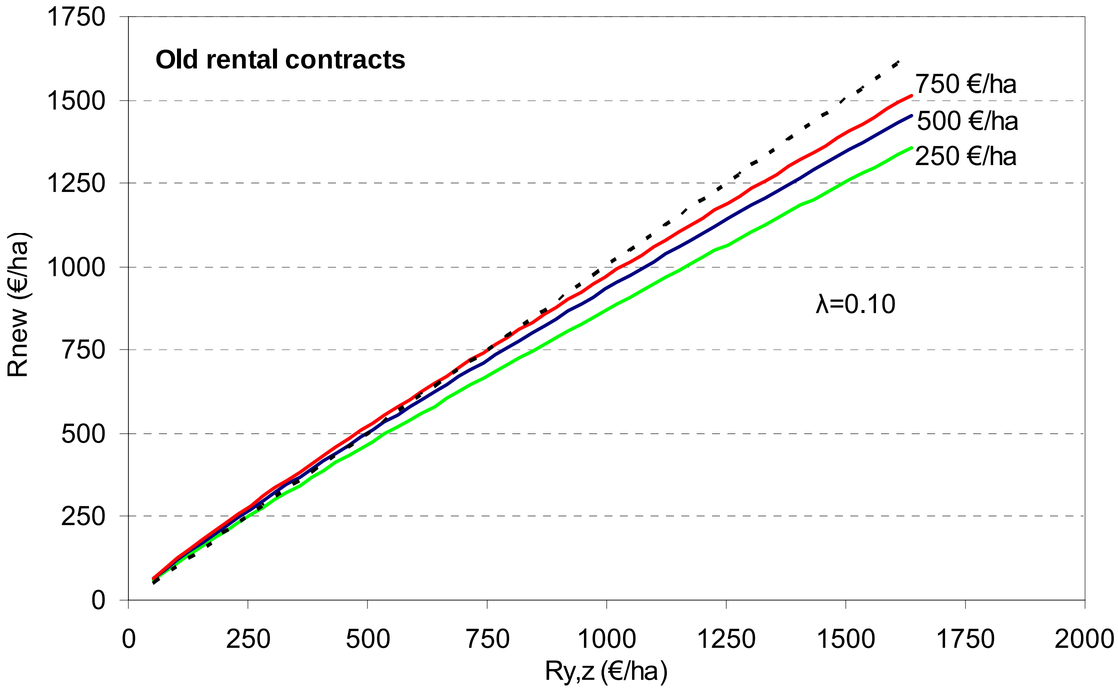
Source: Own figure.

As it is often the case in reality, also the rent fixed in older rental contracts is adjusted. Frequently, such an adjustment is due to strong product price changes, policy changes, or changes in the regional reference rent. In AgriPoliS, the adjusted rent $R_{y,z}^{new}$ for old contracts is the weighted geometric average of the average rent in the region and the previous rent of the plot

$$R_{y,z}^{new} = \overline{R}^{\lambda} \cdot R_{y,z}^{(1-\lambda)}, \tag{3.12}$$

whereby the weight λ is given by the share of newly rented land in the entire region. Depending on λ and the average regional rent, the adjusted rent develops close to the initial bid. This is plotted in Figure 3-10.

Figure 3-10: Rent adjustment for old rental contracts assuming 10% newly rented plots



Source: Own figure.

3.5.2.2 Investment

Farm investment activity is typically concerned with the purchase of machinery, buildings, facilities, and equipment. As investment and production are mutually interdependent, they are considered simultaneously in the mixed-integer planning programme presented in section 3.5.1.

Investments in AgriPoliS take place in two steps, investment planning and the actual investment. In the first step, the farm carries out planning calculations based on the farm planning problem presented in section 3.5.1. During the planning calculations, be it in the context of renting land or for production, a farm agent takes investment opportunities into account. However, during all planning calculations the agent does not invest in real terms but plans 'as if' he invested, i.e. production capacities are not actually changed. The number, kind, and combination of investments are not restricted. In principle, a farm agent only invests in one object or a combination of objects if the expected average return on investment, determined in the farm-planning problem, is positive, i.e. if total household income increases. For investment-planning purposes, all expenditures and payments related to an investment are distributed equally over the investment's useful life and considered in the optimisation. Accordingly, the average annual costs AC_h of investment $I_{h,i}$ considered in the objective function of the farm-planning problem are calculated as

$$AC_h = A_h \left[(1-v) \cdot CRF_{i_{bc},N_h} + \frac{v}{N_h} + MC_h \right]. \tag{3.13}$$

Maintenance costs MC_h are expressed as a percentage of total investment costs. The average annual opportunity costs of equity capital bound is determined as

$$A_h \cdot v \cdot f, \qquad \text{with} \quad f = \frac{(1+i_{ec})^{N_h}}{(1+i_{ec})^{N_h} - 1} - \frac{1}{N_h \cdot i_{ec}}. \tag{3.14}$$

Only in the second step, based on the planning calculations, the actual investment activity takes place (see Figure 3-8) resulting in a change of production capacities. After investment, depreciation and repayment are determined as shown further down in Table 3-5.

3.5.2.3 Production

Each farm agent is assumed to optimise production in any one planning period subject to available production capacities using the planning approach described in section 3.5.1 above. All production activities enter the optimisation as continuous activities. That is to say, products are assumed to be fully divisible.

In addition to fixed assets (buildings, machinery, equipment), production requires liquidity to cover running costs in the short-run. Products produced continuously throughout the year (mostly livestock production) have a constant demand of working capital, which in AgriPoliS is defined as liquid assets. Other products such as crops are seasonal products and therefore require working capital only during parts of the year. To overcome short-term liquidity shortages, farm agents can take up loans to finance working capital.

3.5.2.4 Farm accounting

The financial year of a farm agent ends with an annual financial statement. This statement produces indicators on incomes and profits, the stability and financial situation of the farm agent, and the remuneration of fixed factors. Table 3-4 lists central indicators and how they were derived; Table 3-5 shows a list of selected variables in the financial statement.

Table 3-4: Indicators calculated in the financial statement

Indicator (end of period t)	Calculation
Profit (farm income) (t) =	Gross margin + Interest on working capital + Subsidies - Rent paid - Current upkeep of machinery and equipment - Depreciation - Farming overheads - Transport costs - Interest paid - Wages paid
Household income (t) =	Profit + Off-farm income
Farm net value added (t) =	Profit + Rent paid + Interest paid + Wages paid
Equity capital (t) =	Equity capital (t-1) + (Household income - Withdrawal)

Change in equity capital is an indicator of a farm agent's economic stability. A farm is economically more stable the higher the equity-debt ratio of the farms, i.e. the higher the share of equity capital in total capital. Consequently, it would be reasonable for a farm to stop farming if equity capital is less than zero. In this case, all own resources, which could be used, for example, as credit security are used up.

Accumulation of equity capital is the result of balancing total farm income with living expenses. In AgriPoliS, the equity capital stock increases because total household income is greater than withdrawals. Regarding withdrawals, it is assumed that each family labour unit working on the farm consumes at least $WD_{\min}$ per year. A share ε of the remaining farm household income after deducting $WD_{\min}$ is consumed in addition to the minimum withdrawal. The remaining share $(1-\varepsilon)\cdot(Y-WD_{\min})$ is then charged to the farm agent's equity capital. Table 3-5 shows this.

Table 3-5: Definition of variables used in financial statement (selection)

Variable (at end of period t)	Definition
Equity capital	$EC = EC_{t-1} + Y - WD$
Withdrawal	$WD_{\min} \le WD \le (Y - WD_{\min})\cdot\varepsilon + WD_{\min}$ with $0 < \varepsilon \le 1$
Gross margin	$GMA = \mathbf{x}'(\mathbf{p} - \mathbf{c})$
Interest on borrowed capital	$IC = \mathrm{f}(BC, i_{BC})$
Repayment	$RP = (1-v)\sum_{c=1}^{S}\left[A_c \cdot (1+i_{bc})^{(n_c-1)} \cdot (CRF_{i_{bc},N_c} - i_{bc})\right]$
Long-term loans	$BC = BC_{t-1} - RP + BC^{new}$
Depreciation	$D = \sum_{c=1}^{S}\left[A_c \cdot (1+i_{bc})^{(n_c-1)} \cdot (CRF_{i_{bc},N_c} - i_{bc})\right] + \sum_{c=1}^{S}\left[A_c \cdot (1+i_{ec})^{(n_c-1)} \cdot (CRF_{i_{ec},N_c} - i_{ec})\right]$
Farming overheads	$OV = \gamma \cdot GMA$ with $\gamma \le 1$
Current upkeep (maintenance)	$MC = \sum_{c=1}^{S} MC_c$
Rent paid	$RE = \sum_{y}\sum_{z} R_{y,z}$
Transport costs	$TC = \mathrm{f}(DI_{y,z})$
Liquidity[a)]	$L = EC_{t-1} - LA - A_{ec}$
Interest on working capital	$IR = i_{ec} \cdot L$

Note: a) Liquidity is updated throughout the accounting year whenever the total equity capital stock changes due to investment or disinvestment.

Lasting farm profitability requires that all farm-owned production factors (own land, family labour, liquid equity capital, and quota) receive an adequate payment when used on-farm. To assess farm profitability, all on-farm production factors have to be valued at their opportunity costs (Table 3-6). Since costs of fixed assets are assumed sunk, they are not considered in this calculation. In the case of handing over the farm to the next generation, opportunity costs of labour are also higher if a farm is handed over to the next generation. This reflects the comparable industrial salary a successor could potentially earn if he/she would not take over the farm. Accordingly, a successor would only take over the farm if the farm were able to generate income that is at least as high as the opportunity costs.

A decision on whether to quit is necessary subject to the expected household income in future periods. As mentioned above, the planning horizon of a farm agent is one period. Hence, the calculation of expected household income takes account of investment possibilities and off-farm employment possibilities in the next period. Moreover, expected household income rests on the assumption that a farm agent's land endowment does not change. The resulting expected household income is contrasted with the opportunity costs of all on-farm production factors.

Table 3-6: Opportunity costs of production factors

Factor	**valued at**
Farm family labour	Off-farm income
Labour of farm successor	Comparable industrial salary
Working capital	Long-term savings rate
Owned land	Average regional rent
Milk quota	Quota price

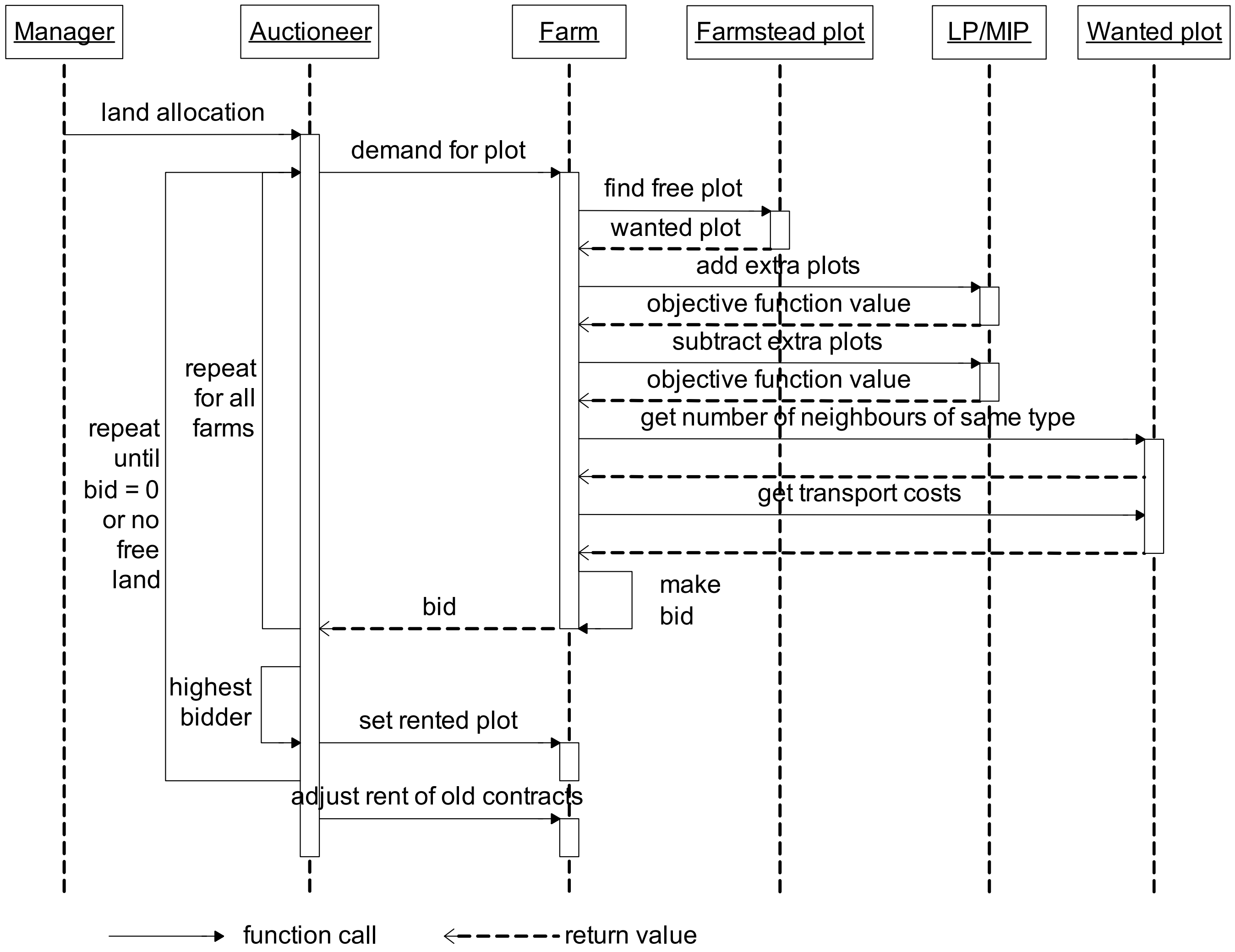
If expected household income does not cover opportunity costs, it is rational for the farm to quit and use all production factors outside the farm. This decision rule defines a clear threshold between quitting and staying. In some instances, it may be reasonable to blur this threshold, for example, by introducing a tolerance margin in which farms stay in business despite of higher opportunity costs.

3.6 Factor market agents

3.6.1 Land auctioneer

Compared to a farm agent, the auctioneer is a very basic kind of agent. The auctioneer to co-ordinates the auction of free plots by collecting bids from farm agents; it then compares the bids, and finally allocates a free plot to the highest bidder. The auctioneer acts on behalf of land owners who are not engaged in farming, but receive all rent payments. The exact auction process is illustrated in Figure 3-11 using UML notation.

Figure 3-11: Sequence diagram of the land auction using UML notation



Source: Own figure.

According to this figure, the order of events is the following: Triggered by the `Manager` class, the auctioneer carries out an iterative auction of free plots. It does so by asking each farm agent intending to rent additional land to produce a bid for one plot. As discussed in section 3.5.2, the farm does so by first searching for a free plot closest to the farmstead. It then determines a bid for that plot based on a combination of the shadow price of land, the number of plots adjacent to the desired plot, and transport costs. Following, the auctioneer ranks the bids and allocates the desired plot to the highest bidder. As farm agents can only bid for one plot at a time, the bidding procedure continues until all plots are allocated or the highest bid is zero. In a final step, the auctioneer determines the actual rental price that is to be paid for the plots just allocated. In addition to setting the price for new rental contracts, the auctioneer also initiates the price adjustment of old rental contracts by applying the rent adjustment procedure shown in section 3.5.2. This ends the land allocation procedure.

3.6.2 Product market

The product market agent determines a market price for all produced outputs in any one period. For this, the market agent makes use of a number of price functions. The demand function for agricultural products in AgriPoliS assumes neither a fully elastic nor a fully static demand. In analogy to the function for gross margins developed in BALMANN (1995), it is assumed that for most products of products i the price in period t is a function

$$p_{i,t} = p_{i,0} \cdot \gamma_i^{-(t+1)} \cdot \left(\frac{\sum_k X_{k,t}}{\sum_k Z_{k,t}} \right)^{-b_i} \text{ with } k = 1,\ldots,K, \tag{3.15}$$

where $p_{i,0}$ denotes the initial price of product i at the outset of the simulation (period t=0), the coefficient γ_i controls for a price trend over time, and the last term allows for price variation in depending on the cumulative quantities produced by K farm agents. The parameter $b_{i,t}$ represents price flexibility which is equivalent to the inverse demand elasticity (cf. BALMANN 1995).

The price function differs for selected products. In particular this is:

- *Piglet production:* Piglets are assumed to be used as intermediate inputs in fattening pig production. For this reason, the total quantity of piglets produced is reduced by the quantity of piglets used for fattening pig production.[42]

- *Milk quota:* Since the year 2000, prices for milk quota in Germany have been determined in quota auctions. Implementing such an auction would be a complex matter (comparable to the land auction). Regarding quota, AgriPoliS therefore implements a highly simplified quota market in that it reflects only the results of quota auctions. In principle, farms can buy and sell quota indefinitely. But, to keep milk production within realistic limits, the price of quota is related to a regional reference quota.[43] If milk production is above (below) the regional reference level plus a 10% tolerance, the quota price rises (falls) by a given percentage. The quota market as implemented in the model resembles a quota leasing market. To prevent quota from leaving the region, the marginal revenue of selling quota is less than the marginal revenue of buying additional quota.
- *Manure trading:* Regarding manure trading, farm agents generally pay to dispose of excess manure, on the one hand. On the other, farm agents receive payments for taking excess manure up to a given limit. Manure trading is not limited to the region. That is why in the simulation there may be more farms taking up manure than farms disposing of manure and vice versa. Similar to the market for milk quota, the price of disposing manure rises the more excess manure is offered.

3.7 Data input, results preparation and data output

AgriPoliS has an interface to a spreadsheet file that includes data on the regional agricultural structure to be studied to initialise the model. The file contains data on individual farm agents (family labour, machinery, buildings, production facilities, land, production quota, liquid assets, and borrowed capital) as well as regional data (number of farms, farm types, total land). Figure 3-12 illustrates the procedure of reading data into AgriPoliS in a schematic way.

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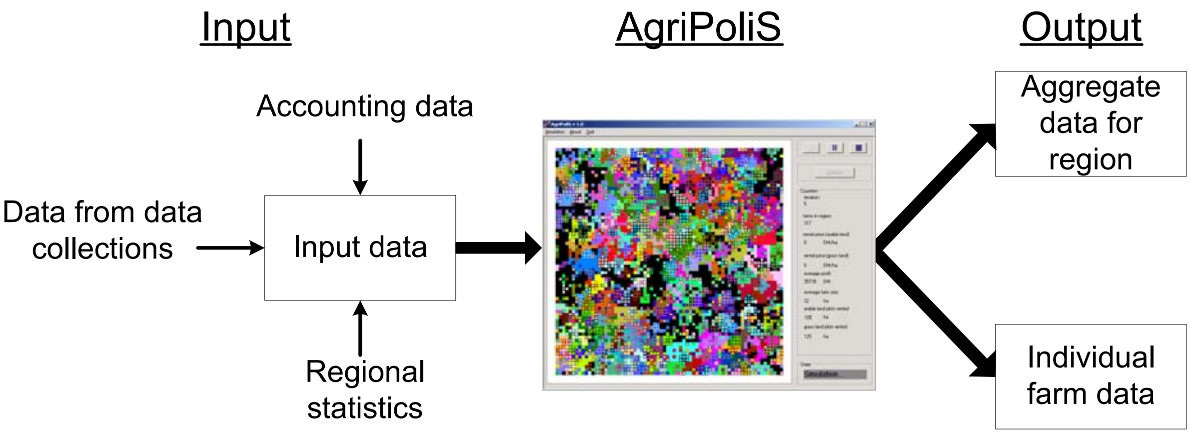
42 At the current development stage, there is no interdependence between the price of piglets and the gross margin of pig fattening.

43 The regional reference quota is calculated as the total number of dairy cows in the region to be modelled times the average milk yield in that region. A tolerance range of ±10% around the regional reference quota is assumed, so that it does not function as the exact threshold value for price changes.

Figure 3-12: Schematic representation of AgriPoliS input and output



Source: Own figure.

On the input side, data – broadly speaking - input consists of farm accountancy data, regional statistics, and stylised data on technical coefficients, prices and costs. On the output side, AgriPoliS compiles aggregate data at the sector level (class `SectorResults`), on the one hand, and individual farm data, on the other hand. More specifically, data output at sector level and at farm level (class `DataOutput`) include data listed in appendix A-2. Based on these indicators it is possible to draw conclusions with respect to production, economic performance of farms, production intensity, income distribution, and farm structure.

Part II

Applying and testing AgriPoliS

4 Adapting AgriPoliS to the region Hohenlohe

4.1 Introduction

The previous chapter introduced the agent-based model AgriPoliS, which was designed to simulate the structural development of regional agricultural structures. The purpose of this chapter is twofold: first, it presents a methodology for coupling AgriPoliS with data of an existing regional agricultural structure. Second, this chapter presents an adaptation of AgriPoliS to the agricultural structure of the region Hohenlohe in southwest Germany. Adapting AgriPoliS to Hohenlohe (as well as to any other region) requires the representation of key regional indicators such as the number of farms, the specific farm size distribution, farm specialisation, income sources, and production in a reference year.[44] Moreover, farm agents need to be initialised based on real farm-data, for example, on production activities, capital endowment, farm specialisation, labour endowment. The adaptation and the model calibration focus primarily on matching the starting conditions of AgriPoliS with Hohenlohe's structure in the financial year 2000/2001.[45] The political framework conditions are given by Agenda 2000.

The adaptation of the starting conditions is done in two steps. The first step is to represent the structure of Hohenlohe based on a number of typical farms. The second step is to represent the internal organisation of each of these typical farms, that is to say, their specialisation, main production activities, asset and

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44 The specific methodology to couple AgriPoliS with real data that is presented in this chapter was originally developed and tried out for the purpose of this study. It involves the replication and representation of a single reference year. The original idea to replicate a historical reference period to identify the model's parameters (as intended in the project proposal) was not followed because it proved to be very demanding (see also the discussion in section 4.9). The back-casting of previous development will be the subject of further research.

45 Calibration is the simulation of a model with different parameter values such that simulated data and real data correspond in the best way (GREGORY and SMITH 1990).

capital endowments. As this chapter builds upon work by KLEINGARN (2002) and SAHRBACHER (2003), a detailed description of the calibration procedure, selection of data, and discussion of parameter values can be found in these references. The following summarises the most important results of these studies.

4.2 Study region 'Hohenlohe'

The federal state of Baden-Württemberg in southwest Germany is subdivided into homogeneous regions of similar natural production conditions ('Gebiete gleicher landwirtschaftlicher Ertragsfähigkeit') (MLR 2002). This differentiation takes into account the different geological, topographical, and climatic conditions in Baden-Württemberg. Accordingly, 21 such regions are defined for Baden-Württemberg. The choice of the study region was guided by this subdivision of Baden-Württemberg. In particular, the region Hohenlohe proved to be suitable for this study as it is characterised by a diverse agriculture with intensive livestock production (fattening pigs, sows for breeding, and turkeys) on the plains, and dairy and forage production in the valleys. Although soils are heavy on the plains, crop and forage production dominate (MLR 2002).[46] Table 4-1 gives an overview of the natural production conditions in Hohenlohe.

Table 4-1: Natural production conditions of region Hohenlohe

Altitude	350-500 m
Average annual temperature	7-8° Celsius
Average annual precipitation	650-750 mm
Soil quality[a)]	30-50
Share of arable land	50-60 % of utilised agricultural area

Note: a) Soil quality measured on a scale from 0 (very bad) to 100 (very good).
Source: MLR (2002).

In the year 1999, Hohenlohe comprised about 73,439 ha of agricultural area, managed by approximately 2869 farms (STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG 1999).[47] Approximately half of the farms were run as professional (full-time) farms, with the remaining farms being non-professional (part-

46 The majority of available data (number of farms, livestock numbers, and agricultural area) is classified according to administrative entities such as municipalities, or counties. Unfortunately, the definition of administrative entities does not correspond with regions of homogenous production conditions.

47 Full agricultural surveys are conducted every five years. The most recent agricultural survey available was from 1999. For the reference year 2000/2001 no data was available.

time) farms.[48] Professional farms, due to their larger average farm size (average farm size of professional farms 36.4 ha, non-professional farms 11.3 ha), have cultivated 66% of the agricultural area in Hohenlohe. All farms have the legal form of a family farm. More than 97% of the work on farms is done by farm family members (KLEINGARN 2002). Table 4-2 shows the agricultural structure in 1999 in Hohenlohe differentiated by professional and non-professional farms and by farms types.[49]

Table 4-2: Farm structure in Hohenlohe in 1999

Farm types	All farms		Professional farms		Non-professional farms	
	Farms (%)	UAA[a)] (%)	Farms (%)	UAA (%)	Farms (%)	UAA (%)
Total	100	100	100	66	100	44
Specialised crop	15	12	7	4	25	9.5
Grazing livestock	30	29	30	20.5	30	9.2
Spec. granivore	34	38	41	26.4	24	9.9
Mixed	17	20	20	14	14	5.1
Permanent crops	5	0.4	1.6	0.2	8	0.3

Note: a) UAA = utilised agricultural area in hectares.
Source: STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (1999).

It shows that among professional farms, grazing livestock farms and specialised granivore farms (pig/poultry) take the largest share with 40% and 30%, respectively.[50] This indicates that livestock production plays an important role in

48 The term 'part-time farming' may cause some confusion because it can include both the 'part-time farmer' and the 'part-time farm' (FENNELL 1997). Whereas the former suggests that the farmer has another occupation, the latter suggests that the farming operation is too small to provide full-time employment for at least one labour unit. In the context of this thesis, the latter concept is meant. To avoid confusion, in the following the terms 'non-professional' and 'professional' are therefore used instead of 'part-time' and 'full-time'.

49 Specific natural production conditions will not be further discussed since structural data is at the centre of interest.

50 The classification of farms by farm type and income sources in this table is based on the system valid in Germany at the time of the survey (1999). Farms are classified in either class if farm standard gross margin of the most important production line exceeds 50% of total gross margin. Professional and non-professional farms are differentiated based on annual work units and standard farm income (see e.g. MLR 2002). In 2002, classification of farms was changed according to EU rules. According to the 'new' EU classification a professional farm is defined by an economic size of at least 16 ESU and employs at least one labour unit (HESSENAUER 2002; LANDESAMT FÜR VERBRAUCHERSCHUTZ UND LANDWIRTSCHAFT BRANDENBURG 2003). Whereas the EU classification differentiates between professional and non-professional farms solely based on economic size units, in Germany

Hohenlohe and less so arable farming. Approximately a quarter (26.5%) of total UAA is farmed by professional, specialised granivore farms, and 20% of the total UAA is farmed by grazing livestock farms. Specialised crop farms are generally of minor importance, in particular when professional farming is concerned. According to REISCH and ZEDDIES (1992), the concentration of intensive livestock production in Hohenlohe is due to the fact that particularly in the 1980s pig production as a land-independent production activity was considered to have a high growth potential.

4.3 Representing Hohenlohe's agricultural structure based on typical farms

For calibrating AgriPoliS to Hohenlohe, the agricultural structure of Hohenlohe in the reference year 2000/2001 is represented based on typical farms, i.e., farms one could typically find in the region. SAHRBACHER (2003) developed a procedure, based on BALMANN et al. (1998a,b), to simultaneously select typical farms and scale them up to represent a range of regional capacities. The approach identifies typical farms of different types and sizes, on the one hand. On the other, it generates a scaling factor for each typical farm. This factor denotes the number of times a typical farm has to be located in the region such that the agricultural structure of the region is represented best.

This particular approach requires two kinds of data: first, data about the region representing aggregate regional capacities, and, second, data about the organisation as well as economic indicators of individual farms in the region from which to select typical farms. Regarding the first requirement, regional statistical data sources were available (e.g. STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG, 2003). As for individual farm data, farm accountancy data (as collected in the FADN network) compiling information about farm organisation and economic indicators, provided a suitable data source. Although farms in the farm accountancy data sample are not representative, the sample nevertheless covers the most important farm types in the region (ANGENENDT 2003).

For Hohenlohe, farm accountancy data from 101 professional and 20 non-professional farms were available in the reference year 2000/2001. Considering that about 50% of all farms in the region are non-professional farms, they are heavily underrepresented in the accountancy data sample. Because of this, data on 20

the labour restriction was introduced in addition.

non-professional farms from regions similar to Hohenlohe were added to the farm sample to provide a more suitable basis for selecting typical non-professional farms. Furthermore, these small farms are predominantly specialised crop farms.

Applying the mentioned up-scaling procedure to the farm data sample resulted in the identification of 24 typical farms (Table 4-3). Of these, 19 farms operated as professional, and five as non-professional farms. The last row gives each farm's scaling factor. The selected farms match the characteristics of agriculture in Hohenlohe quite well as Table 4-4 shows. In most cases, deviation is below 5%. For instance, in the model professional farms manage 57,350 ha land, in reality it is 57,464 ha. The deviation between the adapted model and real regional statistics is largest for specialised crop farms and farms with less than 10 hectares of land. The reason behind is that very small farms are underrepresented in the underlying accountancy data sample. Larger differences exist only when smaller farm sizes and livestock capacities are concerned. On the one hand, this is because of a sample error in the German farm accountancy data sample in which particularly small farms are underrepresented in the sample. Thus, it is particularly difficult to represent the many small non-professional farms. Furthermore, these small farms are predominantly specialised crop farms. This explains the deviation with regard to this farm type.

Table 4-3: Characteristics and frequencies of typical farms (reference year 2000/2001)

	Professional farms																			Non-professional farms				
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Specialisation [a)]	SG	SG	SG	SG	SG	SG	SG	SG	GL	GL	GL	GL	GL	GL	SC	SC	MI	MI	MI	SG	SG	GL	SC	MI
Land [ha] [b)]																								
Total	55	20	50	35	32.5	15	35	55	30	90	32.5	37.5	15	30	77.5	30	20	50	42.5	17.5	25	15	10	10
Arable land	55	20	50	35	32.5	15	35	55	12.5	57.5	10	10	10	22.5	77.5	30	20	50	27.5	17.5	25	10	10	5
Grassland	-	-	-	-	-	-	-	-	17.5	32.5	22.5	27.5	5	7.5	-	-	-	-	15	-	-	5	-	5
Rented land	32.5	0	37.5	7.5	7.5	2.5	17.5	35	10	67.5	17.5	25	5	5	52.5	15	-	-	25	2.5	5	5	-	10
Equity capital [1000 €]	905	457	714	949	687	427	518	980	455	773	558	516	208	493	322	449	681	1,121	239	454	444	326	326	38
Family labour [1000 h]	4.1	2.9	3.1	3.5	3.5	2.6	3.1	3.2	1.7	3.9	3.3	2.7	2.6	2.6	2.6	1.9	2.3	4.1	1.8	3.4	3.0	3.0	1.9	3.2
Livestock [head]																								
Beef cattle	-	-	-	-	-	-	-	-	-	-	10	10	-	-	-	-	-	-	-	-	-	15	-	-
Suckler cows	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-
Dairy cows	-	-	-	-	-	-	-	-	25	65	40	30	10	14	-	-	-	-	-	-	-	-	-	7
Sows	110	45	128	128	130	55	80	200	-	-	-	-	-	22	50	-	150	75	50	25	-	-	-	-
Fattening pigs	800	-	260	160	-	-	-	25	-	-	-	-	-	-	-	140	-	-	25	30	430	-	-	-
Turkeys	-	-	5,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Milk quota [1000 litres]	-	-	-	-	-	-	-	-	143	371	228	171	57	80	-	-	-	-	-	-	-	-	-	-
Scaling factor	49	178	83	42	67	94	13	72	140	41	111	101	122	63	52	20	110	140	109	183	59	295	449	263

Notes: SC: specialised field crop farm; GL: grazing livestock farm; SG: Specialised granivore farm; MI: Mixed farm; a) Based on German classification before 2002 with a threshold at 50% of total standard gross margin; b) Land endowment is adjusted to fit plot size of 2.5 ha assumed in AgriPoliS.

Source: SAHRBACHER (2003) based on MLR (2002).

Table 4-4: Comparison of regional statistics and up-scaling results

Indicators	Regional statistics	Initial structure AgriPoliS	Deviation
Farms	**2,869**	**2,857**	**-0.42%**
Incl.: Specialised crop farms	459	521	13.56%
Grazing livestock farms	906	873	-3.66%
Specialised granivore farms	988	951	-3.74%
Mixed farms	516	512	-0.82%
Professional farms	1,553	1,607	3.50%
Non-professional farms	1,316	1,250	-5.05%
Agriculturally used area (ha)	**73,439**	**73,587**	**0.20%**
Incl.: Arable land	57,468	59,034	2.72%
Grassland	15,971	14,553	-8.88%
Agriculturally used area by farm type (ha)			
Incl.: Specialised crop farms	9,569	9,143	-4.45%
Grazing livestock farms	21,683	23,408	7.95%
Specialised granivore farms	27,766	26,774	-3.57%
Mixed farms	14,421	14,261	-1.11%
Professional farms	57,464	57,350	-0.20%
Non-professional farms	16,276	16,237	-0.24%
Agricultural holdings (holdings) with an agriculturally used area of … to under … ha			
1-10	828	712	-14.04%
10-30	981	1,042	6.22%
30-50	630	666	5.71%
50 and over	430	437	1.68%
Production structure (head) number of livestock kept in stocks of … to under … head			
Fattening pigs	*106,008*	*106,074*	*0.06%*
under 100	9,541	10,007	4.89%
100-200	9,541	9,519	-0.23%
200-400	22,262	21,635	-2.81%
400-600	25,442	25,531	0.35%
600 and over	39,223	39,382	0.41%
Sows	*101,122*	*104,452*	*3.29%*
under 30	6,067	10,643	75.41%
30-50	8,090	8,022	-0.84%
50-100	25,281	24,740	-2.14%
100 and over	61,684	61,047	-1.03%
Dairy cows	*17,667*	*17,562*	*-0.59%*
under 20	4,063	3,942	-2.99%
20-29	3,533	3,502	-0.90%
30-39	3,003	3,032	0.94%
40-59	4,417	4,445	0.64%
60 and over	2,650	2,641	-0.33%
Beef cattle	*50,902*	*48,006*	*-5.69%*
Turkeys	*450,000*	*461,227*	*2.49%*
Livestock units (LU)[a]	**117,839**	**120,146**	**1.96%**

Note: a) One livestock unit corresponds to about 500 kg of alive weight.
Source: SAHRBACHER (2003) based on STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (1999, 2001a, 2001b, 2003).

4.4 Product prices

Prices of products and means of production are taken from data collections on gross margin calculations published by various German government agencies and organisations (e.g. Kuratorium Technik und Bauwesen in der Landwirtschaft, Regierungsbezirk Mittelfranken, Landesanstalt für Landwirtschaft Brandenburg, STMLF – Bayerisches Staatsministerium für Landwirtschaft und Forsten). Prices taken from these data source may not necessarily reflect the actual price situation in the reference year. Nevertheless, they represent averages calculated over a number of years. Accordingly, Table 4-5 lists product prices and prices of produced means of production assumed for this study. Crop and grassland yields are calculated based on averages from the accountancy data sample for Hohenlohe (MLR 2002).

Table 4-5: Yields and product prices

Product	Yield	Market price per unit [a)]
Arable/grassland		
Cereals	65 dt/ha	13.40 €/dt
Sugar beet	675 dt/ha	5.43 €/dt
Rape seed	35 dt/ha	21.91 €/dt
Protein plants	35 dt/ha	11.43 €/dt
Silage maize [b)]	165 dt/ha [c)]	-
Intensive pasture[b)]	70 dt/ha [c)]	-
Extensive pasture[b)]	50 dt/ha[c)]	-
Livestock		
Sows (piglets)	21 piglets/year	55 €/piglet
Fattening pigs	94 kg	1.46 €/kg [d)]
Beef cattle	660 kg	3.16 €/kg [d)]
Suckler cows (calves)	235 – 265 kg	1.97 €/kg [e)]
Dairy cows (milk)	5,700 kg/cow	0.35 €/kg
Turkeys	rooster: 19.4 kg hen: 9.5 kg	rooster: 1.06 €/kg hen: 0.96 €/kg

Notes: a) prices including value added tax; b) not sold on market, used on-farm; c) dry matter; d) carcass weight; e) alive weight.

Sources: Own calculations based on SAHRBACHER (2003), KTBL (2000), REGIERUNGSBEZIRK MITTELFRANKEN (2001), LFL BRANDENBURG (2001), MLR (2002), STMLF (2003), STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (2001b), LEL (2003a).

4.5 Production activities

In this section, the main arable, grassland and livestock production activities in Hohenlohe are described. Altogether 13 production activities are considered.

The data was collected and adjusted to Hohenlohe by SAHRBACHER (2003) and KLEINGARN (2002). All production activities are defined in a very general way, by including only one intensity level.

4.5.1 Arable and grassland production activities

Regarding arable production activities (Table 4-6), gross margins, variable costs and labour requirements are calculated mainly based on REGIERUNGSBEZIRK MITTELFRANKEN (2000), and the Bavarian Ministry of Agriculture and Forestry (STMLF 2003). These data sources prove to be useful because of the proximity of the region Mittelfranken to Hohenlohe and the similarity in natural production conditions.

Table 4-6: Arable and grassland production activities

Arable/ grassland activities	Gross margin	Direct payment (Agenda 2000)	Labour requirement	Machinery requirement	Max. N-uptake	Crop rotation limit
	€/ha	€/ha	h/ha	ha	kg N	% UAA
Cereals [b)]	360	324	10.0	1.00	221	75
Sugar beets	2,628	-	12.0	1.20	221	2.4
Rape seed	230	324	8.5	1.00	221	30
Protein plants	57	384	8.8	0.88	221	5
Silage maize	-670	459	12.0	1.00	221	-
Intensive grassland	-290	-	6.0	0.60	273	-
Extensive pasture	-82	-	1.7	0.20	100	-
Set aside land	-32	333	4.0	0.30	221	10-33

Notes: a) dry matter; b) subsuming winter wheat and barley.
Sources: SAHRBACHER (2002) based on REGIERUNGSBEZIRK MITTELFRANKEN (2000), LFL BRANDENBURG (2001), STMLF (2003), KTBL (2000), MLR (2002), STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (2003), LEL (2002), HAPPE et al. (2001).

Variable costs are assumed to contain the costs of seeds, fertilisation, plant protection, variable machinery costs of farm-owned machinery, and other yield-dependent costs such as drying and crop insurance. Variable costs are not further disaggregated but taken directly from the respective data sources. Costs of fertilisation are assumed to correspond to the expenditure on the mineral fertilisers phosphate and potassium. Nitrogen requirement is met by animal manure. Machinery costs include only variable costs of farm-owned machinery, plus contracted machinery for harvesting. Fixed machinery costs and transport costs are treated separately (Table 4-9).

Grassland is differentiated into intensive grassland and extensive pasture. It is assumed that two thirds of the intensive grassland area is used for silage, the other third for hey. Data for intensive grassland is taken from LFL BRANDENBURG (2001).

Based on averages from the accountancy data sample and empirical experiences (KAZENWADEL 2003), restrictions on crop rotation are implemented introducing limits on the maximum percentage of agriculturally used area to be planted with a specific crop. Sugar beet area is restricted to 2.4% of the UAA. This corresponds to the average observed in the reference year 2001.

As a reaction to the EU Nitrate Directive 91/676 and the German Fertiliser Decree (BGBl, 26/01/1996), upper limits for the total nitrogen application from animal manure are introduced at the farm level. These limits are fixed to 170 kg total N/ha on arable land and 210 kg total N/ha on grassland. Considering losses during storage (5.5%) and fertilisation (20%), this corresponds to a nitrogen production of 221 kg N/ha and 273 kg N/ha (HAPPE et al. 2001).[51] For extensive grassland, a maximum nitrogen uptake of 100 kg N/ha is assumed.

4.5.2 Livestock production activities

Intensive livestock production is the most important production branch in Hohenlohe. In recent years, turkey production has gained importance in addition to pig fattening and piglet production (ALLB ÖHRINGEN 2002). Unlike suckler cow production, the importance of dairy production has declined steadily over the past decade.

Table 4-7 gives an overview of the livestock production activities considered in AgriPoliS. To reduce the computing time of simulations with AgriPoliS, farm production activities are aggregated as much as possible by considering only one activity per product type. This applies to livestock production activities as well as to arable and grassland production activities alike. Different performance and intensity levels for one product type are thus not considered. Details of each livestock production activity on annual revenue, variable costs, performance, and premium payments are given in appendix A.1. Gross margin is calculated as product prices given in Table 4-5 less variable costs.

Dairy cows, suckler cows, and beef cattle require silage maize, intensive and extensive grassland as fodder base. Extensive grassland is exclusively used for grazing. Manure from livestock production is used as nitrogen fertiliser up to the

51 Calculations are based on the German fertiliser decree before revision in 2001.

limits given in Table 4-6. Regarding dairy production, costs of replacement are included in the gross margin. Hence, it is assumed that all calves are sold.

Table 4-7: Livestock production activities

Livestock activities	Gross margin	Premium (Agenda 2000)	Labour require-ment	Milk yield	Fodder requirement			Nitrogen excretion
					Silage maize	Intensive-grassland	Ext. pasture	
	€/year	€/year	h/year	kg/year	ha/year	ha/year	ha/year	kg/year
Sows	468	-	20.0	-	-	-	-	30
Fatt. pigs	57	-	2.1	-	-	-	-	10
Beef cattle	264	223	12.0	-	0.12	0.09	-	50
Suckler cows	368	317	28.0	-	-	0.33	0.54	50
Dairy cows	1,380	-	52.0	5,700	0.17	0.34	-	100
Turkeys[6)]	7.15	-	0.134	-	-	-	-	1.4

Sources: SAHRBACHER (2003) based on KLEINGARN (2002), REGIERUNGSBEZIRK MITTELFRANKEN (2000), STMLF (2003), KTBL (2001), LEL (2003b).

4.5.3 *Additional activities*

To cover short-term capacity bottlenecks or to reduce over-capacities, a number of additional activities are considered. These activities include hiring labour and offering farm-owned labour outside the farm, buying and selling milk quota, machinery lease from a private contractor, and animal manure import or export. Table 4-8 lists additional activities and their effect on farm factor capacities.

It is assumed that a farm exporting excess manure pays the importing farm. However, the importing farm is assumed to cover the costs of transport and spreading. A farm short of machinery capacity can hire additional machinery capacity offered by a private contractor. Moreover, farms have the possibility to hire labour or offer family labour on a short-term per hour basis. In addition, or alternatively, labour contracts can also be made on a fixed basis. Regarding fixed contracts, one annual work unit (AWU) is assumed to correspond to 2000 hours. To bridge liquidity shortages, farms can take up short-term credit at 8 % interest rate. Likewise, the savings interest rate on excess liquidity is 4 %.[52] To keep the model simple, milk quota is introduced as quota lease (cf. chapter 3).

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52 Since the model assumes no inflation, real average interest rates derived from the German Federal Bank (DEUTSCHE BUNDESBANK 2003) are adjusted downwards by an assumed 1.5% inflation rate.

Table 4-8: Additional activities

Additional activities	Revenue / Costs a)	Effect on capacity					
		Labour	Liquidity	Machinery	Nitrogen	Livestock unit	Milk quota
	€	h	€	ha	kg	LU	kg
Manure import (1 ha)	170	5	-	-0.5	221	-	-
Manure export (1 ha)	-180	-	-	-	-221	-	-
Machinery lease (1 ha)	-307	-	-	1	-	-	-
Hire labour (1 h)	-12.3	1	-	-	-	-	-
Offer family labour (1 h)	9.2	-1	-	-	-	-	-
Hire 0.5 fix labour (h)[b)]	-12,300	1,000	-	-	-	-	-
Offer 0.5 fix labour (h)[b)]	9,715	-1,000	-	-	-	-	-
Interest on short-term borrowed capital (1 €)	-0.08	-	1	-	-	-	-
Savings interest (1 €)	0.04	-	-1	-	-	-	-
Buy milk quota (1 kg)	-0.051	-	-	-	-	-	1
Sell milk quota (1 kg)	0.046	-	-	-	-	-	-1
Add livestock unit (1 LU)	-175	-	-	-	-	1	-

Notes: a) Costs have a negative sign; b) one year contract assumes labour trained in agriculture.
Sources: Own calculations based on SAHRBACHER (2003), KLEINGARN (2002), KELLERMANN (2003), DEUTSCHE BUNDESBANK (2003), HAPPE et al. (2001).

Specific measures of the agri-environmental programme MEKA (Marktentlastungs- und Kulturlandschaftsausgleich) are not explicitly considered. Others have modelled their impact in detail (see e.g., KAZENWADEL 1999; BAUDOUX 2000). However, in the past, the great majority of farms in Hohenlohe has taken part in one or more measures of this programme. Accordingly, as a proxy for participation in the programme, a maximum livestock density of 2.5 livestock units (LU) per hectare is introduced. In fact, a stocking density of 2.5 LU/ha is a prerequisite for taking part in the programme (ALLB BIBERACH 2002). If a farm's livestock density is above the threshold, the farm incurs a 'fine' of 175 € per additional livestock unit.[53]

4.6 Investments

Farm accountancy data in general includes no information on livestock production technologies, machinery endowments of farms, and the respective vintages of assets. To define investment options, data on the type, size, and vintage of investments were required. Based on expert information from local farmers and

[53] The fine was introduced somewhat artificially to offer the possibility to farm agents in the optimisation (see chapter 3) to exceed the threshold.

the agricultural administration in Hohenlohe, a set of investment options typical for Hohenlohe is defined based on data from KTBL (2001, 2003) and ALLB ILSHOFEN (2001). The list of investment options, shown in Table 4-9, includes the most important production branches. For each production branch, different investment sizes are defined.

In the context of AgriPoliS, the list serves two purposes. On the one hand, based on this list, the typical farms' endowment with production technology and machinery is defined, as no information on this is available from accountancy data. On the other hand, the list provides a catalogue of possible investments for future re-investments or additional investments by farm agents during the simulation of AgriPoliS.

The capacity column shows the size of the respective investment options. For livestock production activities size corresponds to the number of places in a stable. As for machinery, this is introduced as a pool containing all machinery on a farm. Machinery capacity thus represents the total acreage that can be managed with the respective machinery investment is shown. For example, a farm can manage 85 ha of land with investment option 'Machinery 3'. The useful life of an investment option includes also equipment and facilities, even though the useful life of equipment and facilities is often shorter than that of animal housing. But, to keep things simple and limit the number of investment options, housing and equipment are not treated separate.[54]

Investment options of the same type differ with respect to capacity, investment costs, labour requirements, and technological standard. More specifically, larger investment options have advantages compared to smaller ones in that investment costs per unit and labour requirement per unit produced are lower (see chapter 3).The labour saving effect of larger investments are calculated relative to what can be considered a typical technology in the reference year. For example, technology 'Sow housing 1' requires 2.5 hours per unit produced less than the typical technology in the reference year ('Sow housing 3'). Labour saving per unit produced together with technological advances in equipment defines the technical standard of livestock investment options. Based on this classification, larger investment objects are associated with a higher technical standard than smaller objects, resulting in efficiency gains by way of lower production costs.

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[54] Considering that each investment option represents one integer activity in the mixed-integer optimisation problem, differentiating between animal housing and facilities would add an increase computing time at least 23 columns. This would increase computing time significantly.

Table 4-9: Catalogue of investment options

Nr	Investment type[a)]	Unit	Investment costs	Capacity	Useful life	Labour saving [b)]	Technological standard
			€/unit	Unit	years	h/unit	
1	Sow housing 1	Places	2,100	252	20	-2.50	High
2	Sow housing 2	Places	2,200	170	20	-1.17	Moderate
3	Sow housing 3*	Places	2,300	128	20	0.00	Low
4	Sow housing 4	Places	2,500	64	20	0.78	Old
5	Sow housing 5	Places	2,600	40	20	0.78	Old
6	Fatt. pig sty 1	Places	350	1,000	20	-0.25	High
7	Fatt. pig sty 2	Places	360	600	20	-0.13	Moderate
8	Fatt. pig sty 3*	Places	420	400	20	0.00	Moderate
9	Fatt. pig sty 4	Places	510	200	20	0.05	Low
10	Fatt. pig sty 5	Places	560	100	20	0.05	Old
11	Cattle barn 1	Places	2,100	200	25	0.00	Moderate
12	Cattle barn 1	Places	2,400	100	25	0.00	Low
13	Cattle barn 1*	Places	2,600	40	25	0.00	Old
14	Suckler cows 1	Places	790	40	25	0.00	Low
15	Suckler cows 2*	Places	1,053	10	25	0.00	Old
16	Turkey house 1	Places	54.20	15,000	20	-0.02	High
17	Turkey house 2	Places	56.75	10,000	20	-0.01	Moderate
18	Turkey house 3*	Places	57.78	5,000	20	0.00	Low
19	Dairy barn 1	Places	3,680	480	25	-20.83	High
20	Dairy barn 2	Places	3,780	240	25	-8.33	Moderate
21	Dairy barn 3	Places	4,160	120	25	-1.67	Moderate
22	Dairy barn 4*	Places	5,470	60	25	0.00	Low
23	Dairy barn 5	Places	5,800	30	25	2.50	Old
24	Machinery 1	ha	771	350	12	-6.36	dependent on farm size and adjacent plots
25	Machinery 2	ha	1,107	150	12	-3.64	
26	Machinery 3	ha	1,235	85	12	-1.82	
27	Machinery 4*	ha	1,302	55	12	0.00	
28	Machinery 5	ha	1,527	30	12	0.36	
29	Machinery 6	ha	2,107	15	12	0.55	

Notes: a) typical technology in reference year is marked with an asterisk (e.g. 'Sow housing 3'); b) Defined relative to capacity of typical technology in reference year.

Sources: SAHRBACHER (2003) based on KLEINGARN (2002), KTBL (2001, 2003), ALLB ILSHOFEN (2000).

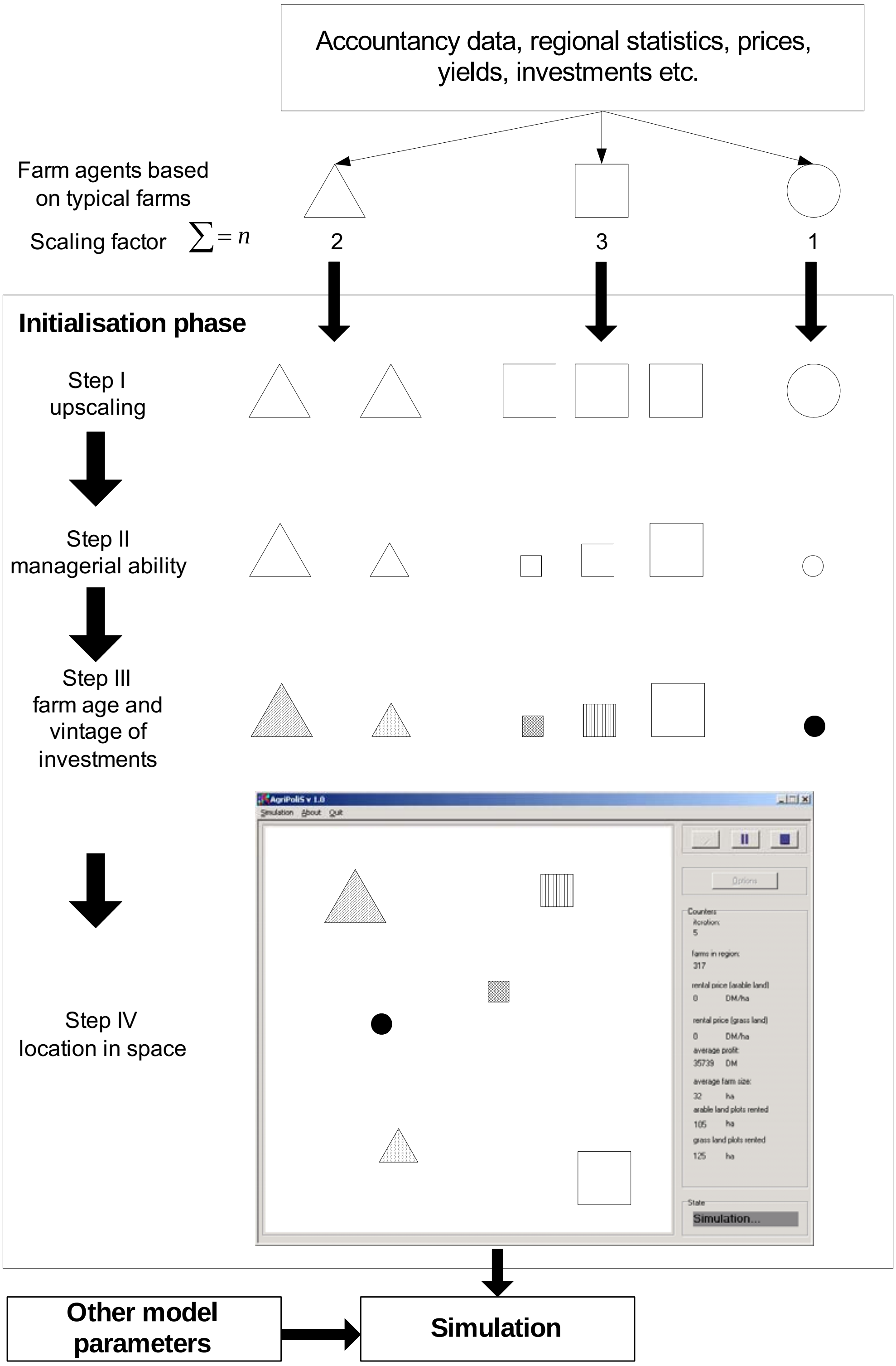
4.7 Initialising AgriPoliS

Figure 3-5 in chapter 3 showed the model dynamics of AgriPoliS. The figure distinguished between two model phases: the initialisation phase and the simulation phase. One important step in the initialisation phase is to supply AgriPoliS with the type of data specified in this chapter. More specifically, farm agents, production activities, plots, and investments are initialised with the data collected for Hohenlohe. Another step in the initialisation process of AgriPoliS is to individualise farm agents further.

The initialisation phase is visualised in Figure 4-1 using the example of a hypothetical region. To simplify things, the figure considers three exemplary typical farms. Of these, farm 1 (triangle) has a scaling factor of two, farm 2 (square) has a scaling factor of three, and farm 3 (circle) has a scaling factor of one. The scaling factors sum up to the total number of farms *n* in the hypothetical region. The initialisation phase includes four steps: up-scaling, individualising farms with respect to managerial ability, individualising farms with respect to farm age and vintage of investments, and allocating farms in space. With each step, the heterogeneity of farm agents increases.

Before the start of the actual simulation, a number of global model parameters need to be specified default values of which are listed in Table 4-10. They are called global, because they apply to all farms alike. Where possible, these parameters are based on available standard data sources (e.g., DEUTSCHE BUNDESBANK 2003, or KTBL). Due to a lack of specific data, some parameter values could only be based upon expert knowledge, reasoning, and careful estimation. This applies in particular to the specification of managerial ability, technological change, and the bid adjustment. In the next chapter a set of simulation experiments are carried out that specifically explore the impact of these parameters on simulation results. These simulation experiments help in deciding whether the assumptions about parameter values are reasonable or not.

Figure 4-1: Details of AgriPoliS initialisation phase



Source: Own figure.

The way in which technological change is introduced was mentioned several times in this and previous chapters. According to Table 4-9 and Table 4-10, a high, moderate, and low technological standard of an investment object is associated with cost savings of 1.5%, 1.25%, and 1% respectively.

Table 4-10: Default values of global parameters

Description	Notation[a)]	Parameter value
Cost saving effect due to technological standard (% of standard variable costs) [b)]	$f_{k,i}$	
High		1.5%
Moderate		1.25%
Low		1%
Managerial ability (% of standard variable costs) [c)]		
High managerial ability	m_{min}	95%
Low managerial ability	m_{max}	105%
Interest rate level		
Long-term borrowed capital	i_{bc}	5.5%
Short-term borrowed capital	i_{bcs}	8%
Equity capital interest	i_{ec}	4%
Overhead costs (administration, taxes, professional association etc.) plus current upkeep	MC + OV	150 €/ha
Bid adjustment [d)]	β	0.75
Surcharge on bid for adjacent plots	∂	10 €/plot
Plot size		2.5 ha
Farm is handed over to next generation		every 25 periods
Minimum withdrawal of farm household labour unit	WDmin	15,300 €/AWU
Opportunity cost increase when generation change		15%
Equity finance share	v	0.5
Milk quota price adjustment		2%
Labour hours of annual work unit (AWU)	h	2,000
Max. permissible stocking density (LU/ha) in region		2.5 LU/ha
Annual transport costs e)	TC	50 €/km

Notes: a) For abbreviations see Table 3.1; b) Cost saving due to investment differentiated by size of investment; c) Heterogeneity of farms regarding cost structure as deviation from average (value < (>) 100% corresponds to low (high) cost producer); d) Factor determining the share of bid which is actually paid as rent for a plot (see chapter 3); e) based on 10 rides from a farmstead to plot.

Sources: Own calculations based on DEUTSCHE BUNDESBANK (2003), KTBL (2001), MLR (2002), BALMANN (1995), KTBL (2003), ALLB BIBERACH (2002).

On the subject of managerial ability, it is assumed that total production costs of farms with high managerial ability and farms with low managerial ability differ by at most 10%. In AgriPoliS it is assumed that managerial ability remains constant throughout the entire simulation. This means, farm agents cannot improve their ability of managing the farm. Furthermore, managerial ability is also not related to farm size – although this may make a difference in reality. One way to compensate for low managerial ability and realise additional cost savings is to invest in new labour-saving technology.

4.8 Further assumptions

In the dynamic setting of AgriPoliS, the following assumptions are particularly relevant. Technological change is assumed to affect the model exclusively through the technical standard of investment options, which in return affects production costs (see chapter 3). In fact, lower production costs in arable production could equally be attributed to yield increases through breeding progress instead of better machinery technology. In the current version of AgriPoliS this would be difficult, though, because arable production activities are modelled in a rather aggregate way that does not differentiate between varieties and intensities. Therefore, yields are assumed to remain constant throughout the entire simulation.

Because of the relatively small size of the region and the family farm-dominated structure, it can be expected that farms are price takers.[55] Moreover, in AgriPoliS farm agents are price takers and therefore face the same product prices. With regard to Hohenlohe, prices therefore do not change in response to quantities produced. This implies that price flexibility $b_{i,t}$, introduced in equation 3-14 in chapter 3, is zero. Nevertheless, for certain products a low annual price increase or price decrease was introduced to reflect pressure on prices that could be observed in reality. Price trends assumed in AgriPoliS are shown in Table 4-11.

Table 4-11: Assumed price increase/decrease

Product/variable/activity	Annual price increase/decrease
Labour (fix and variable)	+ 0.50 %
Machinery lease	+ 0.20 %
Cereals, sugar beet, silage maize, protein plants	- 0.20 %
Fattening pigs, piglets	- 0.06 %
Turkey	- 0.06 %

Source: Own calculations.

There is no downward price trend for milk because the milk premium granted under Agenda 2000 from the year 2004 onwards is not considered explicitly.

55 This assumption should be reconsidered if large scale farms with a high production share are concerned, as these farms are more in the position to negotiate about prices of inputs as well as about output prices.

4.9 Definition of the reference scenario

The analysis and evaluation of the various policy scenarios in part III of this thesis is accomplished by comparing them to a reference scenario. The initial conditions of the reference scenario are given by the data and parameters presented in this chapter. Agenda 2000 as implemented at the end of 2002 defines the policy environment. Agenda policies implemented after 2002 are not considered. After the start of the simulation, no further changes are made to the reference scenario. Hence, during simulation run-time of the reference scenario – except for the assumed price changes – are endogenous to the system.

In chapter 2, the difficult issue of validating agent-based models and complex system models in general was addressed. The argument was put forward that an exact validation of such a model is a difficult and challenging undertaking. Rather, with regard to these models there has been a shift away from statistical tests toward more qualitative and subjective tests, which are mainly tests of the model's structure and model behaviour tests (KWAŚNICKI 1999). A first attempt to testing the model's structure is presented briefly in the following. Testing model behaviour will be the topic of chapter 5.

In the context of this thesis, a test of the model's structure is understood in a way that the model should be able to reproduce some developments of indicators observed in the real world. Although no formal back-casting of a historical reference period is undertaken, selected key structural development indicators obtained from simulation runs can still be compared.[56] In particular, the annual rate of farms leaving the sector as well as the change in average farm size can be compared to past developments 'in the real world'. Table 4-12 compares results of the initial simulation period (optimised initial situation) with real data.

In the optimised initial situation, nearly all of the land is farmed, only 5% of the grassland was not farmed. This is also reflected in the significantly lower number of cattle in the region. If farm organisation is optimised, merely 12% of the actual number of beef cattle is produced. This significant deviation suggests two things. On the one hand, it suggests that gross margins from beef production are too low to be profitable despite of direct payments coupled to the production of beef.

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56 SAHRBACHER (2003) undertakes a first, limited, attempt at replicating the structural development of a reference period. However, a formal and detailed back-casting would have been a very challenging task to do, as it would have gone beyond the financial and time limits available for this thesis.

Table 4-12: Comparison of optimised initial situation with region

		Region based on typical farms	Optimised initial situation AgriPoliS	Fit
Farms	Number	2,855	2,850	99.82%
Total area	ha	73,585	73,225	99.51%
Arable land	ha	59,035	58,737	99.50%
Grassland	ha	14,555	13,646	93.75%
Fattening pigs	Number	106,075	101,543	95.73%
Sows	Number	104,450	126,644	121.25%
Dairy cows	Number	17,562	16,580	94.41%
Beef cattle	Number	48,006	6,075	12.65%
Turkeys	Number	461,227	425,000	92.15%

Source: STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (2004), MLR (2002).

On the other hand, since AgriPoliS explicitly allows farm household labour to be used off-farm, total farm household income of farms producing beef cattle was higher if labour was used outside the farm, even at the expense of leaving beef production facilities unused. Regarding the remaining livestock production activities, the deviations shown in Table 4-12 indicate that some production capacities were not fully used. Structural change in the reference scenario is very similar to real structural change observed in the past (Table 4-13).[57]

Table 4-13: Comparison of average bi-annual change in variables[a)]

Variable	Baden-Württemberg (all farms)	AgriPoliS (Hohenlohe)
	1981 – 2001	20 time periods
Average farm size	6.4 %	6.37%
Number of farms	-7%	- 6%

Note: a) Statistical data is only issued every two years.
Sources: STATISTISCHES LANDESAMT BADEN-WÜRTTEMBERG (2004), MLR (2002).

In reality, every two years or time periods, average farm size increased by 6.4 % and 6.37%, respectively. Change with respect to the total number of farms was stronger for the whole of Baden-Württemberg than in AgriPoliS. This is because the data for Baden-Württemberg includes all farms greater 1 ha. AgriPoliS only considers farms with at least 10 ha of land. In the past, change has been particularly strong in the group of small farms with less than 10 ha of land (STATISTISCHES

57 A further possible indicator would be the volume of land transferred. However, this indicator proves to be very unreliable as only a fraction of actual land transfers are reported to the respective authorities.

LANDESAMT BADEN-WÜRTTEMBERG 2004). Moreover, compared to other regions in Baden-Württemberg (e.g. Black Forest), Hohenlohe's farm structure is characterised by larger farms in general.

5 Exploring the behaviour of AgriPoliS

5.1 Introduction

At the end of chapter 4, it was shown that a simulation of the reference scenario with AgriPoliS led to outcomes that were in fact similar to some key indicators' developments in Hohenlohe. In chapter 4, the comparison of model results with reality was referred to as a test of the model's structure. In this chapter, three simulation experiments are carried out to elucidate different facets of AgriPoliS' behaviour when applied to the Hohenlohe data set described in the previous chapter. The goal of the chapter is to gain insights into the simulation behaviour of AgriPoliS in the reference scenario. Such insights relate to the sensitivity of the model to parameter changes, the identification of important factors (parameters) and their interactions, and to finding a robust configuration (e.g. framework conditions, policies).

AgriPoliS maps some key components of the agricultural structure in Hohenlohe, but as with any model, it cannot capture the complexity of the agricultural system of Hohenlohe in full extent. Inevitably, guesses and assumptions about the true nature of the region (the region will also be referred to as the target system) have to be made and implemented into AgriPoliS. In this sense, the particular focus of this chapter is on the behaviour of AgriPoliS when framework conditions change. In AgriPoliS, framework conditions refer to all parameters that are not directly affected by policy measures such as interest rates, managerial ability assumptions, region size, labour costs, and technical change assumptions. Default values were already shown in Table 4-10 in chapter 4. The reason behind the simulation experiments presented here is to devise ways of revealing how the target system would behave if the guesses and assumptions regarding framework conditions were correct.

An important step in simulation modelling is sensitivity analysis which can be thought of as the systematic investigation of the reaction of a simulation model to (extreme) values of the model's input or drastic changes of the model's structure (KLEIJNEN 1999). Sensitivity analysis can be used to determine whether simulation output changes significantly, when one or more inputs are changed

(LAW and KELTON 1991). Sensitivity analysis is one form of validation as the analysis shows whether input factors have effects that agree with prior knowledge about the system. With respect to simulation models of complex systems, the importance of validation and therefore sensitivity analysis is emphasised, for example, by MANSON (2002), who discusses validation and verification of agent-based systems, or LEMPERT et al. (1996), who apply parameter variation strategies to derive robust climate change policies.

With complex simulation models, sensitivity analysis often occurs in an unstructured way by varying some parameters, but not doing so systematically (KLEIJNEN et al. 2003). A widely used approach in sensitivity analysis is to vary one parameter at a time, while leaving all other parameter values constant. However, as agent-based systems are meant to act as complex systems, the model is often not amenable to traditional testing methods that rely on changing only one input parameter at a time (Manson 2002). The 'one-at-a-time' approach leaves out possible interactions between input parameters, i.e. whether the effect of one factor depends on the level of one or more parameters. Hence, the 'one-at-a-time' approach can be a too crude simplification of the underlying model (VONK NOORDEGRAAF et al. 2002). The statistical techniques of Design of Experiments (DOE) and metamodelling provide a way to carry out simulation experiments systematically that takes account of parameter interactions (e.g., BOX et al. 1978; KLEIJNEN and VAN GROENENDAAL 1992).

In this chapter, first a straightforward and textbook-like DOE will be applied to study results from simulations of the reference scenario (section 5.2). Section 5.3 gives an example of the sensitivity of selected output variables of AgriPoliS in response to random model initialisations. Finally, in section 5.4 the impact of heterogeneous managerial ability on structural development will be analysed. At the centre of this particular investigation is a more disaggregated analysis of the impact of different assumptions about managerial ability with respect to groups of farms.

5.2 Design of experiments

Design of experiments provides a way to investigate some aspects of a simulation model systematically and to bring statistical aspects into the analysis of results. It represents a way to understand relationships between some parameters in the model. DOE originates from real world experimentation, but the techniques can be transferred to experiments with artificial computer worlds. KLEIJNEN et al. (2003) have found DOE to be a useful technique also in the context of agent-based models because it can uncover details about model behaviour, help to identify the relative importance of inputs, provide a common basis for discussing simulation results, and help to identify problems in the programme logic. SANCHEZ and LUCAS (2002), on the other hand, argue that there are quite some differences between assumptions made conventionally in DOE and agent-based modelling. For example, traditional DOE assumptions involve only one response variable, whereas an agent-based model such as AgriPoliS includes many performance measures of interest. In the view of Sanchez and Lucas, a straightforward application of DOE to agent-based models may therefore not always be appropriate. Nevertheless, an application of DOE should provide at least some information about model behaviour that would not be known without DOE.

In DOE terminology, model input parameters, variables and structural assumptions are called *factors*, and model output measures are referred to as *responses*. Factors can be either quantitative or qualitative in nature. The choice of factors depends primarily on the goal of the experiment.[58] Suppose that there are k (k>2) factors in the model and that each factor takes two factor levels. The simplest way to measure the effect of a particular factor would be to fix the level of all other k-1 factors and simulate for varying levels of the remaining factor. This procedure of varying only one factor at a time (OAT) is rather inefficient as it allows identifying only main effects (KLEIJNEN and VAN GROENENDAAL 1992); it is not possible to identify interactions between factors. A more efficient way that also allows computing interaction effects is what is called *full factorial design*. Assuming that each factor takes two levels, a full factorial design involves $n = 2^k$ factor setting combinations, or scenarios. This procedure is, however, only useful for a small number of factors as the number of runs increases exponentially with the number of factors and factor levels considered. In such case, so-called fractional factorial designs are more efficient to use.[59]

After simulating the 2^k possible parameter constellations, it is common to analyse simulation results by applying a regression model. In simulation terminology, the regression model is also called a *metamodel*. A metamodel establishes a functional relationship between sensitivity and various factors. Often, a metamodel is defined as a regression model where the independent variables are factor

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58 Key references for this section are LAW and KELTON (1991), VONK NOORDEGRAAF et al. (2002), BOX et al. (1978) and KLEIJNEN and VAN GROENENDAAL (1992).

59 See LAW and KELTON (1991), KLEIJNEN and VAN GROENENDAAL (1992), and BOX et al. (1978) for more information on fractional factorial designs.

levels and the dependent variable is the simulation response. Assuming white noise, Ordinary Least Squares (OLS) yields the best estimates (best linear unbiased estimates) of the regression model. An important step in metamodelling is the validation of the metamodel, i.e. determining the degree to which the metamodel represents the underlying simulation model correctly. This can be done either by running additional simulation scenarios and comparing results with metamodel predictions, or by analysing residuals.

5.2.1 Experimental design and data output

5.2.1.1 Experimental design

Five factors are selected for the DOE analysis of the reference scenario.[60] The factors determine the framework conditions of production. In particular, they concern the following parameters:

- Technological change (*TC*),
- Interest rate levels (*I*),
- Managerial ability across farms (*MF*),
- Proportion of the shadow price of land which is given as a bid (*RAC*),
- Size of the region simulated (*RS*).

Interest rates were chosen because they affect AgriPoliS at many instances (see chapter 3), e.g., investment, opportunity cost calculations. It was mentioned in chapter 4 that default parameter values for technological change, managerial ability, and the bid adjustment (RAC) could only be based on reasoning and expert knowledge. Because of this, it is interesting to explore the impact of these parameters on simulation results. Besides factors *TC*, *MF*, and *RAC*, a further 'critical' factor is the size of the region. The parameter is critical because a simulation of the full region, i.e. with initially 2800 farms reaches limits with respect to computing time and data management capacities.[61] Output files including data

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[60] As the previous chapter indicated, AgriPoliS contains more than just five factors. However, the particular interest of this chapter was to study the behaviour of AgriPoliS in response to different framework conditions, which were expected to have strong impact on results. Because of this, key factors determining framework conditions were included in the experimental design. Admittedly, this is a rather subjective selection of factors, and it is acknowledged that possibly strong interactions between the selected factors and factors not considered here are neglected.

[61] In that case, simulating all 2800 farms over 25 time periods requires about 10 hours of

on individual farms easily reach a size that does not allow for data analysis with standard software packages. One alternative to simulating the full region is to simulate only a fraction of the region while preserving the farm structure of the full region. This can be achieved by dividing the number of farm agents according to the scaling value by a certain factor. Selected factor settings are presented in Table 5-1.

Table 5-1: Factors in the experimental design of the reference scenario (Agenda 2000), with low (-), and high (+) factor setting and selection of fixed key parameters

Factor/ Parameter	Description	-1 (low)	+1 (high)
TC	Technological change: cost saving $f_{k,i}$ a)		
	High	0%	2%
	Moderate	0%	1.5%
	Low	0%	1%
MF	Heterogeneity in managerial ability b)		
	Lower boundary (m_{min})	100%	90%
	Upper boundary (m_{max})	100%	110%
I	Interest rate level		
	Long-term borrowed capital (i_{bc})	0%	7%
	Short-term borrowed capital (i_{bcs})	0%	10%
	Equity capital interest (i_{ec})	0%	6%
RAC	Bid adjustment (β) c)	0.65	0.85
RS	Region size (in % of full region)	10%	100%
Policy setting	Agenda 2000 with modest price trend		

Notes: a) Cost saving due to investment differentiated by size of investment; b) Heterogeneity of farms regarding cost structure as deviation from average (value < (>) 100% corresponds to low (high) cost producer); c) Factor determining the share of bid which is actually paid as rent for a plot (see chapter 3)

Source: Own figures based on Table 4-10.

All selected factors are quantitative in nature. Two out of five factors represent parameter bundles (*I, TC*). These factors as well as factors *RS*, and *RAC* enter AgriPoliS as single values. The factor *MF* (managerial ability) enters AgriPoliS as limits of a rectangular probability distribution. From this distribution, values are assigned to each farm agent at the beginning of the simulation. All initialised factor levels are assumed to remain constant during the following simulation experiments. For each factor, a low and high level was defined, reflecting

computing time on a 2.8 MHz Intel Pentium 4 processor.

uncertainty about these factors in real life. The low and high values were based on expert opinion, statistical data and plausibility arguments. Obviously, the low interest rates, i.e. zero interest rates, is less realistic, if the goal is to set factor settings corresponding to what could happen in reality. But, it was chosen in order to examine how AgriPoliS behaves at the extreme of zero interest rates. These factor levels determine the relevant experimental framework for the DOE analysis. Factors not included in the DOE are assumed to remain fixed during the simulations. Table 5-2 presents the complete design matrix for the 2^5 full factorial design. The design requires 32 design points or scenarios. To compare factor effects by relative importance, factor levels were set at "-" (low value) and "+" (high value) (LAW and KELTON 1991).

5.2.1.2 Data output

Although AgriPoliS produces a multitude of responses, only one response variable, namely average economic land rent per hectare in the region, is chosen for analysis.[62,63] Economic land rent is a central indicator for the economic performance of farms, and in particular for the efficiency of farming in the region (see chapter 6 and BALMANN 1995) as it provides information about allocation of production factors in the region. As AgriPoliS includes some stochastic elements, a tactical issue involves the number of replications for each simulation scenario. Earlier trials with the model as well as the analysis presented in section 5.3 indicated that results varied only within a comparatively small range between initialisations, although this cannot be regarded as a 'fix rule'. To draw statistically valid conclusions one would have to run a large number of repeated simulations. Furthermore, none of the many simulation experiments carried out in previous studies (e.g., BALMANN 1997; BALMANN et al. 2002; HAPPE and BALMANN 2002) produced results showing implausible irregularities between initialisations. Since computing time is the limiting factor, all scenarios are replicated only twice, which is a crude but necessary simplification.[64]

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[62] To calculate the economic land rent, long-term opportunity costs of labour are valued at the comparative salary of an industrial worker. In this chapter, a constant value of 22,400 € per AWU is assumed throughout all simulation periods are assumed.

[63] In the following the word 'average' will be dropped. For a definition of economic land rent see chapter 6, section 6.2.

[64] Scenarios 17 through 32 involve simulations of the full region. A single run lasts for about 10 hours on a 2.8 GHz Pentium IV PC. Running all 32 scenarios took about a week on two PCs.

Table 5-2: Design matrix for the 2^n (n=5) full factorial design

Scenario	Factors				
	TC	MF	I	RAC	RS
1	-	-	-	-	-
2	+	-	-	-	-
3	-	+	-	-	-
4	+	+	-	-	-
5	-	-	+	-	-
6	+	-	+	-	-
7	-	+	+	-	-
8	+	+	+	-	-
9	-	-	-	+	-
10	+	-	-	+	-
11	-	+	-	+	-
12	+	+	-	+	-
13	-	-	+	+	-
14	+	-	+	+	-
15	-	+	+	+	-
16	+	+	+	+	-
17	-	-	-	-	+
18	+	-	-	-	+
19	-	+	-	-	+
20	+	+	-	-	+
21	-	-	+	-	+
22	+	-	+	-	+
23	-	+	+	-	+
24	+	+	+	-	+
25	-	-	-	+	+
26	+	-	-	+	+
27	-	+	-	+	+
28	+	+	-	+	+
29	-	-	+	+	+
30	+	-	+	+	+
31	-	+	+	+	+
32	+	+	+	+	+

Notes: Low (-), and high (+) values.

Each simulation scenario in the DOE analysis is simulated for 25 time periods. Simulation output consists of a panel data set of indicators for each individual farm in each time period and an aggregate data set for the whole region in each time period. Since the following analysis uses average economic land rent as the response variable, altogether 1600 observations could potentially be considered in the analysis (25 time periods times 32 scenarios times two replications).

5.2.1.3 Analysis of results and definition of the metamodel

A range of graphical techniques is applied to analyse simulation output of the DOE specification given in Table 5-2. In addition to the graphical analysis of results, a metamodel is defined to obtain some information about the statistical significance of factor effects, and in particular factor interactions. The metamodel is specified as an additive polynomial

$$y = \beta_0 + \sum_{h=1}^{k} \beta_h x_h + \sum_{h=1}^{k} \sum_{h<i}^{k} \beta_{hi} x_h x_i + \varepsilon \qquad (5.1)$$

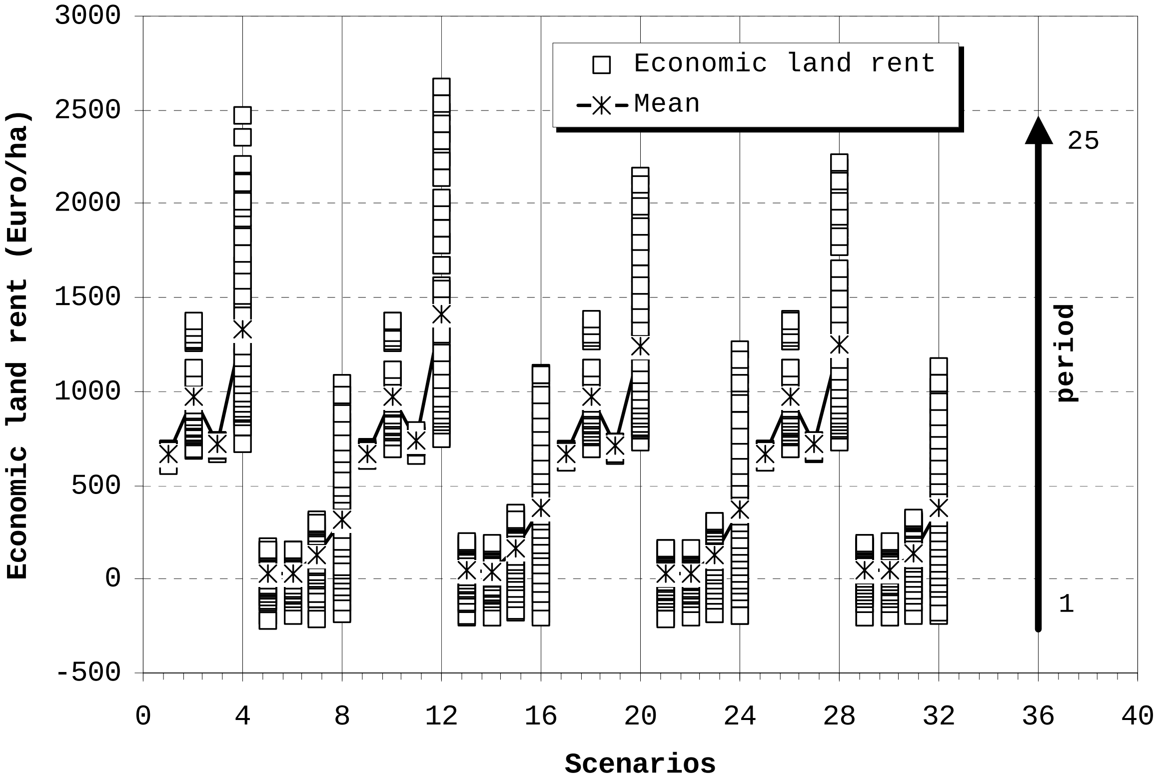
with the *k* factors as independent variables, where y is the simulation response. The intercept is β_0, β_h is the main effect of factor *h*, β_{hi} are two-factor interaction effects between factors *h* and *i*. The *x*'s denote settings of factor scenario *n*, and finally there is an error term ε. Using Ordinary Least Squares (OLS), the metamodel was fitted to data from the simulation experiment. To include only significant factors in the estimation, a stepwise procedure is chosen that excludes all factors with $p \leq 0.05$. The fit of the model is evaluated by the adjusted R^2 and an analysis of residuals.

5.2.2 Results

5.2.2.1 Graphical analysis

A plot of the response variable average economic land rent (mean of two replications) against all 32 scenarios and time periods shows some evidence for structure in the data (Figure 5-1). The figure has to be read from bottom to top for each scenario as this describes the development of economic land rent over time. The upwards pointing arrow shows the direction in which the simulation response develops over 25 simulation periods, i.e. each column contains 50 boxes (2 replications x 25 periods).

Figure 5-1: Scatter plot of individual and mean simulation response of two replications of 25 simulation periods against all 32 scenarios



Source: Own figure.

In particular, three aspects can be identified:

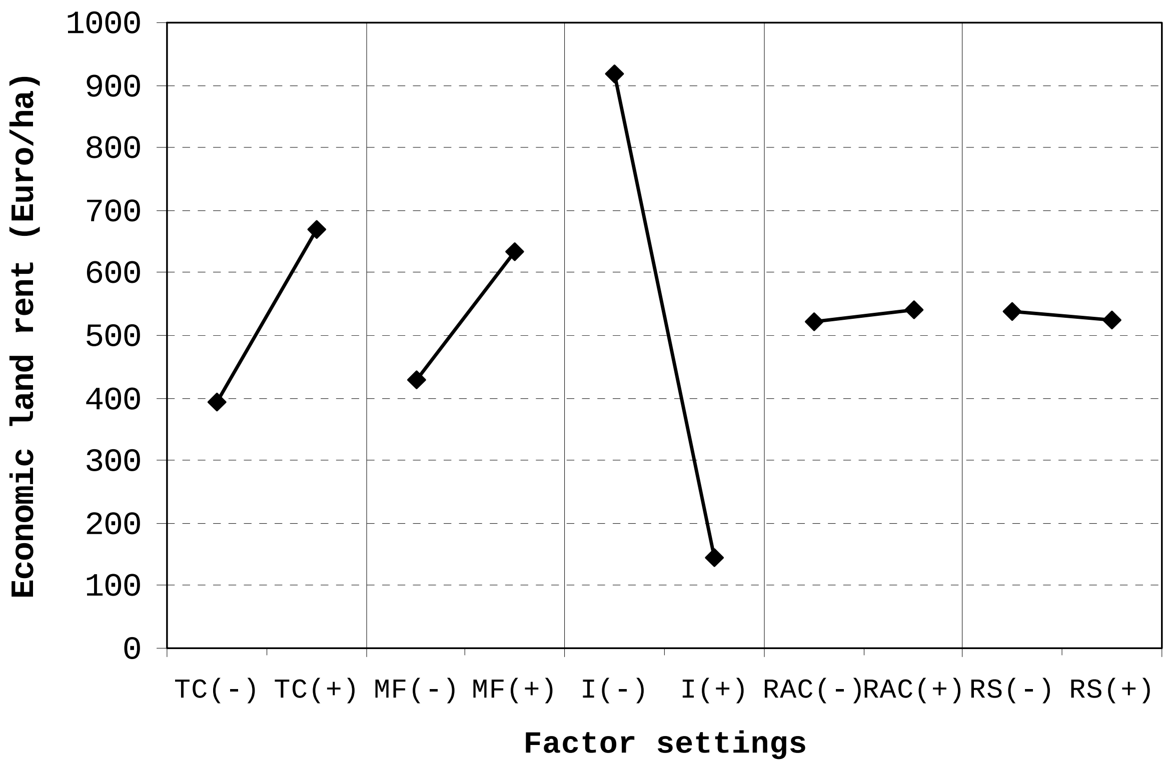
- There is a strong and consistent pairing of the response variable: four high responses, followed by four low responses. Looking at the design matrix in Table 5-2, this pattern follows the level changes of factor *I*, which is the overall interest rate level. Higher interest rates therefore cause a decrease in economic land rent. This corresponds to what could have been expected to happen, namely that at zero interest rates economic land rent is high because of no capital costs.
- Within each block of four scenarios, one can observe that at high interest rates (e.g. scenarios 5 through 8) neither heterogeneous managerial ability nor technical change by themselves lead to a strong increase in economic land rent. But, if both factors are at their "+" level, then the effect is large. In other words, heterogeneous managerial ability together with higher technological change leads to a substantial increase in economic land rent. The same line of reasoning holds for the low interest rate level (e.g. scenarios 1 through 4). However, if interest rates are low, heterogeneous managerial

ability taken on its own also increase economic land rent. Hence, there appears to be some interaction between factors *TC*, *MF*, and *I*.

- Within each block of 16 scenarios (factor level change of *RS*), it shows that the spread of results decreases if the region size is large and interest rates low. But, at high interest rates, there is hardly any difference between a small and a large region.

The following figures shall retrieve some more information on the relative importance of individual factors. Already in Figure 5-1, it could be seen that there are clear differences in results between factor level combinations. Figure 5-2 shows a so-called mean plot (see NIST/SEMATECH 2003) which represents a simple way to identify important factors. The vertical axis shows the mean response for a given setting ("-" or "+") of a factor calculated across all scenarios, for each of *k* factors. The horizontal axis shows the *k* factors with two factor settings. For example, mean economic land rent across all scenarios with factor setting *TC*"-" is approximately 400 €/ha. This increases to about 680 €/ha if technological change is higher. In view of that, the difference between mean responses when moving from the "-" setting to the "+" setting of a factor is most obvious for factor *I*, followed by factors *TC* and *MF*.

Figure 5-2: Mean plot of main effects

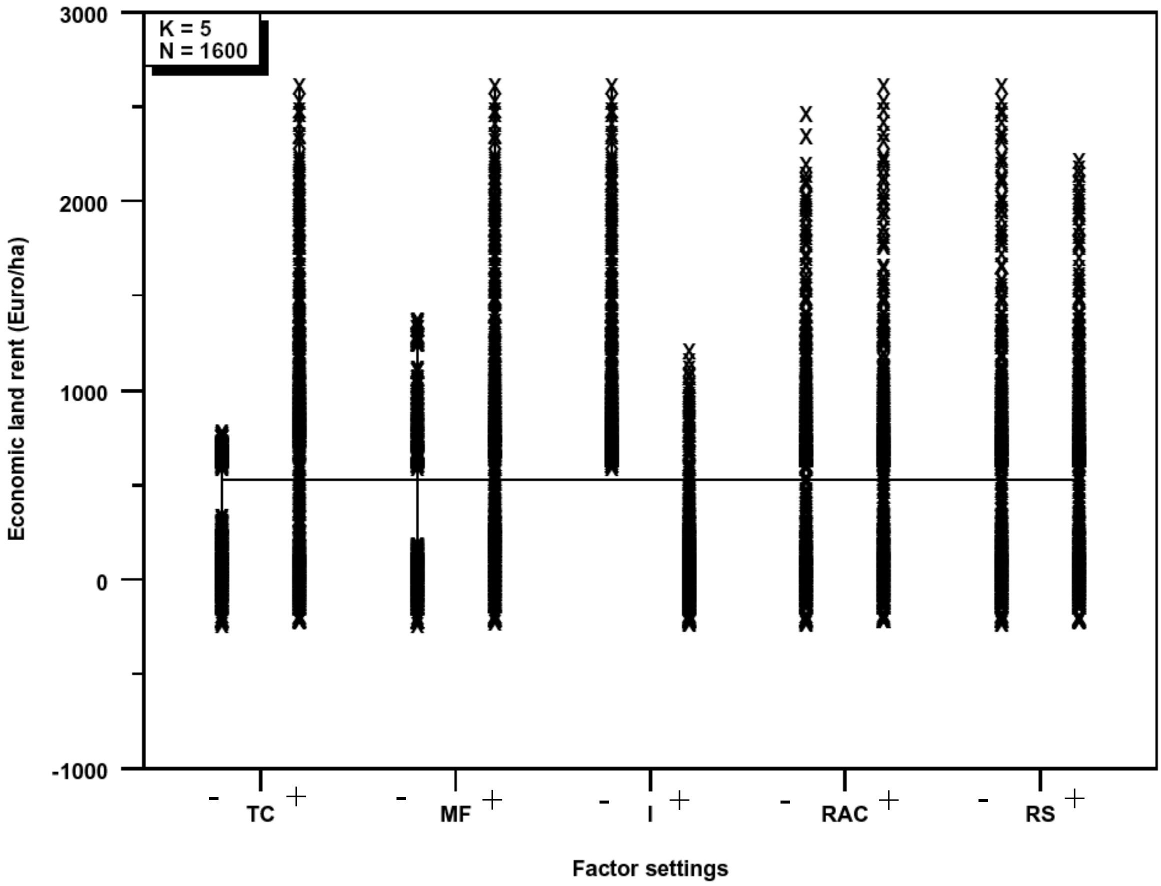


Source: Own figure.

Figure 5-3 gives some additional information on factor importance.[65] A factor is considered important if it leads to a significant shift in either the location or the change in variation (spread) of the response variable as one goes from the "-" setting to the "+" setting of the factor. On the one hand, a large shift with only little overlap in the body of the data between the "-" and the "+" setting (such as for factor *I*) would imply that the factor is important with respect to location. On the other hand, a small shift with much overlap would imply that the factor is not important.

Accordingly, Figure 5-3 shows a large difference between the degree of overlap between factors *TC, MF, I*, on the one hand, and factors *RAC* and *RS*, on the other. These latter factors do not seem important because they lead to no considerable shift in location or variation of the response variable. Using the overlap criterion, factor *I* is the most important factor, followed by *TC* and *MF*.

Figure 5-3: Main effects scatter plot

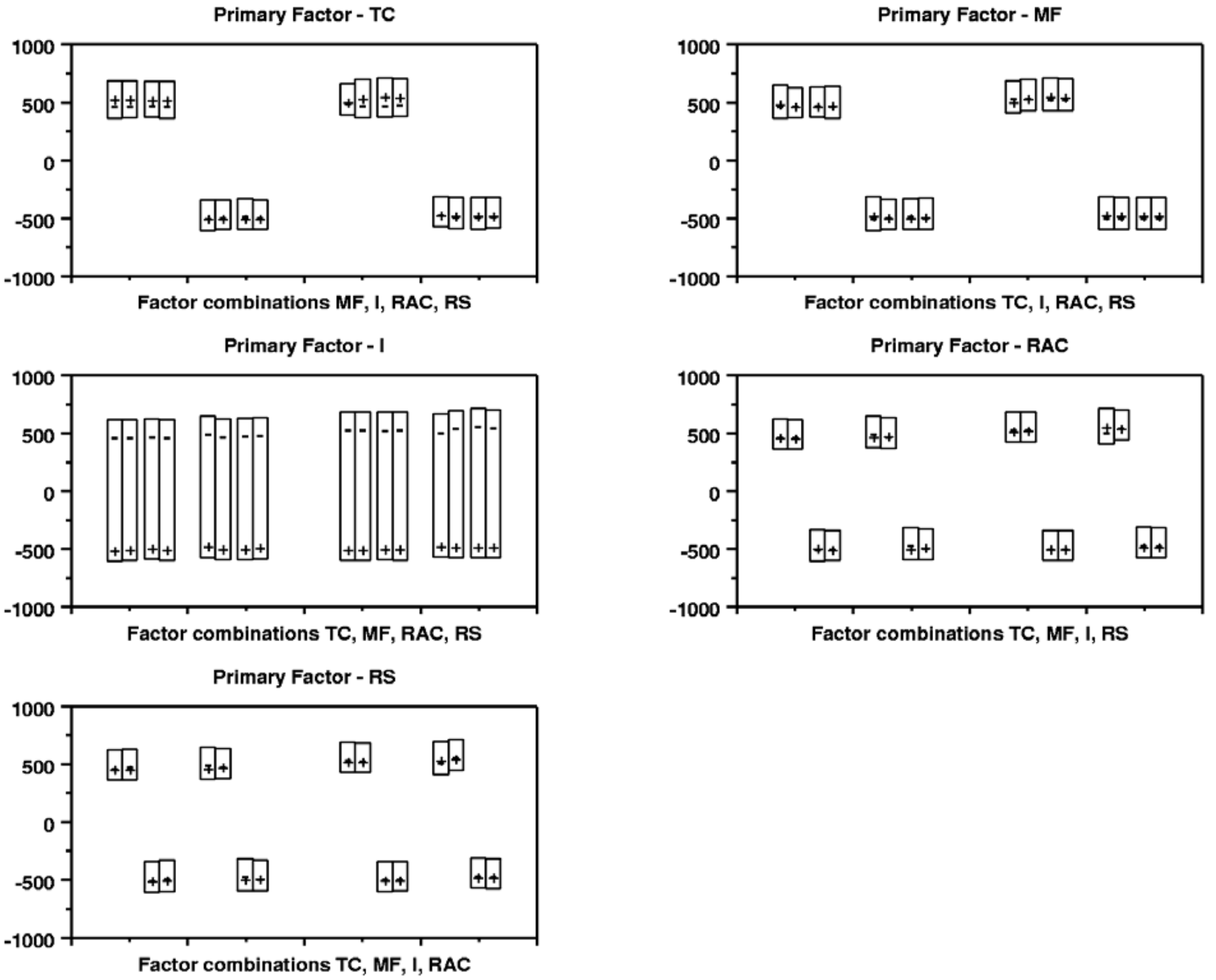


Source: Own figure.

[65] See NIST/SEMATECH (2003) for an in-depth discussion of graphical analysis of DOE simulation results. The plots were generated using the free software DATAPLOT.

Finally, the block plot shown in Figure 5-4 wraps up the graphical analysis of effects. In addition to scatter and mean plots, block plots are useful to establish the robustness of main effects, and to determine factor interactions. The vertical axis shows the response variable, average economic land rent. The horizontal axis of each sub-plot shows all 2^{k-1} possible factor combinations of the (*k*-1) non-primary factors ('robustness' factors). For example, for the block plot focussing on primary factor *I*, the horizontal axis consists of all 2^5-1=16 combinations of factors *MF*, *I*, *RAC*, and *RS*. To read the figure correctly it is important to note that a block's height determines factor importance.

Figure 5-4: Block plot of main and interaction effects



Source: Own figure.

Hence, factor *I* is most important because all bar heights in plot 3 (target factor *I*) are greater than bar heights in all other plots. Also, bar heights in plots 1 and 2 (target factors *TC* and *MF*) are slightly greater than bar heights in plots 4 and 5 (target factors RAC and RS), indicating that factors *TC* and *MF* are more important than factors *RAC* and *RS*. A clear ranking of factor importance is not possible, though. Plot 3 (target factor *I*) has the consistently largest block heights along with a consistent arrangement of within-block +'s and –'s. This indicates that factor *I* also was the most robust factor of all five factors considered. Factors *TC* and *MF* were not robust across the whole range of factor variations, but robust across variations of factors *RAC* and *RS*.

5.2.2.2 Metamodel analysis

To derive some statistical conclusions about factor effects, the linear regression metamodel defined in equation (5.1) is applied in which the average economic land rent of 25 simulation periods is regressed on factor level settings and two-factor interactions. As Figure 5-1 showed, the means display differences between scenarios quite well. Because each simulation scenario is replicated twice, altogether 64 data points enter the regression analysis.

Results are presented in Table 5-3, which only lists factors significant at the 1% level. Accordingly, three out of five factors are highly significant at $p<0.01$ (*I, TC*, and *MF*).

Table 5-3: Factor effects based on OLS regression[66]

Factor	Estimate	Standardised estimate	Standard error	Significance level	t-values
Constant	682.410		12.781	0.000	53.393
I	-773.819	-0.884	8.073	0.000	-95.730
TC	277.290	0.317	8.073	0.000	34.304
MF	203.521	0.232	8.073	0.000	25.178
TC x I	-168.267	-0.192	8.073	0.000	-20.816
TC x MF	127.144	0.145	8.073	0.000	15.729
I x RS	-19.275	-0.022	8.073	0.021	-2.385
RAC	18.353	0.021	8.073	0.027	2.270
MF x RS	16.694	0.019	8.073	0.044	2.065
RS	16.265	0.019	8.073	0.049	2.012
adj. R^2	0.995	N=64			

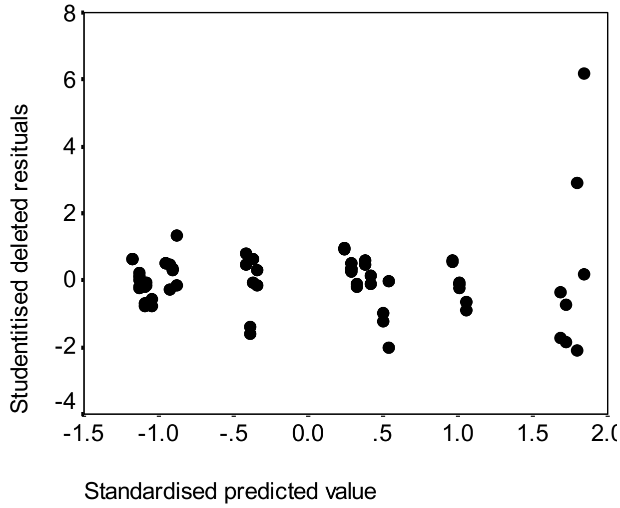
Note: The dependent variable is the average economic land rent across all periods.
Source: Own estimation.

66 The standard errors on estimates are the same for all independent variables except for the intercept. The reason for this is that the model was estimated for a full-factorial design in which 50% of the observations for each factor had a high and a low value. If a fractional factorial design was estimated, standard errors would differ.

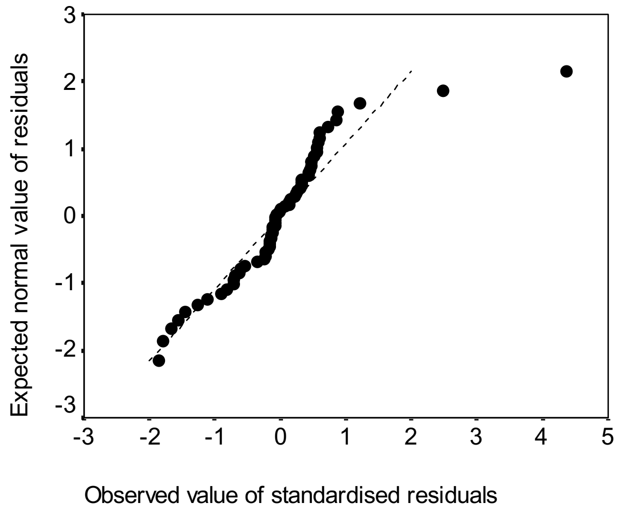
The estimates reproduce what already could be seen in the graphical analysis when changing a factor from its "-" to its "+" setting. In other words, a factor level change of factors *I, TC,* and *MF* significantly change the development of economic land rent. The regression model appears to account for almost all the variability in the response, achieving an adjusted R^2=0.995. The results underline the strong effect of factor *I*. As was expected already from the analysis of Figure 5-1, factors *TC, MF,* and *I*, and interactions between these factors are most important. Results also support the finding that these factors are more important than, for example, the size of the region if economic land rent is taken as the response variable. To further test the validity of the metamodel, regression residuals are analysed. Figure 5-5 (a) shows studentitised deleted residuals plotted versus standardised predicted values of cumulative economic land rent (cf. SPSS 1999).

Figure 5-5: Residual plots. (a) Scatter plot of studentitised deleted residuals versus standardised predicted values; (b) Q-Q normal probability plot

(a)



(b)



Source: Own figure.

Approximately four out of 64 data points lie outside the interval between -2 and +2 indicating that the model could be accepted on the grounds of this plot (see SPSS 1999). The normal probability plot in Figure 5-5 (b) shows that the distribution of residuals deviated in parts from a normal distribution underlying the metamodel. Accordingly, results of the metamodel have to be treated with care. At most, they point out a general direction. The results on the other hand do not provide strong enough evidence to reject the model as a whole, particularly, since results are supported clearly by the graphical analysis.

5.2.3 Discussion

Although the selection of factors is somewhat arbitrary and based upon reasoning, the size of the impact of the significant factors shows that a deeper analysis is indeed meaningful, in particular with respect to the identification of factor interaction effects. The applied methodology and the metamodel provide a more systematic analysis of results of complex simulation models. When summarising the results, it becomes clear that interest rates, technical change and managerial ability influence average economic land rent the most. The size of the region has a much lower impact on economic land rent than expected beforehand. Other analyses in which farm incomes, rental prices, and farm size were taken as response variables confirm this. Due to limited space, these results are not reported here. In addition, factor *RAC* has no significant impact on results.

A problem of DOE is that no defined rules for appropriate factor level settings are given. Because of this, the importance of factors is partly based on what is defined in the experimental setup. In the extreme, if a narrow range is imposed on an important factor, but a wide range on an unimportant factor, then the latter could turn out to be more important than the former (VONK NOORDEGRAAF et al. 2002). Therefore, the fact that interest rates had such an immense influence on model outcomes could partly be explained by the fact that a wide range for the parameter setting was assumed. However, the wide range imposed on factor *RS* did not lead to an overestimation of the effect of region size. Nevertheless, the procedure presented here reveals some information about the importance and interactions of factors that would not have become as apparent if other designs such as varying only one factor at a time had been chosen.

5.3 Impact of random initialisations

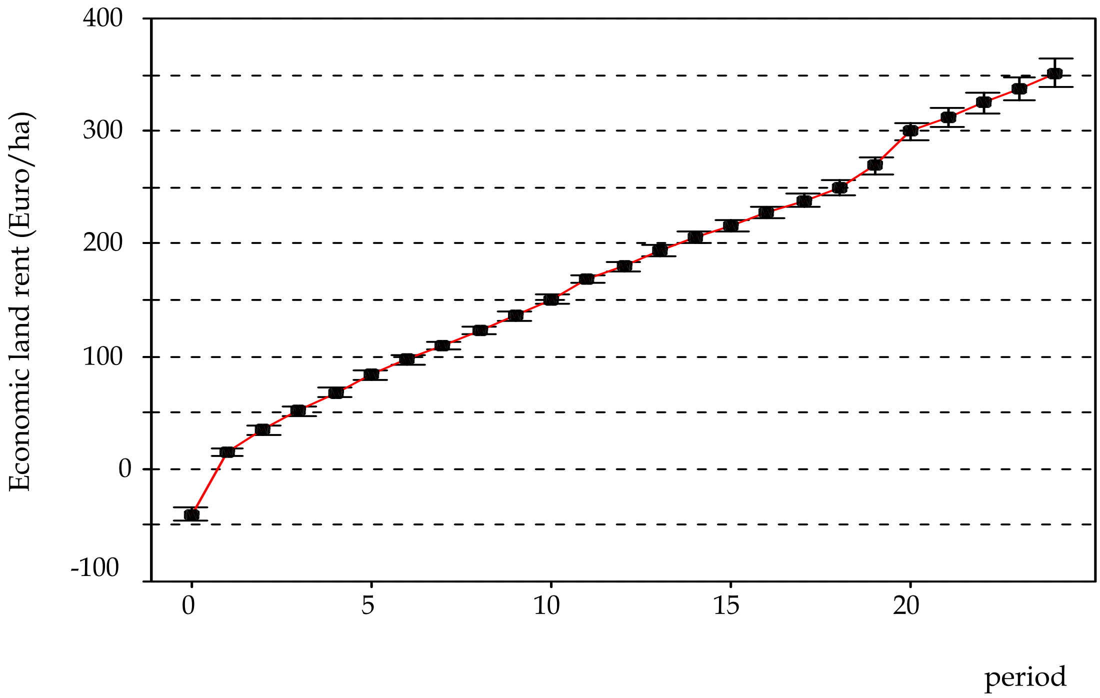
5.3.1 *Experimental design and data output*

The next set of experiments observes the behaviour of AgriPoliS in response to varying initial conditions. Regional averages of three response variables are analysed: economic land rent, farm size, and investment expenditure. Even though for the most part, AgriPoliS is a deterministic model, there are four instances of randomness: farm agent age, asset vintage, managerial ability (see section 5.2.1 above), and the spatial arrangement of farmsteads in the region, all of which are set at the outset of the model. To test the sensitivity of AgriPoliS to different random initialisations, 20 independent simulation runs were carried out. The experimental setup assumes the default parameter values listed in chapter 4.

5.3.2 *Results*

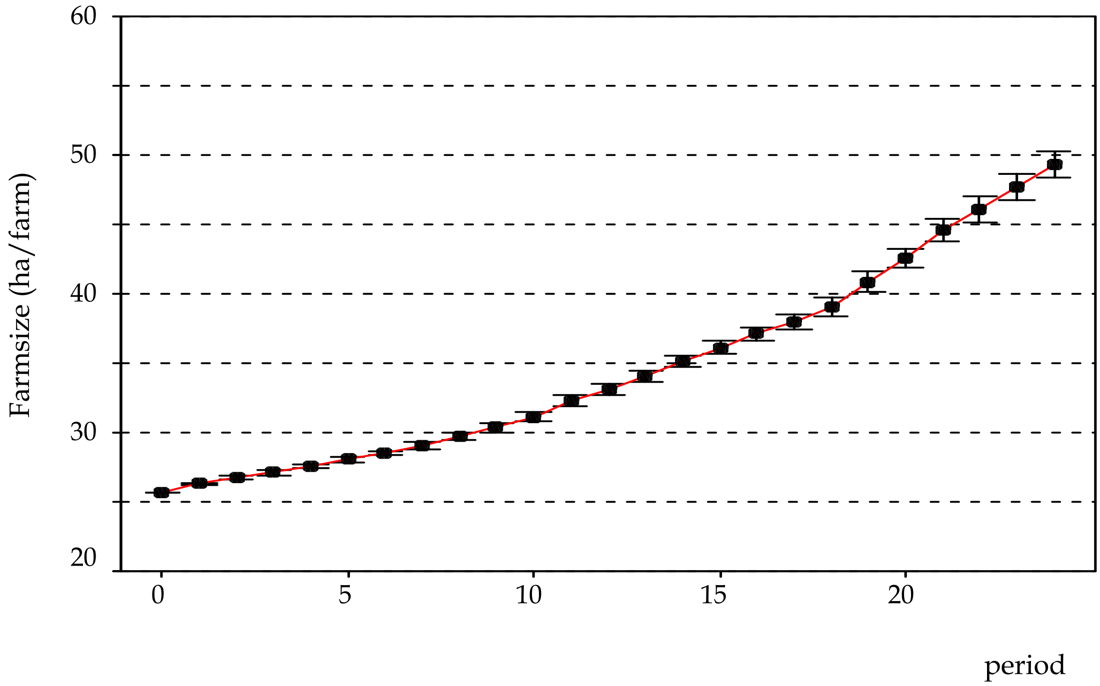
Figure 5-6 and Figure 5-7 summarise results of 20 models runs of 25 periods each. The figures show 95% confidence intervals indicating the range that 95% of model runs lie within.

Figure 5-6: Evolution of the average economic land rent and 95% confidence intervals for 20 simulation runs of 25 periods



Source: Own figure.

Figure 5-7: Evolution of average farm size and 95% confidence intervals for 20 simulation runs of 25 periods

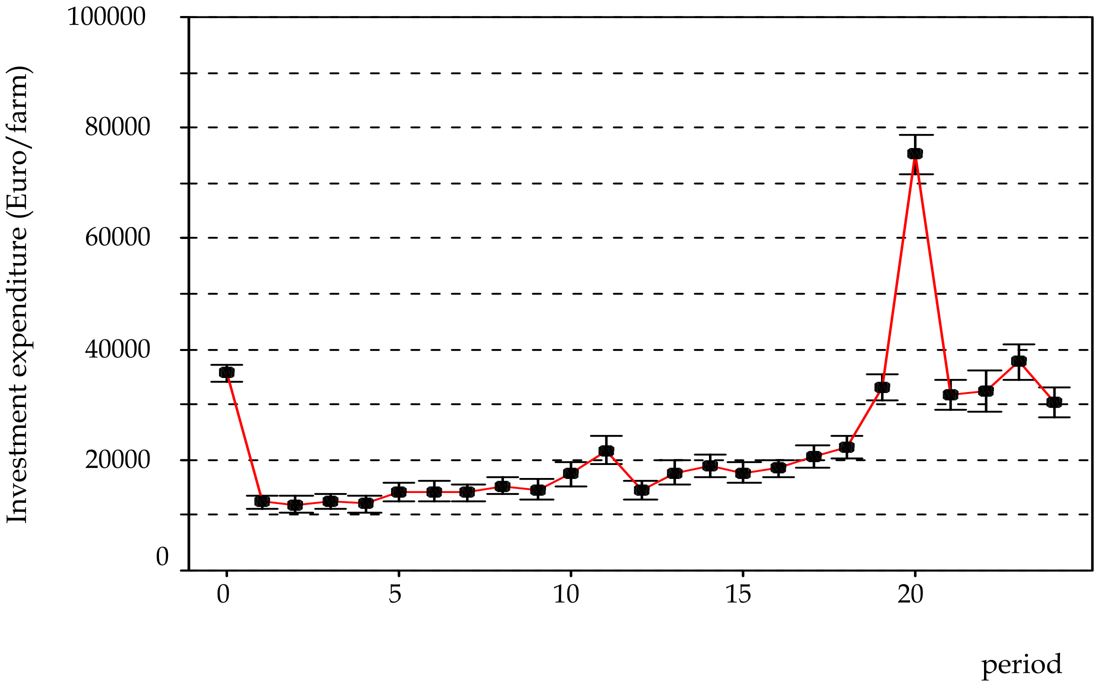


Source: Own figure.

On average, the agricultural structure in the region gradually changes towards a larger average farm size and higher average economic land rent. In each figure, the vertical axis represents the average economic land rent per ha in the region. Whiskers are upper and lower boundaries of the confidence interval.

The figures show a similar pattern in that the spread of results increase over time. Confidence intervals are largest after about 20 periods. One reason for this is the investment-specific pattern that can be observed in the simulations (Figure 5-8). Accordingly, in the first period and period 20 investment expenditure is particularly high. The investment boost in the first period can be explained by the fact that in this period farm agents optimise their respective organisations subject to the parameter values specified for Hohenlohe. It corresponds to the optimised initial situation mentioned in section 4.8 of chapter 4. The second upswing after 20 periods consists of investments replacing assets purchased 20 periods before, and net investments which account for the larger part of total investment expenditure in period 20. Why after 20 periods? The reason is twofold. On the one hand, the majority of investments are assumed to have a useful life of 20 periods (see Table 4-9 in chapter 4). On the other hand, investment costs are sunk costs, meaning that, once an investment is made, its opportunity costs are zero such that the fixed asset is irrelevant for further decision making. This, first of all, prevents some farms from liquidating fixed assets such as buildings at an earlier stage. These farms continue farming at least until the useful life of the respective assets is reached in spite of relatively high opportunity costs for labour and land.

Figure 5-8: Time evolution of expenditure on new investments



Source: Own figure.

5.3.3 Discussion

Although this analysis only presented a very limited analysis of the effect of random initialisations, the following conclusions can be drawn. First, in the simulations carried out for this section, different random initialisations show to have only limited influence on results, and in particular on confidence intervals. The size of confidence intervals increase over time, i.e., effect of random initialisations transfers to later periods, but not to a large extent. Nevertheless, this has consequences, if, for example, results from different policy simulations are to be compared. Furthermore, the analysis does not allow drawing general conclusions for the behaviour of AgriPoliS in response to different initialisations under different parameter settings. This can only be tested if a large number of replications for different parameter constellations were carried out. In view of the time spent on the DOE analysis, the computational limits of a large number of repetitions, particularly of simulations with RS = 100%, are obvious. BALMANN et al. (2002), however, present simulations results for five different model initialisations.

5.4 Structural impact of heterogeneous managerial ability

In real world agriculture, the economic performance of farmers can differ substantially even if they operate under more or less the same production conditions using similar production technologies. These differences in the economic performance of farmers are often attributed to differences in the managerial ability of farmers (cf. NUTHALL 2001; ROUGOOR et al. 1998 for a review of studies on managerial ability). In this thesis, managerial ability is understood as the ability of a farm agent to use its technology to realise cost savings and produce relatively more efficient (see chapter 3). In particular, the managerial ability of a farm agent is introduced by a factor, which alters a farm agent's production costs, such that a farm agent with high (low) managerial ability is assumed to produce at lower (higher) costs.

The set of simulations and subsequent analyses in this section aims to answer the question whether farm agents with higher managerial ability are more successful than farm agents with lower management skills under different exogenously given framework conditions. The hypothesis behind this question is that managerial ability is a key factor when it comes to surviving unfavourable overall (economic and political) framework conditions. In this sense, farm agents with better management skills are considered more robust in withstanding unfavourable situations. Moreover, farm agents with high managerial ability are expected to better exploit economies of scale, and cost-saving opportunities to produce more efficiently. These aspects will be addressed in the subsequent analysis, which follows two steps: The first is to investigate the effect of homogeneous managerial ability versus heterogeneous managerial ability of agents, the second step analyses differences between agents with high managerial ability as compared to agents with low managerial ability. The analysis at each step is placed in the context of different economic framework conditions.

5.4.1 *Experimental design and data output*

The simulation experiments are carried out for three different overall economic framework conditions. Three interest rate scenarios stand as a proxy for overall economic framework conditions. In the first scenario (i_{-1}) all interest rates are close to zero.[67] The second scenario (i_d) assumes interest rates that approxi-

[67] The notation follows that introduced in section 5.2, where "-1" corresponds to a low factor level, "+1" to a high factor level, and "d" to the default factor level.

mately correspond to a five-year average (1997 to 2003) of real interest rates in Germany (5.5%). The third scenario (i_{+1}) assumes interest rates above average real interest rates.

To model the variety of managerial ability across farm agents, two scenarios are considered, one in which all agents have homogenous managerial ability, and one in which managerial ability differs across agents. Table 5-4 gives an overview. Unless stated differently, all assumptions in the reference scenario remain valid. Scenarios are replicated only once using the same random number seed.

Table 5-4: Simulation scenarios

	Level	Definition
Interest rate levels	i_{-1} - zero	i_{ec}=0%, i_{bc}=0%, i_{bcs}=0%
	i_d – medium (default)	i_{ec}=4%, i_{bc}=5.5%, i_{bcs}=8%
	i_{+1} - high	i_{ec}=6%, i_{bc}=7%, i_{bcs}=10%
Managerial ability		
Homogeneous		m_{max}=100%, m_{min}=100%
Heterogeneous		m_{max}=110%, m_{min}=90%

Notes: i_{ec}: interest on equity capital, i_{bc}: interest on long-term borrowed capital, i_{bcs}: interest on short-term borrowed capital.
Source: Own calculations based on DEUTSCHE BUNDESBANK (2003).

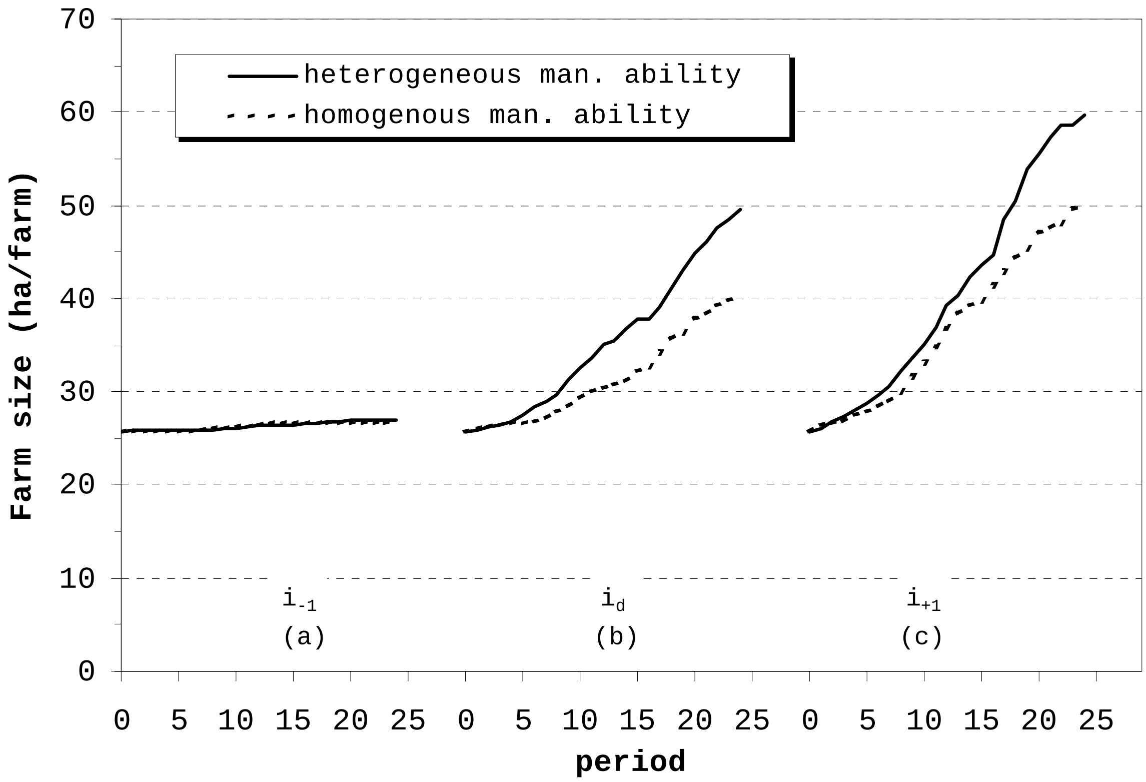
In AgriPoliS, it is assumed that managerial ability becomes evident in variable production costs (chapter 3). Accordingly, farm agents with higher managerial ability will realise lower variable production costs than farm agents with lower managerial ability. To implement this, at start-up each farm agent receives a managerial ability factor m. The factor affects variable production costs of each farm agent. The closer the value of m is to m_{min} (m_{max}), the higher (lower) is the farm agent's managerial ability. For example, if m=0.9 (m=1.1) then the farm agents works at 90% (110%) of the average variable production costs calculated across all farm agents. The values assumed for the case of heterogeneous managerial ability are derived from an analysis of bookkeeping data and expert opinion. Managerial ability of each farm agent is assumed fixed for an entire simulation run. Hence, agents have no capability of learning. Moreover, managerial ability is considered independent of farm-size and technology. In this way, also small farms or farms using older technology could have high managerial ability.

5.4.2 Results

5.4.2.1 Homogeneous vs. heterogeneous managerial ability

Figure 5-9 shows the evolution of average farm size for different interest rates and homogeneous and heterogeneous managerial ability. It shows that farm size growth is positively related to heterogeneous management abilities. This result is plausible and it corresponds to what was expected because lower production costs generally improved the competitive position of a farm agent on markets. Due to this, rental price for land increase significantly, as farm agents with higher managerial ability can place higher bids, therefore obtain more land, and grow faster. Furthermore, Figure 5-9 illustrates that increasing overall interest rates reinforce structural change in terms of the average farm size in hectares.

Figure 5-9: Evolution of average farm size for (a) zero interest rate level, (b) medium interest rate level and (c) high interest rate level



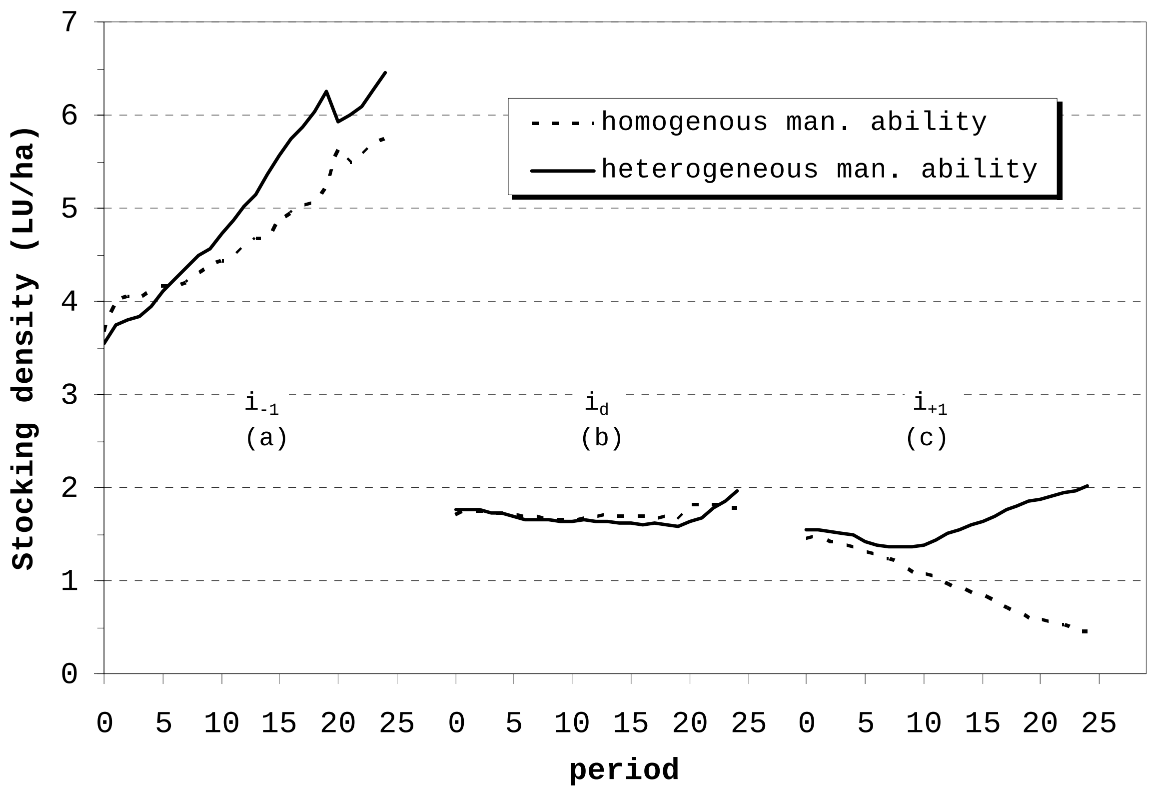
Source: Own figure.

This is not surprising as under the assumption of zero interest rates, opportunity costs of capital are zero, i.e., there is no incentive for moving capital out of farming. Assuming that production in the region does not have significant influences on product prices and factor prices and that the supply of labour and capital is unlimited, it is rational for farms to stay in business as they could invest and engage in capital-intensive production activities almost free of charge. In this case, farms almost exclusively invest into intensive livestock production.

Figure 5-10 reveals that stocking density in the region is significantly higher than in the other scenarios, with a strong increasing trend. Taking into account that farm agents incur a 'fine' of 175 € for every livestock unit above a threshold of 2.5 livestock units per hectare, this result indicates that under zero interest rate conditions the levy does not hold up the intensification of production. However, it is interesting to note that in spite of this, rental prices for land are still considerably high and even increase (Figure 5-11).

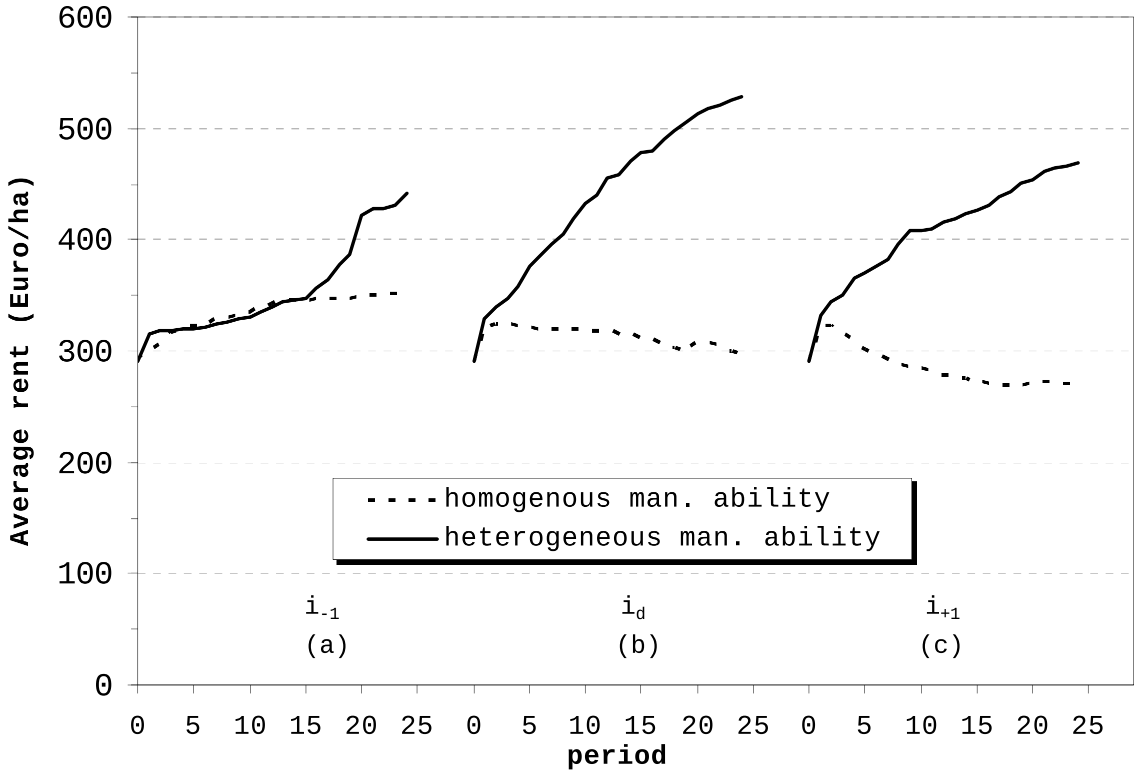
This suggests two things: On the one hand, it suggests that for some farm agents in the region growing via renting land, as far as this is possible, is more profitable than incurring a levy. On the other hand, it suggests that even though farm agents do not leave the sector, there is heavy movement on the land markets because farm agents let unprofitable plots to the market, plots which are then rented again at higher prices.

Figure 5-10: Evolution of average livestock density per different interest rates



Source: Own figure.

Figure 5-11: Evolution of average rents for land for different interest rates

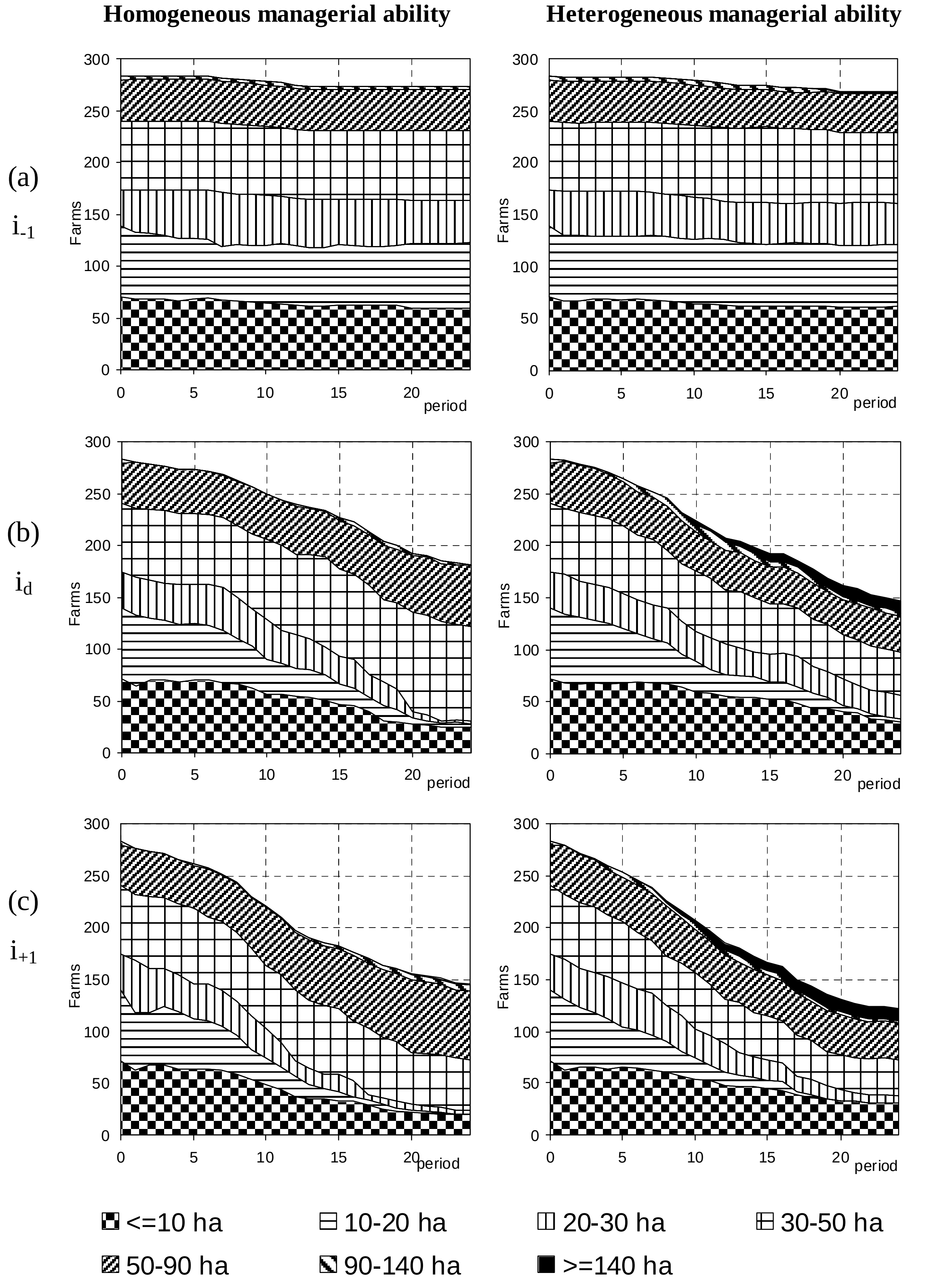


Source: Own figure.

Figure 5-12 shows the evolution of the number of farm agents differentiated by farm size classes in hectares and managerial ability. In accordance with the previous analysis, in the case of zero interest rates, the distribution of farm size classes hardly changes during 25 simulation periods. The higher the interest rate level, the greater the tendency towards larger farm sizes. Note, that there is a dichotomy of results in that the group of farms of 10-30 hectares almost vanishes completely, but the number of very small farms as well as larger farms increase or – in the case of very small farms with less than 10 hectares – decreases to a much lower extent. The presence of farms with heterogeneous managerial ability does reinforce the effect just mentioned.

The relative persistence of very small farms with less than 10 hectares was at first a rather unexpected outcome. But, assuming that off-farm labour opportunities are not limited, converting into a non-professional farm is a reasonable adjustment reaction to maximise total household income. Once a farm in the model has turned into a non-professional farm, further development possibilities are either to remain in the sector and keep up farming at a very low level or to leave altogether. Only in a few cases, farms switch back to operate as a full-time farm.

Figure 5-12: Evolution of the total number of farms by farm size classes for (a) zero interest rates, (b) medium interest rates, (c) high interest rates, and heterogeneous costs

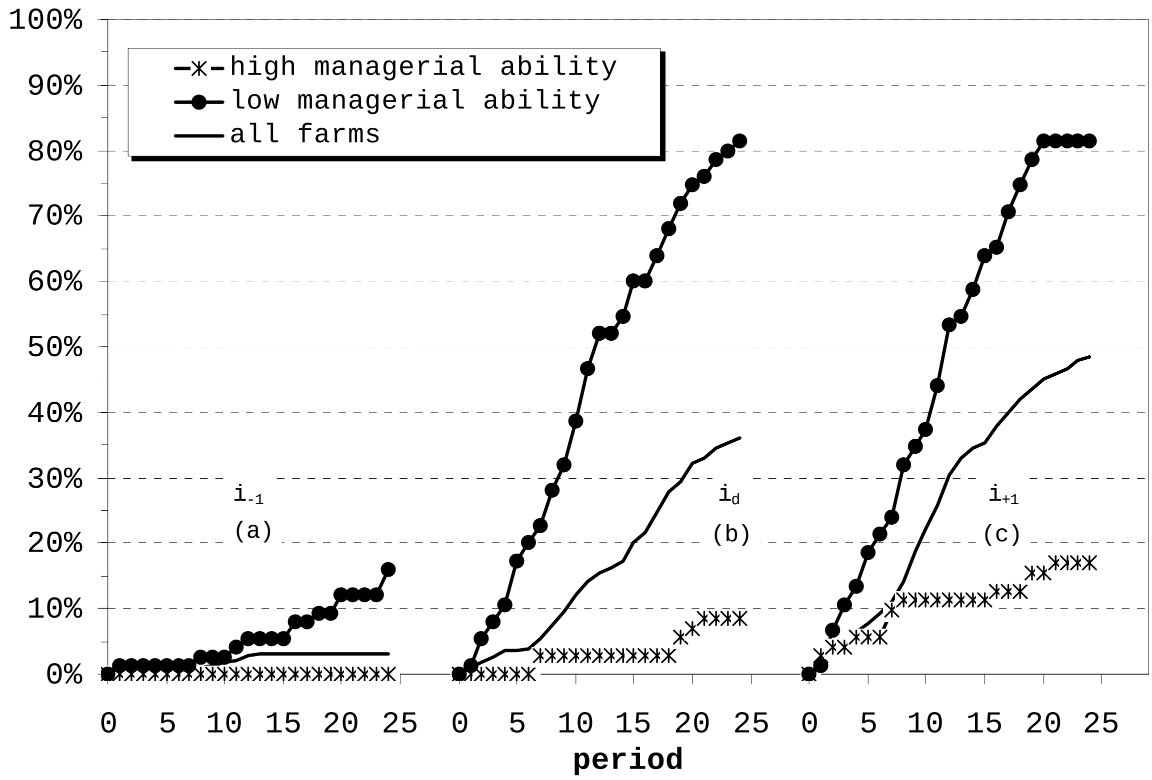


Source: Own figure.

5.4.2.2 High managerial ability vs. low managerial ability

To tackle the question whether farm agents with a higher managerial ability are persistently more successful across different interest rate scenarios, farm agents in the scenario 'heterogeneous management ability' are grouped according to their managerial ability. The first group consists of farm agents with 'high managerial ability'. These are farm agents operating at 90-95% of standard variable production costs. The second group includes farm agents with 'low managerial ability'. This group includes only farm agents that operate at 105-110% of average variable production costs. Other farms are not considered. As Figure 5-13 shows, there is in fact a clear difference between the two groups in terms of the percentage of farms quitting.

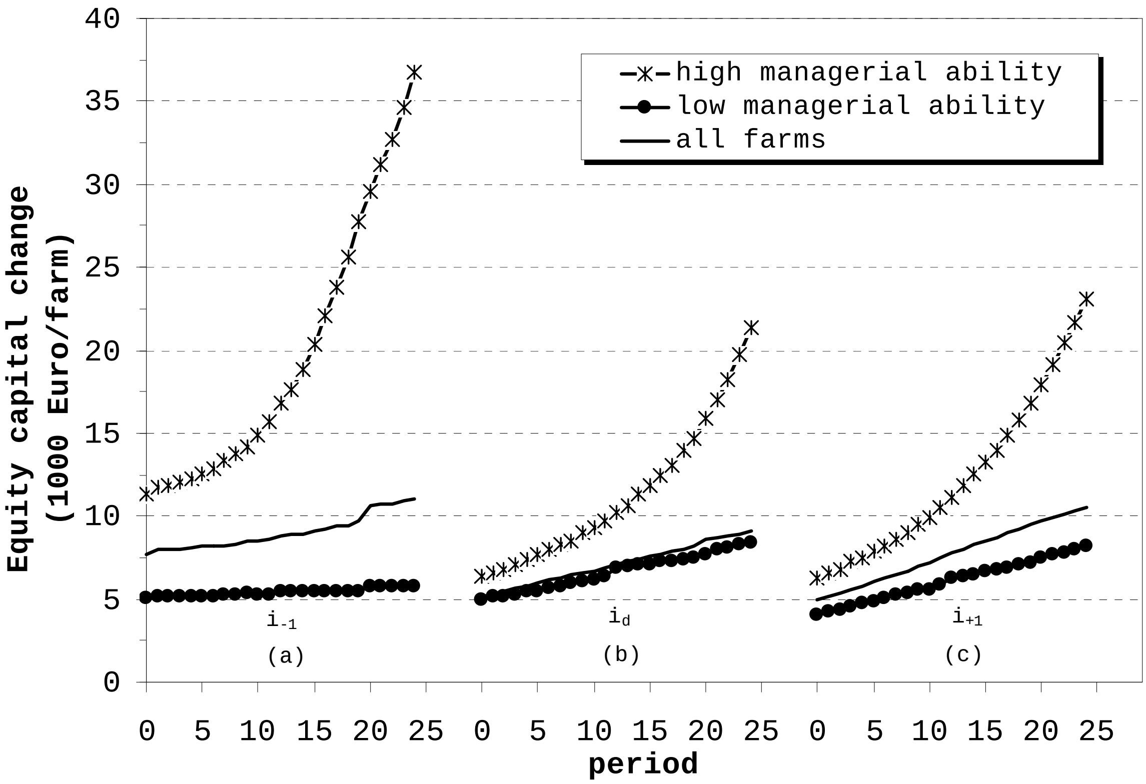
Figure 5-13: Percentage of farm agents leaving relative to first period for (a) zero interest rates, (b) medium interest rates and (c) high interest rates



Source: Own figure.

More than 80% of the farms with low managerial ability quit in the course of the simulation as compared to a maximum of 18% in the case of the better group. This is one indicator for a link between managerial ability and the performance of farms. The same relationship also holds when the cash flow, i.e. the ability of a farm agent to build up equity capital, is concerned. The same patter becomes apparent for the change of equity of farms remaining in the business for either group (Figure 5-14). The figures show farms in the respective sub-sample with either low or high managerial ability that do not quit the sector during a simulation run. In case of farms with a low managerial ability, the potential to accumulate equity is very low; it grows only slowly over time. These farms are marginal farms continuously on the verge of quitting. On the opposite, equity capital of farms with a high managerial ability increases strongly over time. Note that with respect to equity capital accumulation, the advantage of farms with high managerial ability is most obvious; the average equity capital build-up across all farm agents is much lower.

Figure 5-14: Evolution of average equity capital change of farms remaining in business for (a) zero interest rates, (b) medium interest rates, and (c) high interest rates



Source: Own figure.

5.4.3 Discussion

Summarising the results of this simulation experiment, it becomes clear that farm agents respond quite differently to different interest rate levels if managerial ability is heterogeneous (which is the case in real world agriculture). Despite of this comparatively strong result, the shortcomings of the chosen approach should be mentioned. First, it was assumed that farm agents could not learn, i.e. their managerial ability could not improve (or decrease) in the course of a simulation run. Accordingly, a farm initialised as a farm with low managerial ability will remain so during the entire simulation.

Second, the definition of managerial ability and the way of operationalising it are admittedly very simple and it is questionable whether it is possible and admissible to narrow down such a diverse concept to only a single factor and a single effect. Measuring managerial ability real systems is in fact an ambitious task that often involves such diverse subjects as psychology as well as production frontier approaches. Furthermore, the interpretation of managerial ability as the ability to realise costs and produce more efficiently is certainly not generally applicable although there is some evidence that management contributes more to the efficiency of production than for example organisational structure (GALUSHKO and BRÜMMER 2003).[68] However, factors like the motivation of employees or personnel management play a role as well. However, as for family farms in the region Hohenlohe considered in this study, the chosen interpretation of managerial ability seems more appropriate.

5.5 Conclusions from the analyses

The simulations in this chapter underline the importance of analysing the sensitivity of a model from different points of view. This chapter followed three different approaches to exploring the reference situation given by the Agenda 2000. The first approach applied the DOE methodology and a simple regression metamodel to observe the impact of parameters expected to have significant effects on the simulation outcome. It showed that, for example, the size of the region has no significant effect on results whereas interest rates, on the other hand, together with technological change and managerial ability significantly influence model results.

The second approach analysed the effect of multiple random initialisations on simulation results. Results of 20 independent model replications did not show any significant abnormalities or extreme values, although these can never be excluded fully if more replications are made or parameter values changed.

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68 See BALMANN and LISSITSA (2003) for a collection on the topic of large farm management, or BALMANN and CZASCH (2001).

Third, an analysis of the effect of heterogeneous managerial ability was undertaken which focussed on the adjustment of different groups of farms. From this analysis, it becomes apparent that different farm agents follow different adjustment strategies depending on their individual situation regarding managerial ability, but also with regard to aspects like factor endowment, farm type, or location, which were not analysed further. Adjustment strategies will differ across farm agents. Hence, it can be expected that some policies will lead to more adjustment processes in one group of farm agents than in another. A policy change thus is expected to affect different farms in different ways. This could be an interesting result for policy makers because it shows that policies made based on an average farm do most likely overestimate or underestimate the effect of the policy on a particular group of farms or even individual farms.

Furthermore, results show that different and important insights can be gained from simulating different possible framework conditions such as for different interest rate scenarios. Most of these framework conditions could be interpreted as possible futures of the target system. Although, in this chapter, only interest rates were considered, the merit of analysing the effect of different framework conditions becomes obvious. First, this procedure allows the modeller to get a feeling for how the model behaves under different (plausible) conditions, which may eventually make it easier to detect errors. Second, it suggests that the model reacts quite differently under different conditions. As for policy analysis, it could therefore be interesting to carry out simulations not exclusively for one plausible parameter constellation, but also for other plausible constellations. This may be of interest if the introduction of new policy measures is concerned as it is certainly in the interest of policy makers to introduce policies that are equally effective for different future scenarios.

Part III

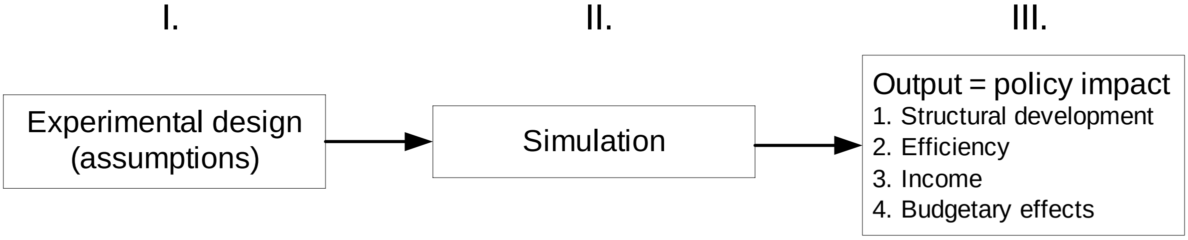
Policy analysis

6 Analytical framework and assumptions for measuring policy impacts

6.1 Introduction

The goal of this chapter is to set the general analytical framework for the policy experiments presented in chapters 7 and 8. In particular, this chapter provides the reader with information on the tools used to analyse results from policy experiments (sections 6.3 and 6.4). General assumptions underlying the policy experiments are presented (section 6.5). The analytical framework for policy analysis is presented in Figure 6-1. Three steps can be distinguished in setting up the policy experiments: definition of experiments and setting of assumptions, simulation, and the analysis of simulation output representing policy impact.

Figure 6-1: Framework for analysing the effect of agricultural policies on regional agricultural structures



Source: Own figure.

Results are investigated mainly from four perspectives: structural development, efficiency, income, and budgetary effects. The analysis of structural development is based on a range of indicators of which the most important are defined in section 6.2. An important analysis tool to investigate differences between farms and to show the distribution of results is Kernel density estimation, which is explained in section 6.4. The second perspective focuses on analysing Hohenlohe's agricultural structure with respect to efficiency (section 6.3). To measure individual efficiency differences between farms, a Data Envelopment Approach (DEA) is applied. Economic efficiency is measured based on the concept of economic land rent. To investigate income and equity issues, income distribution among farms is analysed using Gini indexes and the Lorenz curve (section 6.4).

6.2 Performance indicators

Along the lines of the European Farm Accountancy Data Network (FADN), AgriPoliS produces a data set for each farm in each time period providing information – among others – on production, factor endowment, farm size, financial situation, balance sheet, incomes, and production intensity (see appendix A.2 for a listing). AgriPoliS calculates these at the aggregate regional level, but also at the individual farm level. In the following analysis, AgriPoliS generates data that is used to study the development of selected indicators over time. For the purpose of this study, key indicators are the acreage and economic size of a farm, economic land rent, farm income, and household income.[69] Figure 6-2 demonstrates definitions of the income indicators used in the policy analysis.[70]

In addition to these income indicators, there are a number of indicators used for the analysis of structural effects such as farm size in hectares, economic farm size, and land rental prices, which are compared between different policy scenarios. The economic size of a farm, measured in European Size Units (ESU), is an important measure of farm size employed within the European Union. It is a measure of the economic importance of arable and livestock production and the calculation is based on standard gross margins, whereby a standard gross margin of 1,200 € corresponds to one ESU. In this thesis, standard gross margins correspond to the gross margins defined in chapter 4. These gross margins furthermore provide the basis for the specific classification of farm types used in the following chapters. In principle, if the share of gross margin from a production branch (field crops, grazing livestock or granivore production) is greater than two thirds of total gross margin, a farm is specialised in either one of these production branches. All other farms are classified as mixed farms.[71]

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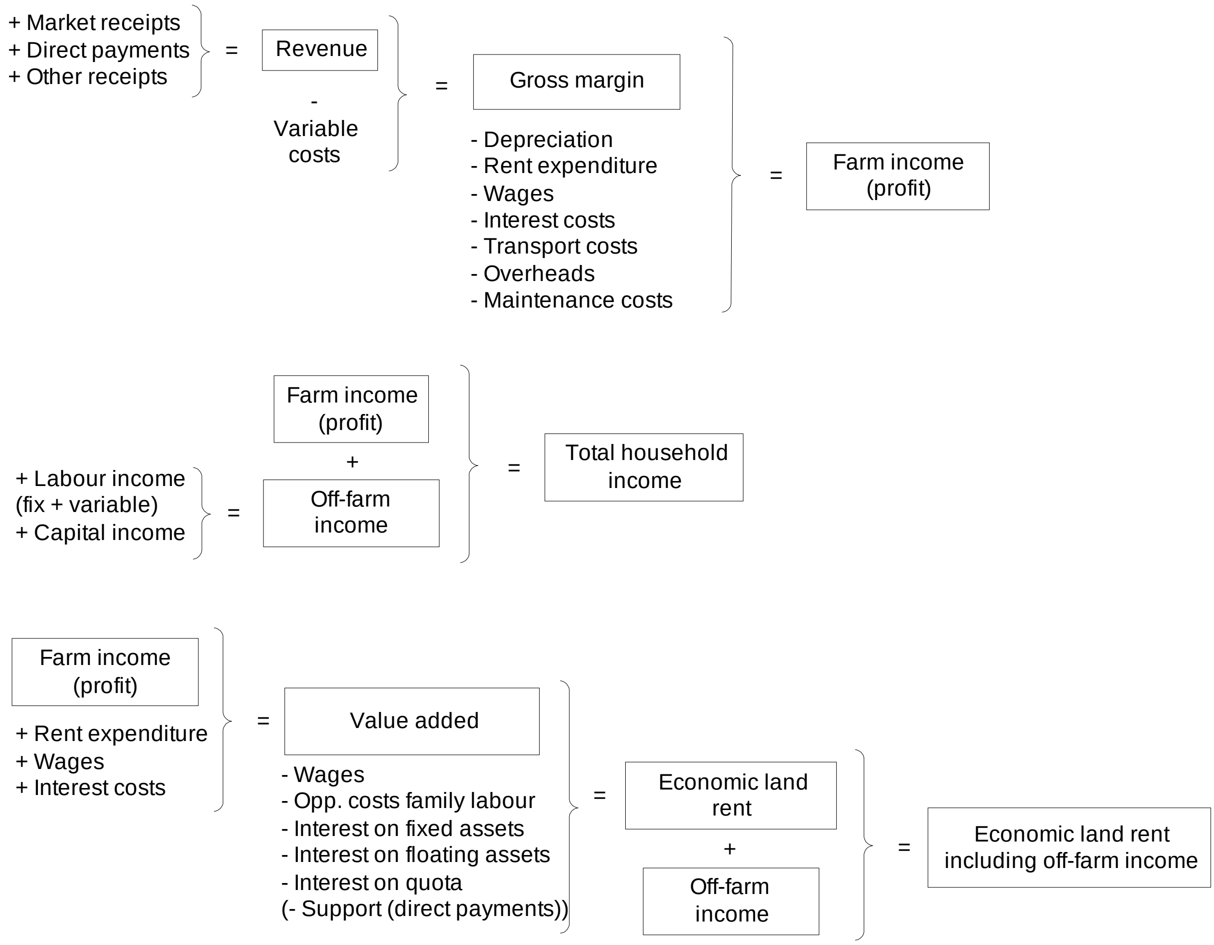
[69] Household income refers to the total income earned by all members of the farm family either on or off the farm.

[70] In Germany, the term 'farm income' is used interchangeably with the term 'value added'. In this thesis, the term 'farm income' is used as in OECD (2003), where farm income refers to all profit earned from agricultural production.

[71] See also chapter 4.

Figure 6-2: Definition of income indicators and economic land rent



Source: OECD (2003), modified based on MLR (2002).

6.3 Measuring production efficiency of agricultural structures

6.3.1 Starting points for measuring efficiency

The goal of the methodology proposed in this section is to derive a measure of the production efficiency of agricultural structures, which is based on empirical observations. The question of empirical efficiency measurement has been an important topic in applied economics in the past 50 years. Already in 1957, FARRELL (1957) introduced a measure of *economic efficiency* (EE) consisting of two components: *technical efficiency* (TE) and *allocative efficiency* (AE). Technical inefficiency relates to the comparison of maximum attainable output to observable output. Allocative inefficiency reflects the firm's inability to use production factors in optimal proportions given their respective factor prices (COELLI et al. 1999; LOVELL 1993).

Questions central to efficiency measurement are: what is the definition of output? What is efficiency measured against? Here, these questions will be addressed only briefly and in relation to the application in this study. Any further explanation would require a deeper theoretical discussion of efficiency and its normative implications as well as limitations.

Regarding the first question, efficiency is understood exclusively in terms of production efficiency, i.e., the ratio of maximum attainable output to observable output. In the model presented below, output is defined as revenue, but it could equally be defined in non-value terms. As for the second question, in this thesis, efficiency is measured against a best-practice production frontier established by a group of relatively successful firms (FURUBOTN and RICHTER 1991; CANTNER and HANUSCH 2003). Thus, the frontier is not based on a normatively defined opportunity set, but usually constructed from empirical data.[72] Data envelopment analysis (DEA) is one way to estimate a best-practice frontier based on empirical data. This study uses simulated data generated from applying AgriPoliS to the Hohenlohe data set.

Within the context of this study, one could envisage differentiating between two levels at which conclusions about efficiency could be drawn: the individual farm level, and the structural or regional level. Regarding the farm level, individual farms in AgriPoliS are assumed to maximise farm household income. From a comparative static point of view, i.e. looking at each period individually, and employing the definition of efficiency given above, a farm is efficient if it achieves the maximum attainable output in the given period with given inputs. In AgriPoliS, the farm optimisation problem combines production factors with production activities to maximise farm household incomes (see chapter 3). Because of this, an individual farm agent as defined in AgriPoliS is efficient with respect to itself at individual points in time.[73]

More interesting in the context of this study is to find out about a farm's efficiency relative to all other farms in a group as well as to investigate the aggregate or structural efficiency of all farms in the region. In AgriPoliS, inefficiencies

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72 Regarding normative implications of agricultural policy analysis see e.g. HENRICHSMEYER and WITZKE (1994), BULLOCK and SALHOFER (2003). For a critical account of the efficiency concept in particular with respect to agricultural policy analysis see BROMLEY (1990), BOGGESS (1995), or BONNEN and SCHWEICKHARDT (1998).

73 Viewed over time, a farm agent, however, can get more or less productive. That is, the input-output ratio can change because a farm has the possibility to invest in new technology, realise size effects and thus produce at lower unit costs.

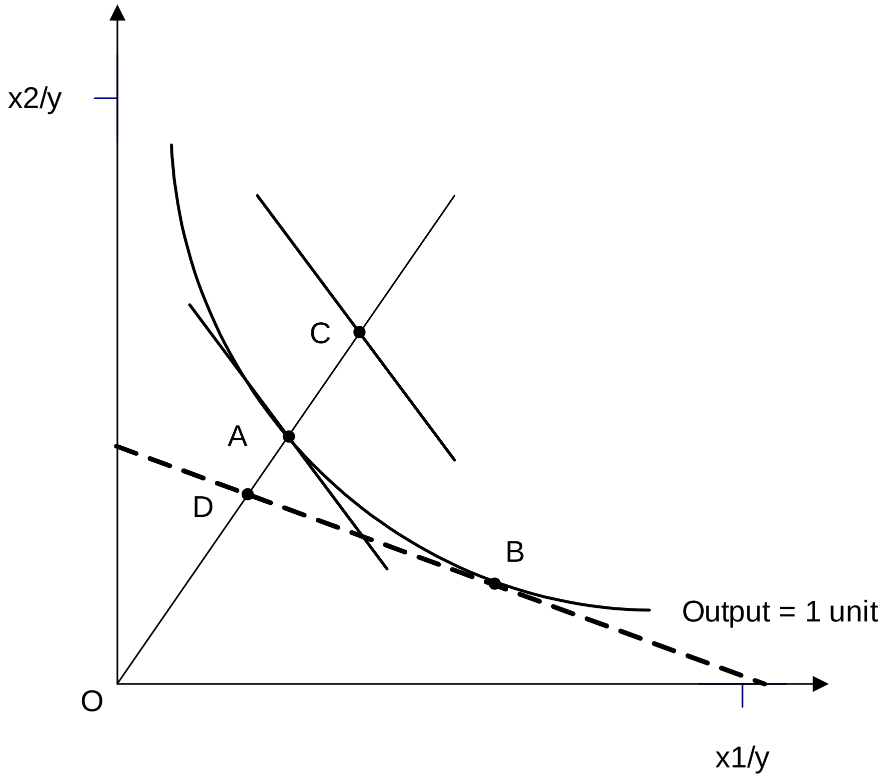
can potentially arise because farms are heterogeneous with respect to size, labour input, production technology, managerial ability and the fixity of assets. Furthermore, individual farms in AgriPoliS are boundedly rational, meaning that individual farms pursue the goal of individual farm income maximisation, but do not include other farm's objectives and behaviour into their planning and decision-making. Except for the price information on rents and product and input prices, individual farms in AgriPoliS do not know what other farms in the region are doing, what they produce, what specialisation they follow, what their size is, etc. Because of this, it is possible that a farm following successfully its maximisation objective produces efficiently with respect to itself, but is inefficient relative to other farms in the region.

The following sections introduce the various efficiency concepts and ways of measuring them. To measure individual farm efficiency, a DEA-based model is defined. In particular, the concept of structural efficiency is introduced. This is followed by the specification of the DEA model used in the policy analyses in chapter 7 and chapter 8. The average economic land rent in the region is employed as an appropriate indicator to assess the overall economic efficiency of agriculture in the region (see section 6.3.6).

6.3.2 Traditional efficiency measures of individual firms

Figure 6-3 depicts the technical relationship between two inputs x_1 and x_2 under the condition of a technology displaying constant returns to scale. The isoquants represent technically possible combinations of inputs to produce output. The figure shows that a firm operating at point C produces the output quantity y_1 as firm A and B; hence, firm C is technically inferior to firms A and B. A firm producing at point A uses less of both inputs to produce the same output quantity than firm C. Firm B uses less of input x_2, but more of input x_1 to produce y_1. If the same output cannot be produced with any less inputs than used by firm A and B, firms A and B are *technically efficient*. In other words, farms A and B lie on what is called the best-practice frontier defining the current state of technology. The technical efficiency of firm C can be measured by the distance *QC*. This is equivalent to the amount by which all inputs could be reduced to produce the same output; hence the term input-oriented efficiency measures. Based on this, the input-oriented measure of technical efficiency of firm C is defined as $TE_C = OA/OC$. Whenever $TE_C = 1$, the input-output set is called fully efficient. If $TE_C < 1$, i.e., the distance *OC* is greater than *OA*, the technology is inefficient with inefficiency score given by TE_C.

Figure 6-3: Input-oriented Farrell technical and allocative efficiencies

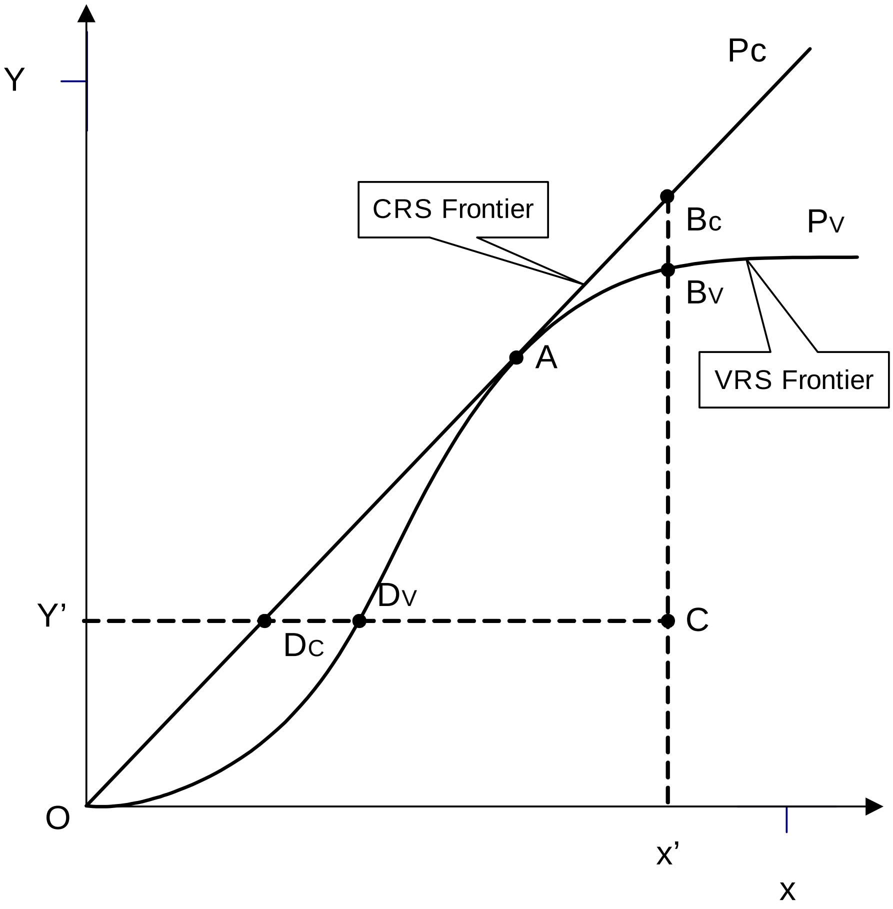


Sources: TOMICH et al. (1995); COELLI et al. (1999), modified.

To show the concept of allocative efficiency, input price relationships are shown in the figure by the straight lines. If all firms face prices of inputs x_1 and x_2 indicated by the solid lines, then the slope of the line identifies the allocatively efficient input proportions. In this sense, point C is allocatively efficient, but not technically efficient. Point B, on the other hand, is technically efficient but not allocatively efficient. Only point A is economically efficient, i.e. it is both technically and allocatively efficient. If prices change as depicted by the dashed price line, efficiency evaluations change. Now, point B is economically efficient, i.e., it is both technically and allocatively efficient. Point C is both technically and allocatively inefficient. Point A is no longer allocatively efficient. Using the distance measure, allocative efficiency of the firm C is then defined as $AE_C = OD/OA$. The distance DA represents the reduction of production costs that would occur if production were at the allocatively and technically efficient point B instead of A. Following Figure 6-3, it means that allocative inefficiency raises production costs by using other than the cost-minimising input combination (CURTISS 2002). Overall economic efficiency is defined by the ratio $EE_C = OD/OD = TE_C \times AE_C$.

The input-oriented efficiency measure addresses the question by which quantity inputs can be reduced to produce the same level of output. Alternatively, the question could be asked from an output-oriented point of view, namely, by how much output could be increased using the same quantities of inputs. The following Figure 6-4 depicts a simple one-input, one-output production frontier.

Figure 6-4: Output-oriented technical and scale efficiency



Source: COELLI et al. (1999), modified.

Consider the inefficient firm operating at point C. The Farrell input-oriented measure of technical efficiency would be equal to the ratio $TE_C^i = Y'D_C / Y'C$ under constant returns to scale which is depicted by production frontier *Pc*. The equivalent output-oriented measure would be measured as $TE_C^o = x'B_C / x'C$. Accordingly, in the output-oriented framework, an efficient firm has an efficiency score of one. If $x'B_C > x'C$, the firm is inefficient. Hence, the output-oriented efficiency measure is bounded by unity at the lower end. Output-oriented and input-oriented efficiency measures are equivalent only when constant returns to scale exist (FÄRE and LOVELL 1978). Assuming a variable returns to scale technology (production frontier P_v), it is obvious from Figure 6-4 that input and output-oriented measures are no longer equivalent.

The assumption of constant returns to scale is only appropriate if all farms operate at an optimal scale. A firm is scale efficient if it exhibits constant returns to scale, i.e., if the average product is at its maximum (FÄRE et al. 1987). Following FÄRE et al. (1987), the assumption of constant returns to scale can be released to allow also for technologies with variable returns to scale. This results in a measure of technical efficiency consisting of two components, 'pure' technical efficiency and scale efficiency (SE). The concept of scale efficiency is also illustrated in Figure 6-4. In this figure, a firm operating at point A is scale efficient (and technically efficient). In other words, at point A an increase in input x would lead to a proportional increase in output Y. Production on the production function using higher inputs (to the right of point A) show decreasing returns to scale, production using fewer inputs (to the left of point A) exhibits increasing returns to scale. The output-oriented technical inefficiency of firm C would be CB_V under variable returns to scale, and CB_C under constant returns to scale. Accordingly, the distance $B_C B_V$ describes scale inefficiency, whereas CB_V corresponds to 'pure' technical inefficiency. Scale efficiency is measured as $SE = TE_{CRS} / TE_{VRS}$ which is equivalent to the distance ratio $x'B_C / x'B_V$ (COELLI et al. 1999). Hence, a firm operating at point B_V could increase output by the distance $x'B_C / x'B_V$ if it were operating at an optimal scale. All output-oriented and scale efficiency measures are bounded by one at the lower bound.

6.3.3 Non-parametric estimation of technical efficiencies

DEA utilises linear programming methods to construct a piece-wise frontier over the data (CHARNES et al. 1978; COELLI et al. 1999). DEA is non-parametric in that the frontier is estimated based on given data. Therefore, efficiency scores of individual firms are estimated exclusively based on available firm data.[74] The following linear programming problem is used to estimate the Farrell-type output-oriented technical efficiency. Assume that there are k ($k = 1, \ldots, K$) farms in the sample. Assume that each farm k's technology, i.e., its production frontier, can be described by its output sets $P^k(x^k) = \{y^k : x^k \text{can produce } y^k\}$, where vector $x^k = (x_1^k, x_2^k, \ldots, x_N^k)' \in \Re_+^N$ denotes N inputs that farm k uses to produce a vector of M outputs, denoted by $y^k = (y_1^k, y_2^k, \ldots, y_M^k)' \in \Re_+^M$. Inputs and outputs are assumed freely disposable. The Farrell output-oriented technical efficiency

[74] DEA furthermore avoids a parametric specification of technology and the distribution of efficiency scores. Furthermore, DEA shows to have good statistical properties (KNEIP et al. 2003; KNEIP et al. 1998).

of farm k defined for all (x^k, y^k) is defined as $TE^k(x^k, y^k) \equiv \max\{\theta : \theta \cdot y^k \in P^k(x^k)\}$. The DEA estimator of frontier $P^k(x^k)$ is determined using the following optimisation problem

$$\begin{aligned}
&T\hat{E}^k(x^k, y^k) = \max\{\theta : \theta \cdot y^k \in \hat{P}(x)\} \\
&s.t. \quad y\lambda \geq y_k \\
&\qquad\;\; \theta x_{ki} \geq x\lambda \\
&\qquad\;\; K'\lambda = 1 \\
&\qquad\;\; \lambda \geq 0
\end{aligned} \tag{6.1}$$

where θ represents the overall Farrell output-oriented technical efficiency $(\theta \geq 1)$under the assumption of weak disposability of inputs.[75] y is the observed vector of outputs, x is the observed vector of inputs. Firm weights are represented by a $K \times 1$ vector λ, where K is the number of firms in the sample. This problem formulation takes the input-output specification of firm k and then seeks to maximise the output vector, while keeping inputs fixed (COELLI et al. 1999). The first and second constraints reflect strong disposability (SD) of outputs and inputs, respectively. The third constraint $K'\lambda = 1$ implies a variable returns to scale technology (VRS). When this constraint is dropped, the underlying technology is constant returns to scale (CRS).

6.3.4 *Structural efficiency of a group of firms*

The measurement of *technical efficiency* of a group of firms, the component parts of a structure, is not new. Already in his seminal paper, FARRELL (1957) introduced a concept of 'structural efficiency of an industry'. According to Farrell, the structural efficiency of an industry measures (p. 216-262) *"… the extent to which an industry keeps up with the performance of its own best firms…"*. It can be measured by the average (weighted by output) of its individual units' efficiency scores. In other words, if all firms perform equally the industry is structurally efficient; otherwise, it is inefficient.[76] However, Farrell has not further

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75 All results were obtained using Matlab and the (modified) code originally programmed by SIMAR and ZELENYUK for their (2003) paper.

76 This particular example may also suggest that structural efficiency can be interpreted as a measure of heterogeneity of a group as done by CANTNER and HANUSCH (2003). However, the authors do not explicitly a measure of structural or aggregate efficiency.

elaborated on his concept beyond the one output, constant returns to scale case.[77]

Recently, FÄRE and ZELENYUK (2003) have extended the structural efficiency concept to the multi-output case. They propose a simple measure of structural efficiency, which is derived from the relationship that *"…maximised industry output (revenue) equals the sum of maximised firms' revenues"*. Based on this relationship, the structural efficiency of a group of firms corresponds to the sum of individual firm efficiency scores weighted by output shares.

However, what is of interest to many researchers is not only the efficiency of a system as a whole, but also the efficiency of various sub-groups within the system. Applied to agricultural policy analysis this gives rise to the following questions: What are the efficiencies of distinct groups of firms operating under different policy regimes? Which group is more efficient? Why is it more efficient?

Based on these questions, SIMAR and ZELENYUK (2003) present a methodology for analysing and comparing the efficiency of various economic systems: firms, industry, regions, etc. The method merges two recent streams of literature in efficiency analysis, aggregation and the smooth bootstrap. Aggregation is used to derive consistent estimates of the structural efficiencies of different sub-groups of firms.

In this thesis, SIMAR and ZELENYUK'S (2003) approach is applied to study the relationship between the efficiency of regional agricultural structures and certain agricultural policies at different points in time. Instead of looking at different sub-groups within one region, a sub-group is interpreted as a regional agricultural structure under one policy scheme. To compare different policies one frontier for the different policies is therefore estimated. Individual firm efficiency estimates underlying the structural efficiency measure are estimated using DEA assuming output-orientation. The smooth bootstrap (SIMAR and WILSON 2000; KNEIP et al. 2003) is used to derive confidence intervals of the structural DEA efficiency estimates and to test for the equality of structural efficiencies of one or more sub-groups.

[77] Only in recent years, a number of studies have explored the concept anew (BLACKORBY and RUSSELL 1999; FÄRE and ZELENYUK 2003; LI and NG 1995; SENGUPTA 1997; YLVINGER 2000). YLVINGER (2000) provides a critical review of even earlier studies pointing out that some approaches yield inconsistent measurements of structural efficiency.

More formally, based on SIMAR and ZELENYUK (2003), a technical structural efficiency measure is derived as follows. Let l be a region under policy scenario l consisting of K firms. Total input allocation within region l is denoted by $X^l = (x^{l,1},\ldots,x^{l,K})$ and the sum of output vectors of all firms in the l^{th} region is $\bar{Y}^l = \sum_{k=1}^{K} y^k$. The output set of a region $\bar{P}^l(X^l)$ is assumed to correspond to the sum of the individual output sets of all firms in the region. The aggregate structural technical efficiency of region l corresponds to the price-independent output-share-weighted sum of individual firm technical efficiencies, i.e., $\overline{TE}^l = \sum_{k=1}^{K} TE^{l,k}(x^{l,k}, y^{l,k}) \cdot S^{l,k}$ with $S^{l,k} = \frac{1}{M}\sum_{m=1}^{M} \frac{y_m^k}{\bar{Y}_m}$. Measure $\overline{TE}^l$ is a multi-output generalisation of what Farrell called the 'structural efficiency of an industry' (SIMAR and ZELENYUK 2003). The measure assumes the standardisation proposed by FÄRE and ZELENYUK (2003) for making output weights price-independent. This particularly avoids that price information impacts the structural measure of technical efficiency. To estimate structural efficiency scores, first, individual farm efficiency scores are estimated using the DEA model in section 6.3.3, which, in a second step, are aggregated to structural efficiency scores. After structural efficiency scores have been determined, a bootstrap is carried out as in SIMAR and ZELENYUK (2003) to determine confidence intervals, bias-corrected estimates and standard errors of the structural efficiency estimates. Confidence intervals are used to statistically test for differences between structural efficiencies of regions and policy regimes. Details of the bootstrap and the statistical test are given in appendix A-3 and A-4.

6.3.5 *Application to data simulated for Hohenlohe*

In this subsection, the model setup in the previous subsections is adapted to the region Hohenlohe. In particular, input and output specifications are given. Results are presented in the respective policy experiments in chapters 7 and 8.

6.3.5.1 Inputs

The DEA model adapted to simulated data from the Hohenlohe region considers four input variables and one output variable. Input variables include the main production factors, land, labour, capital, and intermediate inputs. Labour enters the model as the total annual hours used for agricultural production. The variable includes farm-family labour as well as fixed and variable hired labour. Labour input can vary substantially between farms, depending on the economic and physical size of the farm, operation of a professional or non-professional farm, and depending on the labour requirements of differently sized assets. Land is included as total land in hectares managed by a farm. Capital is included as the aggregate of average annual capital costs of fixed assets including interest on equity and borrowed capital, interest on floating capital, the value of milk quota, and the costs of services provided by private contractors.[78] Book values as a proxy for capital could not be used because in AgriPoliS depreciation is progressive such that farms with relatively young assets (high book value) would be discriminated against farms with old assets (low book value). This would also distort the determination of adequate capital costs because new or relatively new assets are assumed technically more advanced than relatively old assets. The fourth input variable is variable production costs, i.e., costs of fertiliser, feedstuff, seeds, etc. Variable production costs vary across farms either because of the assumed differences in managerial ability, and secondly because of the individual farm's investment activity.

6.3.5.2 Output

Output is considered in value terms as total revenue.[79] It includes all agricultural products in addition to manure exports and imports (see chapter 3 and 4), fines for exceeding the maximum permissible stocking density, and set aside. Subsidies, i.e. compensatory payments, and direct payments are not included. All farms face the same output prices. This is an important assumption required for the aggregation procedure (cf. FÄRE and ZELENYUK 2003). Appendix A.5 shows a detailed listing of all inputs and output considered.

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78 The use of milk quota as a production input is questionable because from a technical point of view it is not necessary input for producing milk. However, one may argue that under the current (and future) policy regime in the EU, milk quota is not a technical requirement for production, but just grants the right to produce milk. If quota costs were not included into the model, some farms could take advantage of selling quota.

79 In a previous DEA-model specification, total gross margin was taken as output, such that variable costs were dropped on the input side. This model resulted in larger (statistically significant) differences in efficiency scores between policy scenarios. The model specification is, however, problematic as gross margin includes both inputs (variable costs) and outputs (revenue). In the literature (e.g., BALMANN and CZASCH 2001; OUDE LANSINK et al. 2002; LISSITSA and BALMANN 2003; ONDERSTEIJN 2002) it is common to define output in terms of revenue or in physical terms, whereas variable costs are included on the production side. To avoid theoretical inconsistencies also in this application revenue was chosen as output.

6.3.5.3 Assumptions

Based on this model specification, the DEA model is estimated assuming constant returns to scale technology and output-orientation. Constant returns to scale imply that all farms in the sample operate at an optimal scale. The resulting individual farm efficiency scores are greater or equal to unity. Efficiency scores greater unity denotes inefficiency.

The choice of constant returns to scale needs to be further explained. Although constant returns to scale imply all farms to operate at an optimal scale, the underlying simulated data sample by definition includes some diseconomies of scale introduced, for example, by the assumption about technological change (see chapters 4 and 5). Despite of this inconsistency, constant returns to scale are still imposed in the DEA estimation mainly because of two reasons: One is that constant returns to scale in addition to variable returns to scale allow identifying scale differences between farm agents. Secondly, under variable returns to scale, each farm agent in the sample is only compared to similar farms. Consequently, a small farm using old technology and operating at high costs may turn out to be technically efficient because it is benchmarked only against similar farms. Despite of being efficient under variable returns to scale, these farms nevertheless often fall victim to structural change in the simulations. The reason is that all farms in a region compete, for example, for land, irrespective of their size and specialisation. The assumption of variable returns to scale thus tends to distort the link between efficiency and farm survival such that farm survival cannot be attributed to efficiency advantages. When assuming constant returns to scale, competition between all farms in the region is explicitly introduced in the DEA estimation.

The assumption of constant returns to scale together with technological change in the data has one further consequence. Because of the presence of technological change in the data, it is no longer only technical differences that are measured by the DEA estimates, but also differences in productivity. Farms with a more advanced technology produce the same output at lower costs. Because of this, the use of the term 'technical efficiency' is dropped in the analysis of results but replaced by 'individual efficiency' which includes the combined effect of technical, scale, and productivity differences.

6.3.6 Measuring overall economic efficiency

Since only one output is considered in the DEA model, technical and allocative efficiency as defined above are the same. However, to assess the allocation of production factors in the region, economic land rent is utilised as an indicator. This is done in analogy to BALMANN (1996).

Economic land rent is based on the functional income of land. It provides a measure of the residual utilisation of land after all other production factors (labour, capital) have been paid for. If calculated at the individual farm level, economic land rent is an indicator for the utilisation of production factors of the farm. Alternatively, it can be calculated as a regional average which serves as an indicator of factor allocation in the entire region.

In this study, economic land rent is measured as total household income (which corresponds to farm net value added plus off-farm income) minus by opportunity costs of capital and farm family labour.[80] Economic land rent as used in this study was defined at the beginning of this chapter in Figure 6-2. Long-term opportunity costs of farm-family labour are valued at the comparative salary of an industrial worker.

To draw conclusions about the allocation of all factors in the region, economic land rent is furthermore adjusted by support payments as well as realised sunk costs of farms leaving the sector to take account of productive capital that is no longer used. The economic land rent calculated here takes a long-term perspective because it includes also the costs of fixed assets, i.e. it includes depreciation. In the short-term, depreciation is not considered.

6.4 Other analysis techniques

6.4.1 Kernel density estimation

The goal of density estimation is to approximate the probability density function $f(\bullet)$ of a random variable *X* (HÄRDLE et al. 2000). Assuming that there are *n* independent observations $x_{1,\ldots,}x_n$ from the random variable *X*. The kernel density estimator $\hat{f}_h(x)$ to estimate the density value *f(x)* at point *x* is defined as

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80 This adjustment to the way economic land rent is calculated may be justified by the fact that in particular non-professional farms cross-finance farm activity with income earned off-farm. This, in turn, can be interpreted as a household-internal transfer payment, which in the end adds stability to the farm household. On the other hand, all family owned labour, i.e., also labour not used on-farm is considered when opportunity costs of labour are calculated.

$$\hat{f}_h(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x_i - x}{h}\right), \qquad (6.2)$$

where K is the so-called kernel function which satisfies the condition $\int_{-\infty}^{\infty} K(x)dx = 1$, h is the bandwidth parameter. In this thesis, K is a symmetric normal probability density function (Gaussian kernel). The critical parameter in density estimation is the bandwidth h. All density estimates presented in this thesis are computed using Matlab code by BEARDAH (2003). The bandwidth chosen is the Silverman bandwidth (SILVERMAN 1986, p. 47) which is computed as $h = 1.06 \cdot An^{-1/5}$ with

$$A = \text{min(standard deviation, interquartile range/1.349)}. \qquad (6.3)$$

Density estimations of efficiency scores are estimated using a Gaussian kernel and bandwidth based on the method by SHEATHER and JONES (1991).

6.4.2 The Lorenz curve and the Gini index

To measure equality or inequality of income within in a population, the Lorenz curve and the Gini index are two popular and widely used approaches. The Lorenz (or concentration) curve describes the distribution of income in a population. The Lorenz curve represents cumulative income share as a function of the cumulative population share (SHKOLNIKOV *et al.* 2003). The Lorenz curve as a function varies from 0 to 1 and is defined on the interval [0,1]. In a situation of perfect equality for any income, the Lorenz curve is simply a diagonal, connecting points (0,0) and (1,1). If income were distributed unequally, the Lorenz curves for income distributions would lie below the diagonal. The higher the variability in income across a population, the greater is the divergence between the diagonal and the Lorenz curve.

The Gini index is a numerical measure of inequality based on the Lorenz curve. The Gini index is a measure of divergence between the Lorenz curve and the line of perfect equality. It is defined as the area between the Lorenz curve and the line of absolute equality, divided by the whole area below the diagonal (equal to 1/2). Analytically the Gini index can be expressed as

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n(n-1)\bar{x}}, \quad (6.4)$$

where the Gini coefficient is one-half of the average of absolute differences between all pairs of a variable x in a population of size n by the average value $\bar{x}$ of the variable: If the variable is ordered by size, then the formula changes to

$$G = \frac{\sum_{i=1}^{n}(2i - n - 1)x_i}{n(n-1)\bar{x}}, \quad (6.5)$$

When based on individual data and when observations are positive, the index ranges from 0 to 1 (OECD 1994). An index of 1 indicates absolute inequality, a coefficient of 0, absolute equality.

6.5 General assumptions underlying the policy analyses

The policy experiments conducted in the following chapters are based on a number of assumptions. Most of these have been mentioned before, either in chapter 4 or in this chapter, but they shall be repeated here. Assumptions specific to a policy experiment will be discussed in the respective chapters.

- Simulation length: Each policy scenario is simulated for 25 periods. This appears a sufficiently long time frame to asses short-term, medium-term and long-term effects of a policy. A longer time frame would be interesting only if the long-term behaviour of AgriPoliS was of interest. In this thesis, this is not done, though.
- Policy change: Each policy scenario is initialised with the reference policy Agenda 2000. Only after 4 simulation periods, a policy change toward an alternative policy sets in.[81]
- Parameter settings: All policy scenarios are based on the data and parameter settings specified in chapter 4. Exceptions are the increase in opportunity costs of labour when a farm is handed over to a successor. Whereas in

[81] Following the convention in the C++ programming language, counting starts with zero, i.e. time period t=3 is the fourth time period in the simulation.

chapter 4 and 5 opportunity costs were assumed to increase by 15%, the value assumed in the policy experiments is 25%. This appears a more reasonable assumption in view of real wage differences between small-scale farms and industrial workers' wages.

- Region size: Although altogether 2800 farms were situated in Hohenlohe in 2000/2001 (see chapter 4), it proved to be technically infeasible to simulate always the entire regions. The reason was mainly, that output files exceeded the maximum permissible number of rows supported by most analysis programmes (e.g. Microsoft Excel, SPSS). However, in chapter 5, section 5.2, some evidence was delivered that the size of the region simulated did not have significant impact on results. Although this was not investigated for policy scenarios other than the reference, in the policy experiments, 20% of the total region is simulated. This means that the respective scaling factors derived for each of the 24 typical farms (see Table 4-3 in chapter 4) was divided by five such that 572 farms were initialised.[82]
- Prices and variable costs: Prices are assumed the same for all farms. Unit costs, however, vary between farms depending on managerial ability and technical change due to farm investment activity (see chapter 4 for details). Because of the relatively small size of the region and the family farm-dominated structure, it can be expected that farms are price takers.83 Prices therefore do not change in response to quantities produced. However, a pressure on some output prices was introduced (see chapter 4).
- Price changes: Product prices as well as prices of short-term variable and fixed labour are assumed to decrease (or in case of labour and capital) increase as specified in Table 4-11 in chapter 4.
- Costs of fixed assets: Once a farm invests, costs of the investment are assumed fully sunk, i.e., opportunity costs are zero throughout the entire useful life of the investment.
- Education of farm agents: Farm agents are assumed equally smart with regard to their ability to work off-farm. Moreover, it is assumed that all farmers have the same opportunities to work off-farm, irrespective of age.

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82 Just to illustrate, a full simulation produces output files of up to 80 MB of data. An analysis of the impact of the region size is presented in chapter 5.

83 This assumption has to be loosened if large scale farms are concerned, as these farms are more in the position to negotiate about prices of inputs as well as about output prices.

7 Retirement payment, phasing out, and a decoupled single farm payment

7.1 Introduction and policies analysed

The general introduction (chapter 1) identified some impacts of agricultural support policies on structural adjustment and possible impediments to adjustment caused by existing agricultural support policies. The starting point of the analysis in this and the next chapter is the hypothesis that Hohenlohe's agricultural structure displays structural inefficiencies because structural adjustment in the past has been impeded by existing agricultural policies and factor immobilities. In addition, this effect is aggravated by existing structural difference, which can be attributed mainly to three phenomena: unexploited returns to scale, adjustment costs causing the immobility of production factors, and path dependencies meaning that a path, e.g. a specialisation or the emergence of a specific structure once taken, can only be left at high costs.

Based on this, the aim of this chapter is to simulate and analyse the effects of three different policy reforms aimed at reducing some of these impediments to structural adjustment while, at the same time, increasing the efficient allocation of production factors. Even if, in reality, a bundle of (often complementary) policies affects structural change, the simulation experiments in this chapter consider one policy at a time. The aim is to identify the specific adjustment patterns induced by the respective policy measure. The emphasis is on support given by way of direct payments. A variation of market price support is not considered here.

The policies considered in this chapter are listed in Table 7-1. The *first* policy, RETPAY, is a factor market policy that intends to provide an incentive for small and inefficient farms to withdraw from the sector. The reasoning behind this policy must be seen against the structural deficits mentioned before. In fact, in Hohenlohe – as in many regions in southern Germany –large amounts of family-labour are bound in agriculture either in very small farms with labour intensive older technologies, or in non-professional farms (chapter 4). Hence, it could be envisaged that an incentive payment for relatively unproductive farms to withdraw labour from agriculture could lead to overall efficiency increases of farming in the region. The policy is introduced such that an incentive payment is offered to all farms, but only farms willing to withdraw receive the payment.[84] In this scenario, everything else but the introduction of the retirement payment is kept equal, i.e. remaining farms operate under Agenda 2000 policy conditions and get the corresponding coupled direct payments.

Table 7-1: Policy scenarios

Abbreviation	Scenario name	Scenario description
REF	**Agenda 2000**	- Full implementation of Agenda 2000 at the end of 2002 - No requirement to manage all land belonging to a farm
RETPAY	**Retirement payment**	- Payment of 10,000 Euros if a farm withdraws from the sector - Leaving farms receive payment for the next 20 periods - Policy environment for active farms is Agenda 2000 - No requirement to manage all land belonging to a farm
PHASEOUT10	**Phasing out of coupled direct payments**	- Linear cut of coupled direct payments as granted under Agenda 2000 over 10 periods - After this, farms operate without subsidies - No requirement to manage all land belonging to a farm
DECOUP	**Fully decoupled single farm payment**	- Each farm household receives a decoupled single farm payment based on the average direct payment paid to a farm during three periods before the policy change - Bound to person of the farmer and legal successor - Single farm payment is granted independent of farming, i.e. it is also paid if a farm leaves the sector, for the next 20 periods after policy change - Farms are required to manage all farmland belonging to a farm at least in a very basic way (cutting)

The *second* policy option (PHASEOUT10) is a step-wise reduction of direct payments granted to farms over 10 time periods. At the final stage, after 10 periods, support to agriculture is zero. Unlike policy RETPAY, the general direction of adjustment, which could be expected from a step-wise reduction of direct payments, is twofold: on the one hand, farms can be expected to diversify into areas with highest productivity, which are less dependent on direct payments. On the other hand, farms whose development potential is low are expected to

[84] Unlike retirement programmes offered within the second pillar of the EU common agricultural policy, the payment introduced here is independent of the age of the farmer. The reason is that the policy is directed at marginal farmers in general.

not renew fixed assets or rental contracts. Whenever the operating life of fixed assets is reached, these farms are expected to leave the sector.

Finally, the *third* policy is geared to increasing the market orientation of production while providing a safety net at the same time to farms through direct payments. Policy DECOUP introduces fully decoupled single farm payment granted exclusively to the person of the farmer. The payment replaces the coupled direct payments to certain products mentioned in chapter 4. The single farm payment is granted independently of farming, i.e., production decisions are decoupled from the provision of payments to certain products. The payment is to give farm agents greater flexibility and to increase their market orientation.[85] In this scenario, the single farm payment granted to each farm agent after a policy change is based on historical payments during a reference periods before the policy change. In the literature, a switching to a single farm payment independent of farm activity is expected to have significant effects on factor markets (see e.g., WISSENSCHAFTLICHER BEIRAT BMVEL 1997; SWINBANK and TANGERMANN 2000; OECD 1994). For example, a decoupled single farm payment could serve as an incentive payment for marginal farmers to withdraw, particularly because the right for the payment remains with the person of the farmer who initially acquired the payment. Hence, the payment should not be transferred into rental prices but rental prices would be at the level of the economic land rent without subsidies. In addition, it is assumed that the bargaining position of farmers on the land market increases (cf. ISERMEYER 2003). To reflect these two aspects in the farm agents' opportunity cost calculations at the end of each period, the specific expectation formation regarding rental prices is changed. As for fully decoupled payments it is assumed that farms expect rental prices (and hence opportunity costs of land) for arable land (grassland) to drop to some 75% (50%) of the regional average.[86]

Having introduced the policy scenarios considered in this chapter, the following sections present results using the analytical framework introduced in chapter 6. As outlined in chapter 6, each policy scenario is simulated over 25 time periods. The policy change sets in after four simulation periods. Simulation results are analysed from different perspectives: structural development, efficiency, and income. At the end of the chapter, results are discussed in a synopsis. To give an overview of results the next section presents a brief summary.

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85 In this and the following chapter, the terms farm agent and farm are used interchangeably.

86 Different values for the expected decrease of rental prices were analysed as well but the

7.2 Summary of results

The goal of this section is to show and discuss selected results for each policy experiment to stimulate the in-depth analysis in the following sections. To provide a preliminary overview about reactions to a policy change, Table 7-2 combines information on farm types with averages for key indicators, and the number of farms in each group. Two time periods are considered, one before a policy change (t=3), and a second shortly after the policy change (t=6). Longer-term effects are discussed further down in the chapter. The table illustrates the average short-run change of key indicators such as farm size, income (with profits from agriculture as a proxy), equity change and stocking density induced by a policy change.

As regards farm size development in the region, certain scenarios (DECOUP and RETPAY) create strong exit dynamics already in the short-run. In the case of policy RETPAY, more than half of the farm agents leave the sector within three periods after the policy change. Accordingly, average farm size increases. These policies have in common that they provide incentive payments for non-profitable farms to leave the sector. These same policies also lead to a concentration of specialised granivore farms (pig and poultry production) in the region. Specialised field crop farms and grazing livestock farms almost vanish completely in response to a policy change.

Farm income is generally higher on average for scenarios DECOUP and RETPAY because of the aforementioned reasons. Farm income varies not only by farm type, but also by policy scenario. In this respect, the only aspect to be highlighted here is the fact that in all policy scenarios (except for scenario RETPAY), average profits of specialised field crop, grazing livestock, and mixed farms are below the average of all farms. This suggests that in response to a policy change, farms either move away from crop and grazing livestock production and reorganise, or leave the sector altogether.

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assumed figures appeared to lead to most plausible results.

Table 7-2: Key indicators by farm type groups before the policy change (t=3) and shortly after the policy change (t=6)

Indicator (Averages)	Farm type [a]	All policy scenarios	REF	RETPAY	PHASEOUT10	DECOUP
		t=3	t=6	t=6	t=6	t=6
Number of farms	*Total*	*530*	*484*	*236*	*463*	*344*
	Spec. field crops	91	77	2	65	1
	Grazing livestock	68	56	3	48	21
	Spec. granivore	236	249	176	262	239
	Mixed	135	102	55	88	83
UAA (ha)	*Total*	*28*	*30*	*62*	*31*	*41*
	Spec. field crops	13	14	199	13	128
	Grazing livestock	36	32	82	33	32
	Spec. granivore	32	35	57	36	43
	Mixed	25	32	72	33	35
Farm income/profit (€/farm)	*Total*	*27,348*	*30,461*	*48,154*	*28,981*	*39,241*
	Spec. field crops	5,871	6,532	40,478	4,954	35,375
	Grazing livestock	30,381	26,463	59,622	24,668	30,349
	Spec. granivore	40,340	42,278	52,011	38,608	45,298
	Mixed	17,589	21,874	35,466	20,422	24,097
Equity change (€/farm)	*Total*	*4,845*	*5,450*	*7,903*	*4,779*	*7,058*
	Spec. field crops	2,446	2,649	6,388	2,149	7,896
	Grazing livestock	4,195	4,039	9,052	3,374	5,534
	Spec. granivore	6,924	7,335	8,857	6,253	8,130
	Mixed	3,156	3,740	4,842	3,101	4,346
Regional stocking density (LU/ha)[b]	*Total*	*1.7*	*1.7*	*1.5*	*1.7*	*1.54*

Notes: a) Farm type classification based on EU classification (see HESSENAUER 2002) using gross margins in chapter 4 as standard gross margin;
b) Based on total livestock divided by farmland.

On the opposite, average profits are significantly above the regional average for specialised granivore farms. What can be observed for profits also applies to the change in equity. Here, as well as for farm income, the level of change in equity is directly related to the size and the number of farms in the region. An exception to this is policy PHASEOUT10, where the stepwise premium cut on average leads to lower income and lower changes in equity compared to all other policy scenarios irrespective of farm type. As regards stocking density, a switch towards policies RETPAY and DECOUP, on average, leads to an immediate fall in livestock production intensity in the region. However, stocking densities may be higher on individual farms specialising in livestock production (see 7.3.3).

7.3 Structural adjustments following a policy change

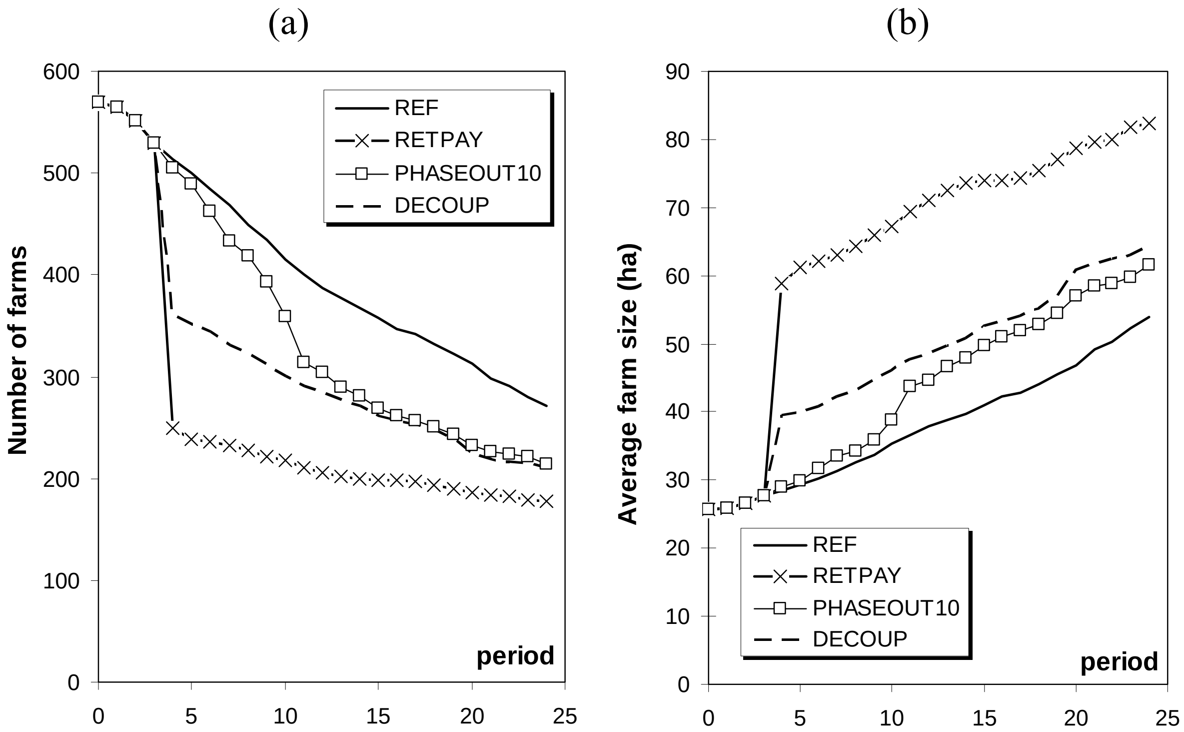
The purpose of this section is to illustrate and discuss key structural effects of the policies defined in Table 7-1 on the agricultural structure of Hohenlohe. In particular, two questions are of interest when interpreting the results: Why do farm agents withdraw from the sector under each policy scenario? How do surviving farm agents in the sector develop with regard to production? The first question will be answered in sections 7.3.1 and 7.3.2 which are devoted to the analysis of farm size changes. As regards the second question, this relates to the activities of farms remaining in the sector. Answers to this question will be given in section 7.3.3.

7.3.1 Farm size dynamics

The evolution of the total number of farms in the region and the average farm size measured in hectares are shown in Figure 7-1.[87] The figure demonstrates clear differences between policy scenarios. It illustrates that the number of farms withdrawing is particularly large in case of the retirement payment. The suddenly decreasing number of farms indicates that many farms take the retirement payment as an opportunity to leave the sector. Thus, for more than 50% of the farms, an annual payment of 10,000 € results in a higher total household income compared to regular farm activity. Because so many farms withdraw, this offers scope for the remaining farms to grow. Figure 7-1 (b) shows that the average farm size doubles immediately after the policy change.

[87] The source of all other figures and tables in this chapter is simulated data. Data has been compiled and prepared by the author.

Figure 7-1: Evolution of (a) number of farms and (b) average farm size



Taking into account that farms can only increase their acreage by renting additional land, the share of rented land increases by up to 30 percentage points over 25 time periods (Table 7-3). After the initial adjustment reaction, average farm size in scenario RETPAY develops parallel to the reference and the number of farms leaving the sector is even below the reference. This indicates that the policy elicits an immediate and strong initial adjustment reaction, which is followed only by small but nevertheless steady further adjustments after the policy change.

Fully decoupled direct payments granted in policy DECOUP have a similar initial effect on the number of farms and on average farm size than a retirement payment, though at a lower level. The fact that farms receive decoupled payments irrespective of agricultural production leads some farms to quit and to take the decoupled single farm payment as a kind of retirement payment. With respect to this, the two policies induce a similar adjustment reaction at the aggregate level.

Table 7-3 Land use by farms and share of rented land in region for different policy scenarios and time periods

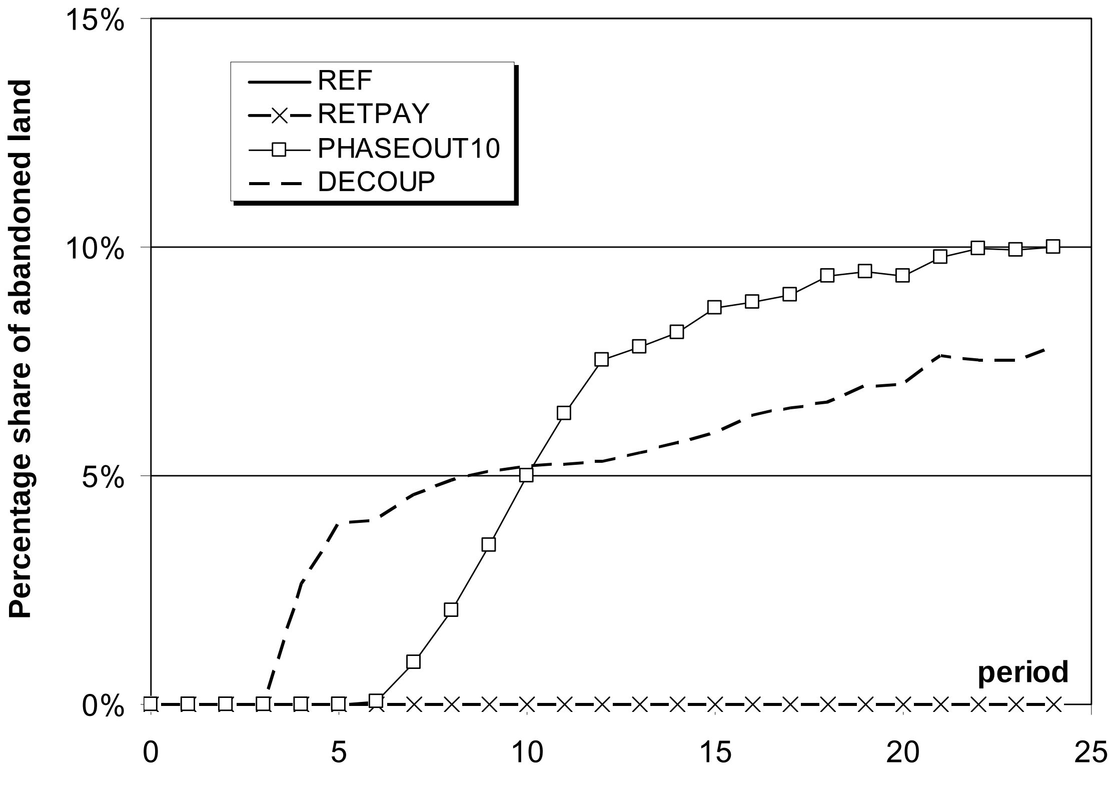
Time period	REF	RETPAY	PHASEOUT10	DECOUP
Before policy change (t=3)				
Total land use (ha)	14,645	14,645	14,645	14,645
Share of rented land	*40.0%*	*40.0%*	*40.0%*	*40.0%*
Short-term effect (t=6)				
Total land use (ha)	14,645	14,645	14,638	14,050
Share of rented land	*43.4%*	*63.4%*	*45.2%*	*53.2%*
Medium-term effect (t=14)				
Total land use (ha)	14,645	14,645	13,453	13,805
Share of rented land	*52.3%*	*68.0%*	*56.6%*	*58.2%*
Long-term effect (t=24)				
Total land use (ha)	14,645	14,645	13,183	13,502
Share of rented land	*60.4%*	*71.0%*	*63.1%*	*64.1%*

Nevertheless, there are differences. One difference is that the retirement payment of 10,000 € per year induces more farms to withdraw than a fully decoupled single farm payment. Since in scenario DECOUP there are some farms with a single farm payment smaller than 10,000 € per farm, more farms remain in the sector under policy DECOUP than under RETPAY. In other words, only if expected yields in policy DECOUP are greater than total opportunity costs, but below 10,000 €, the farm would remain in the sector. In policy RETPAY, the same farm would withdraw from the sector. Accordingly, in particular with respect to small farms, policy RETPAY creates a strong incentive to leave the sector as the retirement payment of 10,000 € maybe significantly higher than the single farm payment granted in scenario DECOUP (see also Table A-9 in Appendix A.6). A second difference is that under policy scenario DECOUP some land is abandoned, i.e., it is not rented by farms (Table 7-3).

In scenario PHASEOUT10, the reasons for farms to leave the sector are different than in either policy DECOUP or RETPAY. As already mentioned in the introduction to this chapter, it is expected that farms with insufficient development potential do not reinvest in fixed assets or renew rental contracts; over time they are expected quit. In fact, in scenario PHASEOUT10, which introduces a gradual policy change over 10 periods, farmers need to adjust to gradually decreasing direct payments. Whereas in scenarios RETPAY and DECOUP the retirement payment as well as the decoupled single farm payment pull farmers out of the sector by providing an incentive payment, in scenario PHASEOUT10 farms are pushed out. When going back to Figure 7-1, one can additionally observe that the number of farms gradually declines in response to the stepwise payment cut. In this scenario, only unprofitable farms at the margin quit; i.e., farms whose opportunity costs of farm-owned factors are just above expected profits. A Farm with opportunity costs just below expected profits remain in the sector at least until the next premium cut, provided the farm's organisation remains unchanged until the next premium cut.

Compared to policies DECOUP and RETPAY, two phenomena are particularly about PHASEOUT10 interesting. On the one hand, after direct payments have ceased, which is 10 periods after the policy change, about the same number of farms remains in the region as in policy DECOUP, despite of no support payments. Figure 7-2 shows the percentage share of abandoned land, i.e., land, which is neither rented nor owned by farms. Accordingly, in scenario PHASEOUT10 all land is rented to farms only until period 6. One could thus conclude that the direct payment level in this period represents a kind of critical threshold below which land was abandoned.

Figure 7-2: Evolution of percentage share of abandoned farmland



Based on Table 7-3 and Figure 7-2 it becomes apparent that land is abandoned only when direct payments are either fully decoupled or if payments undergo successive cuts. The phenomenon of land abandonment thus directly relates to the provision of coupled direct payments. In the case of livestock production, direct payments are linked exclusively to production activities depending on grassland. This is reflected in revenue shares (Table 7-4) as well as in extremely low rental prices for grassland, which is shown in Figure 7-18.

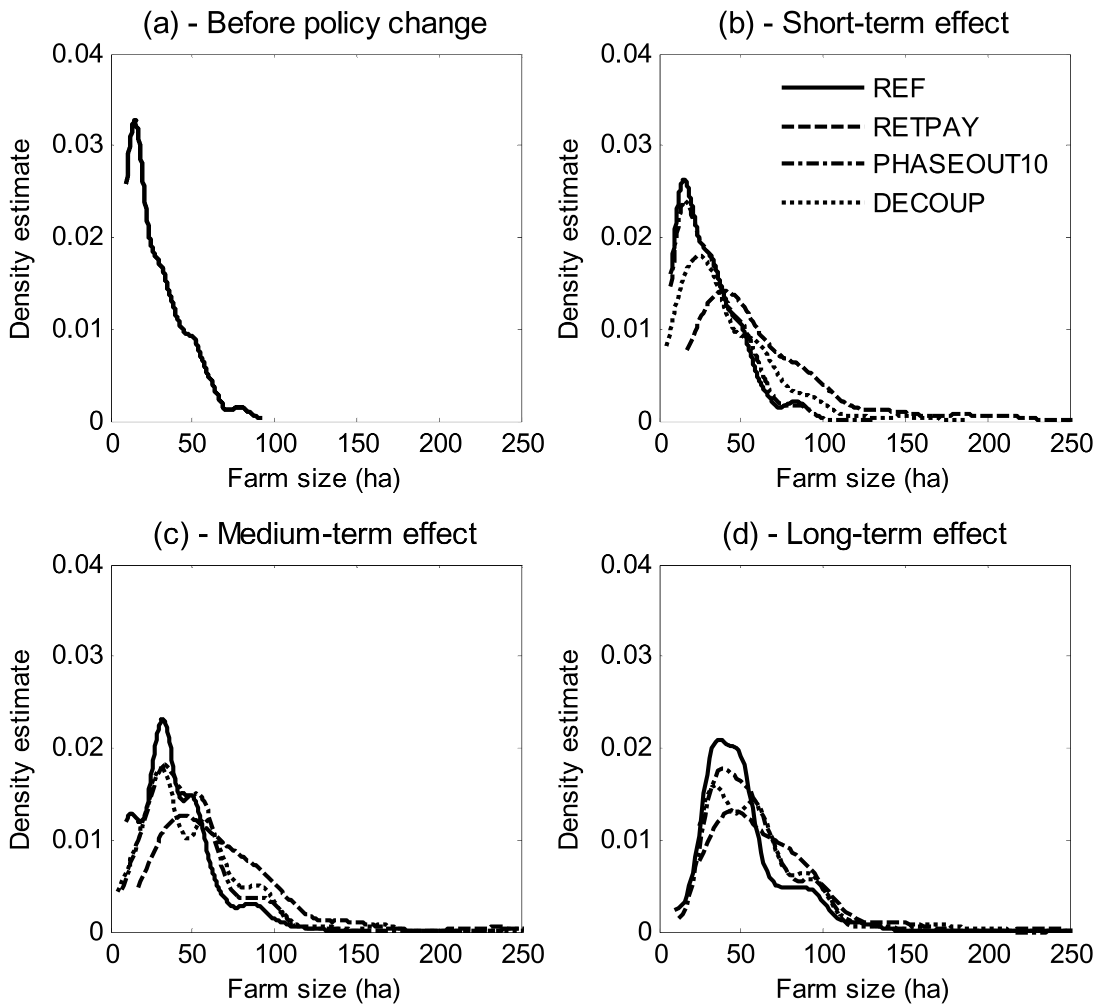
On the other hand, the number of farms in scenario PHASEOUT10 is consistently above the number of farms in scenario RETPAY. This suggests that under free-market conditions more farms would remain in the sector than in case of a retirement payment. From this, one could conclude that also farms with a development perspective leave the sector in response to the retirement payment. Whether or not this is the case, will be analysed – amongst other things – in the remainder of this chapter.

Kernel density estimates and cumulative density functions allow to analyse the distribution of farms in the region and to derive some insights about the evolution of surviving farms. The curves in Figure 7-3 and Figure 7-4 thus show the probability mass of the respective variable across the sample of farms at four time periods: before the policy change (time period t=3), the short-term effect (time period t=6), the medium-term effect (time period t=14), and the long-term effect (time period t=24).

In general, the distribution of farm size in all policy scenarios moves to the right, indicating farm growth. This is inline with the analysis of averages in Figure 7-1. Furthermore, particularly in the medium and long-run, the shapes of the curve are more pronounced for scenarios REF, DECOUP and PHASEOUT10 with peaks appearing at around 40 ha, 60 ha, and 90 ha. Hence, clusters of farms of similar sizes emerge. Nevertheless, distributions show differences, particularly if periods are compared.

For example, Figure 7-3 (b) illustrates the strong initial effect of policy RETPAY. Based on this figure, the significant shift in average farm size, observed in Figure 7-1, could be attributed to small farms withdrawing from the sector. On the one hand, this can be seen from the fact that the smallest farm, after introduction of policy RETPAY, has about 20 ha; i.e., even smaller farms either have quit or grown in size. On the other hand, the peak of the distribution is located considerably further to the right indicating the existence of more large farms compared to the other scenarios. In addition, a few very large farms emerge. It is interesting to observe that the retirement payment is only effective in the short-run, with many farms taking the opportunity to leave. This offers more growth potential to surviving farms. However, in subsequent periods, the retirement payment's incentive function, and the impact on structural change is negligible. Even though policies RETPAY and DECOUP both provide and incentives for labour to move out of farming, farm size distributions differ significantly between the two scenarios.

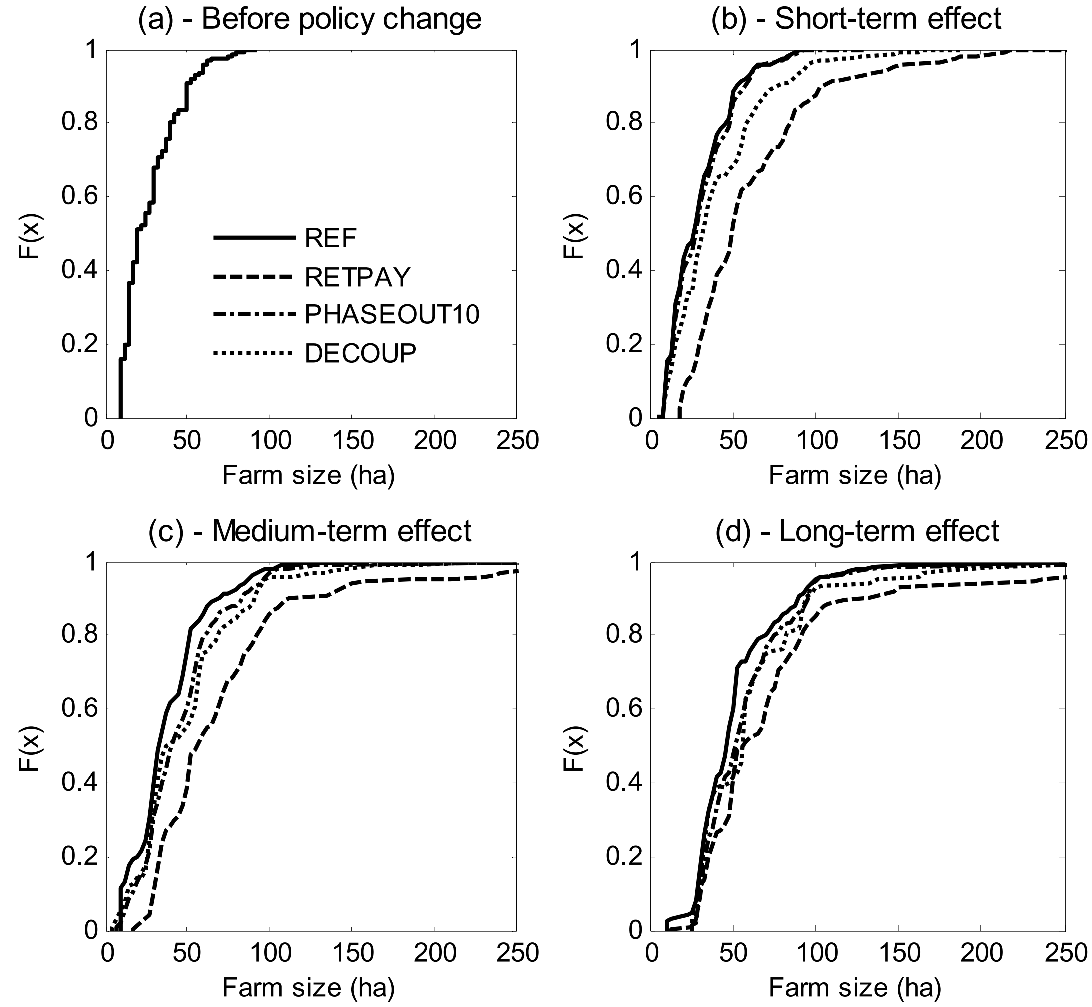
Figure 7-3: Kernel density estimates of farm size



In fact, farm size distributions of policy DECOUP are similar to those of scenarios REF and PHASEOUT10. Overall, for these three scenarios, a similar development over time can be detected. First, the distributions slowly shift to the right indicating that over time small farms either leave the sector, or have grow. Second, particularly in the medium and long-run, the shape of the curve becomes more pronounced with peaks appearing at certain local maxima. However, a further analysis of economic farm size (Figure 7-5), and profits from agriculture (Figure 7-23) suggests that although farms are similar in size, they nevertheless differ with respect to output, and economic importance.

Moreover, policy scenarios REF, PHASEOUT10, and DECOUP create policy environments that allow for the further existence of small farms, at least in the short-run and in the medium-run (Figure 7-4). This particular aspect constitutes a major difference between a retirement payment in scenario RETPAY and a decoupled single farm payment.

Figure 7-4: Empirical cumulative density function of farm size



One possible explanation for small farms to exist in policy scenarios DECOUP and PHASEOUT10 could be that farms under these policy regimes do not quit immediately but convert into non-professional farms. Indeed, a decoupled single farm payment provides the ground for mixing income sources in the best possible way as long as this is profitable. In policy RETPAY, a farm will only receive the payment, if it withdraws. The same line of reasoning applies to policy PHASEOUT10, where, as long as coupled direct payments are granted, small farms mix income sources (see Figure 7-25). In any case, the existence of small farms is a phenomenon, which appears only in the short and medium-run. In the long-run, i.e., after 24 time periods, also small farms disappear in scenario DECOUP. However, as small farms disappear in the long-run, it shows that the strategy of mixing income sources is only viable for a limited number of time periods. It is interesting to observe that also in the case of fully coupled direct payments (REF) very small farms disappear in the long-run. Hence, one may conclude, that very small farms continue to exist not only because of coupled direct payments, but also because the policy provides an incentive to mix income sources. In this regard, only a policy, such as RETPAY, directed at removing labour from the sector, effectively 'removes' very small farms already in the short-run.

7.3.2 Economic farm size

Farm size in hectares is just one indicator for the actual size of the farm. Yet, it does not give precise information about the economic importance of the farm. For this, the economic size of a farm is a more appropriate indicator. The economic farm size, expressed in European Size Units (ESU), corresponds to the total production valued at standard gross margin.[88] Figure 7-5 and Figure 7-6 present kernel density estimates and the empirical cumulative density function of the economic size of farms.

Four points are worth noting here. First, the economic size of farms and its development over time does not exactly correspond to the farm size measured in hectares. For example, in the reference scenario, the average standard gross margin per ha for specialised granivore farms is twice as high (2,103 €/ha) than for grazing livestock farms (1,011 €/ha) or mixed farms (1,116 €/ha). Gross margin per hectare is generally higher for intensive livestock farming than for other types of farming despite of the land required for manure disposal. A comparison of Figure 7-4 and Figure 7-5 shows differences to appear particularly at the lower tails of the distributions. Also with respect to economic size, the speed of adjustment varies between scenarios. Most prominent is policy scenario RETPAY, where the distribution shows a considerable shift immediately after the policy change.

Second, Figure 7-5 shows that in terms economic size all alternative policy scenarios (RETPAY, PHASEOUT10, and DECOUP) increase economic size compared to the reference. Over 20 time periods, the peak of the distributions shifts significantly to the right. Differences also become apparent at the lower tail and the centre of the distribution. At the upper tail, however, differences – in particular relative to the references – get smaller or even disappear (Figure 7-6). This indicates that few very large farms act more or less independently of the prevailing policy environment.

Third, the reference scenario – and less so policy DECOUP – provide the basis

88 See chapter 6 for a definition and the respective data base used for calculation.

for small farms to survive throughout all time periods, even though their number steadily decreases over time. Reasons for this were given above in the discussion of farm size. Fourth, also with regard to economic size local maxima appear in the long-run in scenarios RETPAY, PHASEOUT10, and DECOUP around 70 ESU, 110 ESU, and 210 ESU.

Figure 7-5: Kernel density estimates of economic farm size

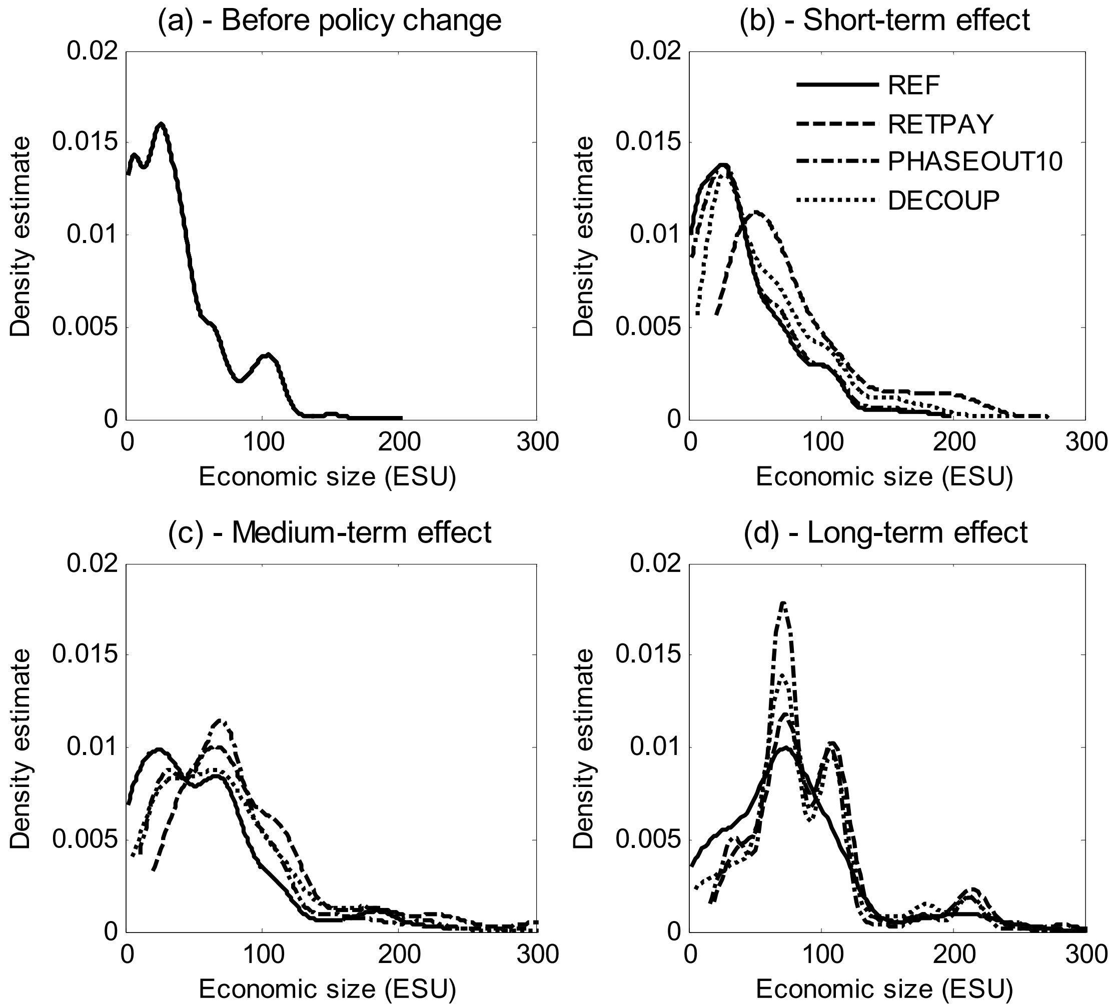
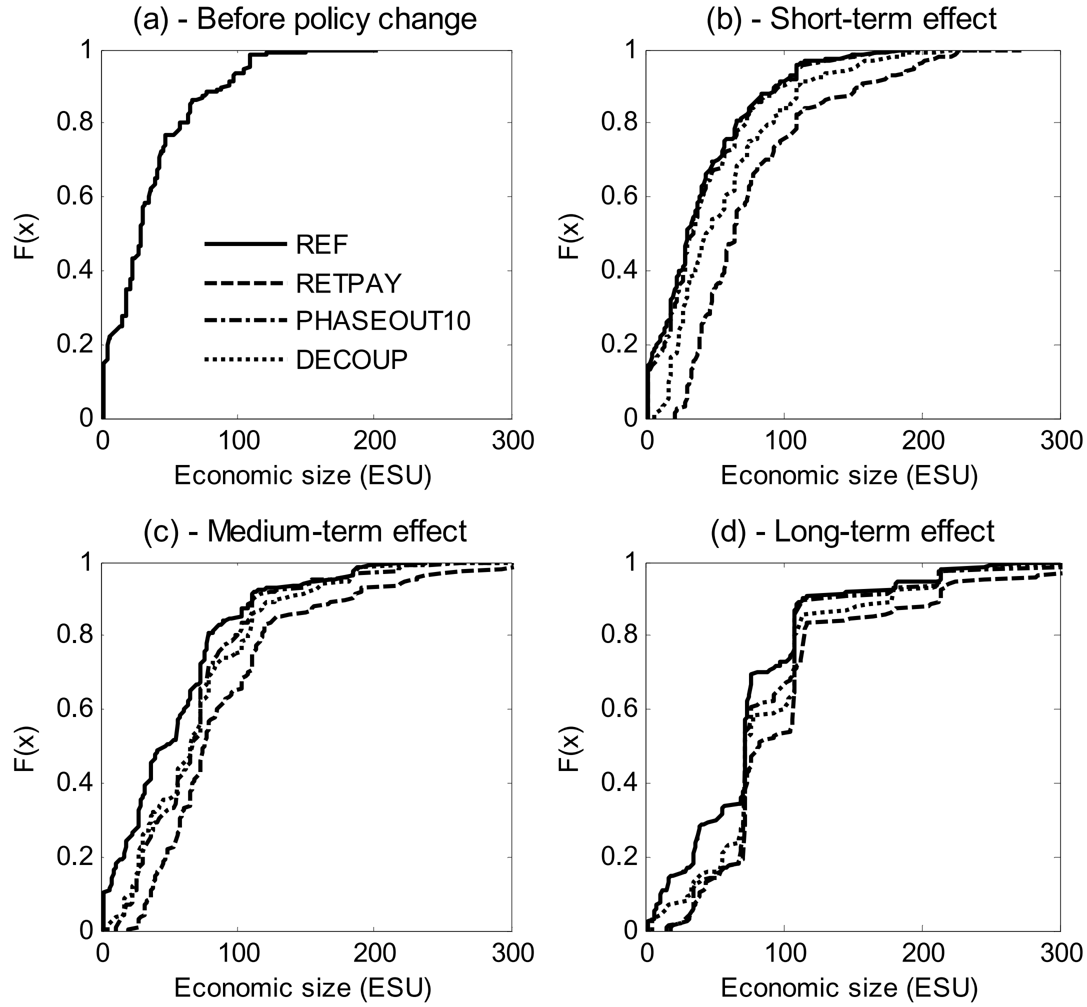


Figure 7-6: Empirical cumulative density function of economic farm size

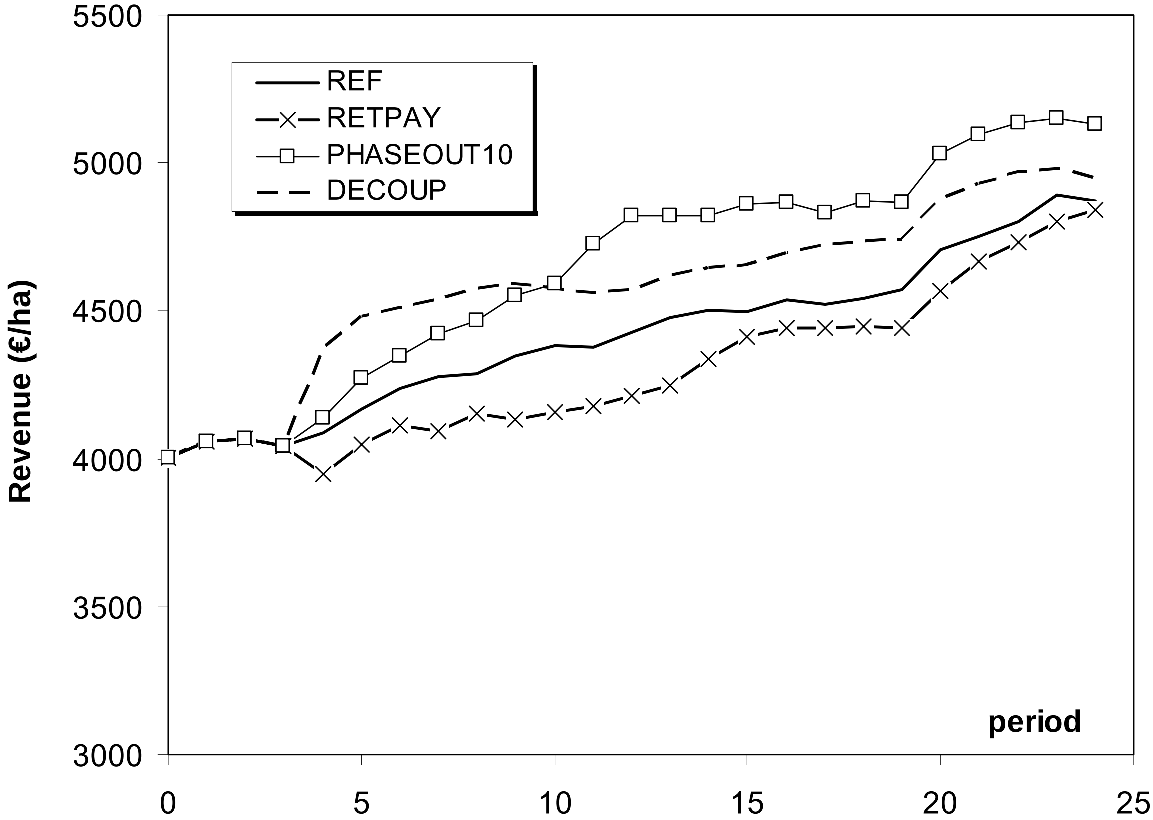


7.3.3 Impacts on production and factor input

As was seen in the previous sections, some of the policy scenarios considered, lead to dramatic and sudden changes on the region's farm structure. Thus far, the analysis has put emphasis on farm size and farms' economic size. This section is devoted to the investigation of specific adjustment reactions of active farms, i.e., farms remaining in the sector. The relationship between policies, on the one hand, and specialisation as well as production intensity, on the other hand, are at the centre of analysis.

Figure 7-7 shows the evolution of revenue per hectare of farmland for each policy scenario. Farmland includes all land rented or owned by farms.

Figure 7-7: Evolution of revenue per hectare of farmland



Revenue per hectare in scenario RETPAY is considerably below that of the reference and the other alternative scenarios. Hence, production becomes less intensive if related to land. The difference to the reference is due to a lower increase in total revenues. In scenarios DECOUP and PHASEOUT10, production intensity is higher in the short-run compared to the reference and policy RETPAY. Immediately after the policy change, growth in revenue exceeds the rate at which land is abandoned in scenarios DECOUP and PHASEOUT10 (refer back to Figure 7-2). A look at revenue shares allows analysing the contribution of production activities to total revenue. Table 7-4 presents revenue shares of main products measured at four different points in time.

Table 7-4: Revenue shares of product by policy and time periods

Policy	Time period	Total	Cereals	Sows	Fatt. pigs	Suckler cows	Tur-key	Beef cattle	Dairy cows
		%							
REF	Bef. policy change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	15.0	56.7	11.5	2.4	6.0	0.7	7.7
	Medium-term	100	14.2	58.1	13.3	2.7	8.6	0.2	2.8
	Long-term	100	13.1	49.1	23.6	2.8	11.4	0.0	0.0
RETPAY	Bef. policy change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	16.0	48.4	22.6	3.2	8.1	0.2	1.4
	Medium-term	100	15.1	38.0	31.0	3.1	12.4	0.1	0.3
	Long-term	100	13.2	25.2	45.8	2.4	13.4	0.0	0.0
PHASE-OUT10	Bef. policy change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	14.7	54.5	14.5	2.0	6.3	0.6	7.4
	Medium-term	100	14.5	53.2	22.0	0.0	8.0	0.0	2.3
	Long-term	100	13.8	43.5	32.4	0.0	10.3	0.0	0.0
DECOUP	Bef. policy change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	15.2	51.3	20.0	0.1	7.3	0.0	6.1
	Medium-term	100	15.2	50.6	24.6	0.1	7.5	0.0	2.1
	Long-term	100	14.0	41.8	36.7	0.3	7.2	0.0	0.0

Although policy RETPAY leads to a more extensive production, revenue shares of products show that in this scenario a dichotomy in production emerges. On the one hand, additional grassland available due to structural change offers scope to increase extensive suckler cow production. On the other hand, arable land of leaving farms provides the grounds for increased intensive livestock production. Interesting with regard to this policy is the fact that both dairy production and intensive beef cattle almost disappear shortly after the policy change, despite of coupled direct payments. The main reason behind this phenomenon is that dairy cows and beef cattle are held in smaller farms, which quit in response to a policy change (see Table A-9 in appendix A.6). The question remains why large farms remaining in the sector after the policy change do not take up dairy production despite of declining quota prices from initially 0.05 €/litre to around 0.03 €/litre. Compared to fattening pig production and turkey production, dairy production is both more labour and capital intensive, and it requires grassland as a fodder base as well as additional quota. In all scenarios, farms do not (re-)invest in larger dairy operations.[89] Dairy investments in Hohenlohe are thus less competitive than investments in pig and poultry.

Unlike scenario RETPAY, production in scenarios DECOUP and PHASE-OUT10 is mainly characterised by intensive livestock production only. Both, beef cattle production and suckler cow production are not viable in the medium and long-run.[90] [91]As for policy DECOUP, direct payments are paid as a decoupled single farm payment, such that production decisions are made exclusively based on market price signals. In this case, the single farm payment adds to household income (section 7.5), but not to the profitability of single production activities.

Finally, the reference policy REF is discussed. Two observations are of interest with respect to this policy: just like in the alternative scenarios, in the reference scenario, the relative share of intensive livestock production, and particularly fattening pig production and turkey production increases. Furthermore, dairy production and beef cattle ceases also in this scenario as in all other scenarios. The reasons for this were given in the discussion of policy RETPAY: dairy and beef production are located mostly in small farms withdrawing from the sector over time.

The specific production development also explains the development of the average stocking density in the region (Figure 7-8). In the figure, stocking density is measured relative to total farmland. Abandoned land is not considered. On average, stocking density is highest in the reference scenario. With respect to that, all other scenarios represent an extensification in the short-run. However, the figures

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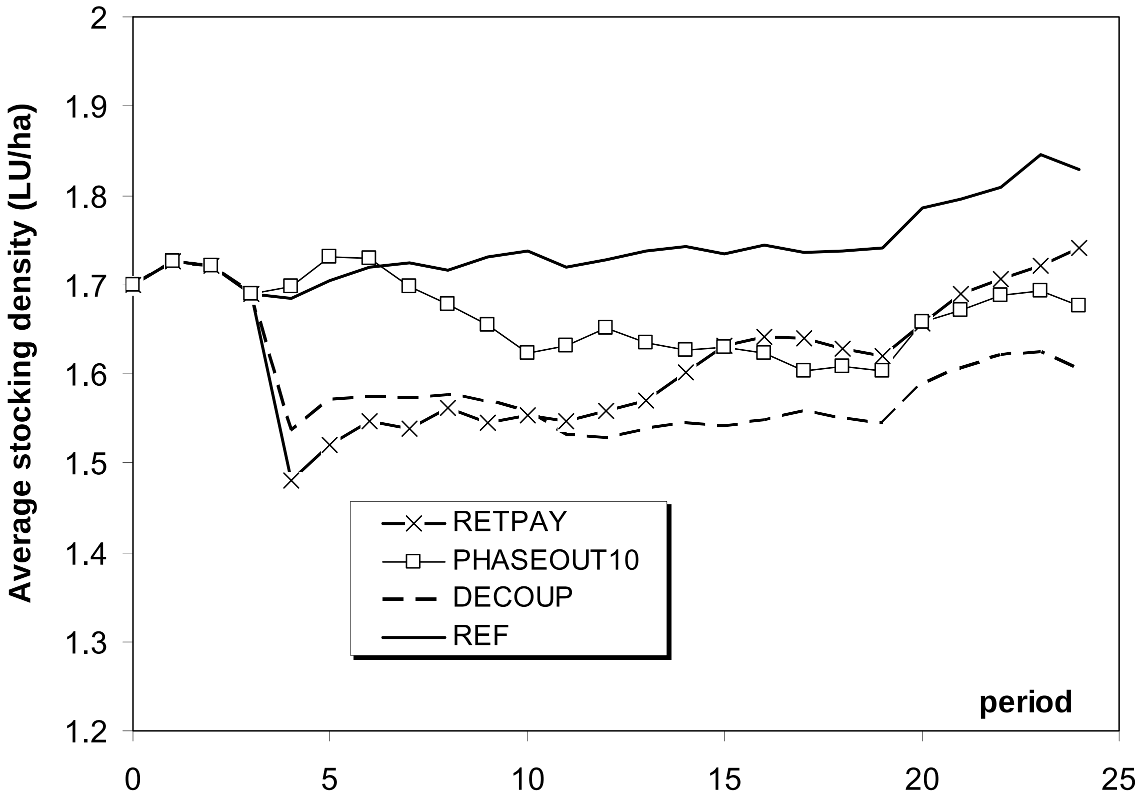
89 Although dairy production ceases in the long-run, quota prices do not decline to zero. There are two reasons for this. One is that quota in AgriPoliS can be traded not only within the region, but across regions. Despite of no production in Hohenlohe, other farms in neighbouring regions could equally produce milk. The other region is that price cuts were introduced as percentage changes relative to the respective price in the year before (cf. chapter 3 and 4). Moreover, the assumption regarding milk price chances does not take account of the potential effect of an additional devaluation of quota in response to decoupled direct payments.

90 This result, however, has to be taken with care because in reality the profitability of suckler cow production also strongly depends on marketing possibilities. Furthermore, suckler cow production is one of the measures specifically supported through the second pillar of agricultural policy of the EU. These policy measures, which mainly include structural, social, and agri-environmental policies, are not explicitly considered here.

91 The fact that in scenario DECOUP suckler cows are still produced although at very low numbers is a direct result of the very low (almost zero) rental price of grassland in this scenario.

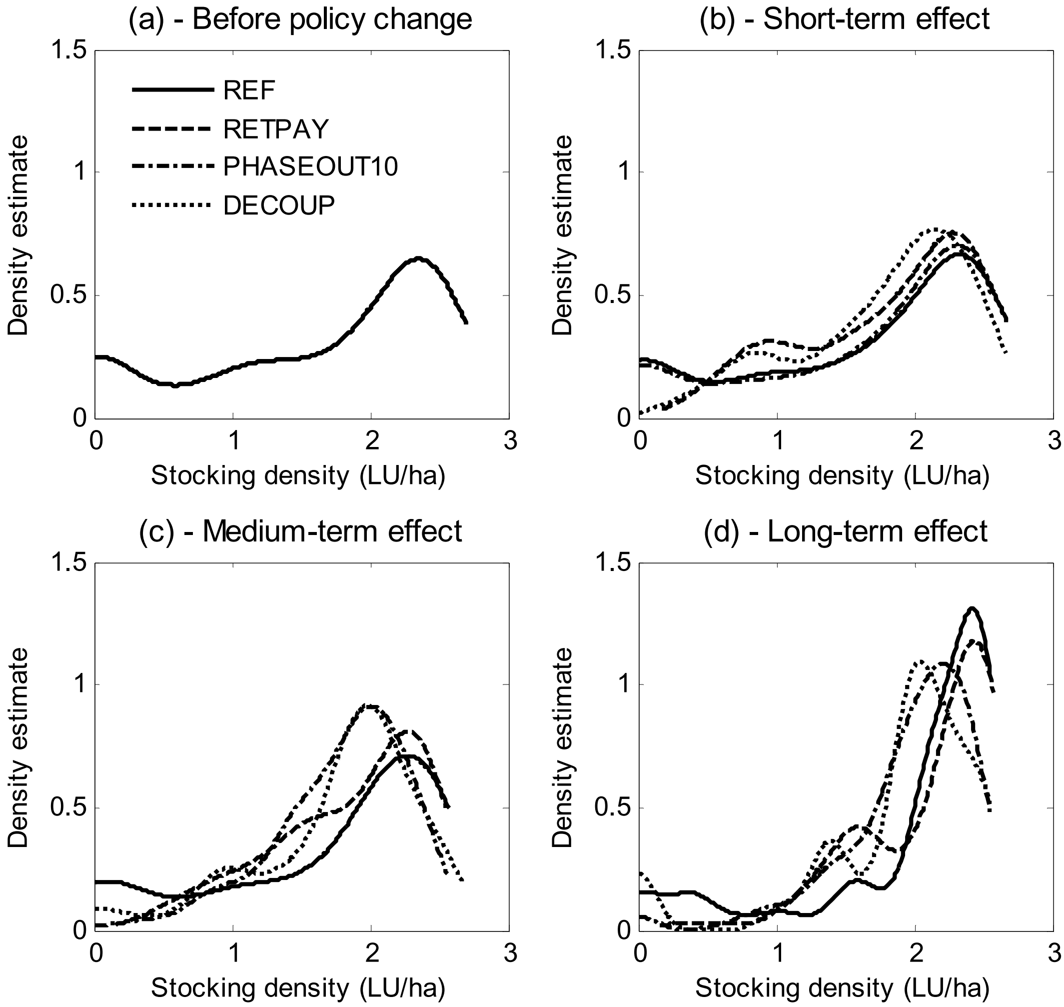
also show that in the medium and long-run only scenarios DECOUP and PHASEOUT10 lead to a lasting extensification of production at a lower level (approx. 2 LU/ha on average) compared to the reference (see Figure 7-9) while RETPAY recovers.

Figure 7-8: Evolution of the average stocking density



Although stocking density in scenarios DECOUP and RETPAY decreases right after the policy change, starting in period 11 stocking density in scenario RETPAY shows a strong increasing tendency, whereas stocking density in scenario DECOUP remains at a lower level. Hence, in scenario RETPAY, where direct payments are still coupled to production, production gradually re-intensifies after the initial policy shock. In response to the policy change in scenario RETPAY, many farms quit (Figure 7-1), letting about 45% of all agricultural land to the land market. Leaving farms are predominantly engaged in producing field crops, and grazing livestock (see Table A-9 in appendix A.6), i.e. the farms use grassland. Farms remaining in the sector are for the most part specialised granivore farms.

Figure 7-9: Kernel density estimates of individual farm stocking density

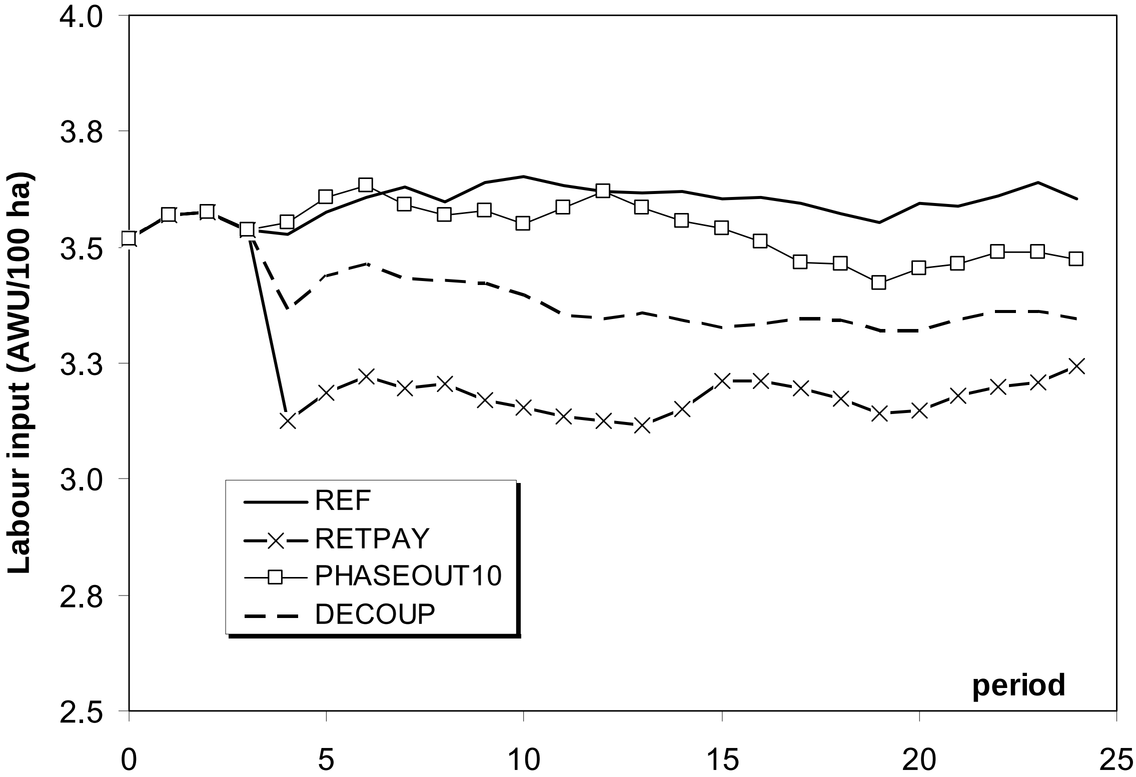


With respect to farms remaining in the sector, the policy change has two effects. Because land becomes cheaper, farms exceeding the maximum stocking density of 2.5 LU/ha before the policy change (and therefore paid fines) can now attain the maximum level without incurring fines. Hence, in the short-run the retirement payment leads to an extensification of production. But, in the longer run coupled direct payments, which are paid in scenario RETPAY, provide the basis for re-intensification. On the one hand, remaining farms increase their engagement in intensive livestock production (fattening pigs, and turkeys). On the other hand, farms increase suckler cow production to take advantage of low rental prices for grassland in addition to direct payments for suckler cows.

The development of livestock production obviously also influences labour input. The average labour input annual work units (AWU) per 100 ha is presented in Figure 7-10. Labour input is measured against all farmed agricultural area. It comprises farm-owned labour as well as hired labour.

As was seen in the previous figures, production in scenario RETPAY re-intensifies after the policy change. This is why permanently lower labour input in this scenario can only be explained with size effects generated by larger production facilities and larger machinery. As was seen, policies RETPAY and DECOUP (and in later periods also PHASEOUT10) favour the development of larger farms.

Figure 7-10: Evolution of average labour input per 100 ha.



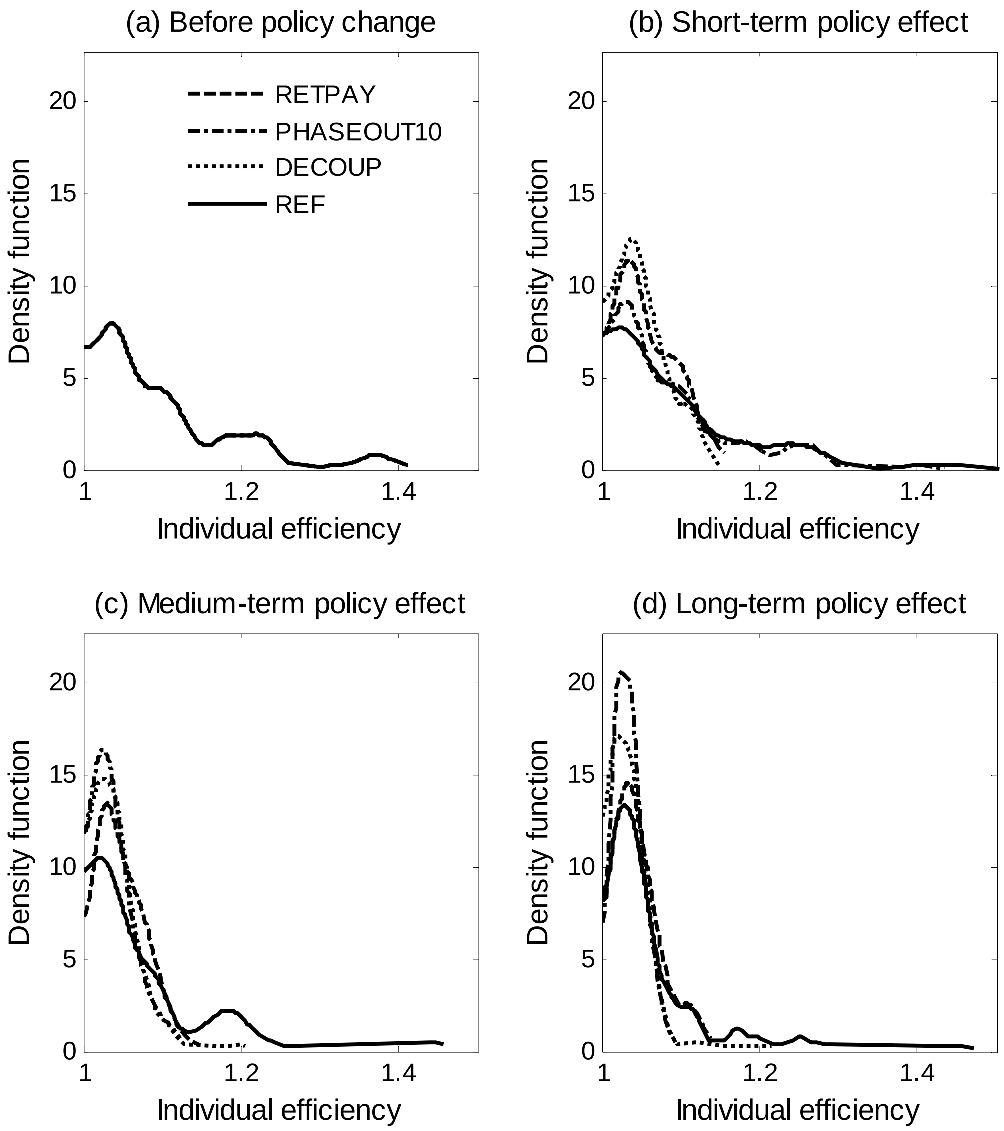
7.4 Efficiency implications

Having analysed the main structural effects, this section will focus in particular on the efficiency effects of policies. Efficiency is looked at from two sides. The frontier-based DEA approach (cf. chapter 6) is used to derive individual efficiency scores for individual farms and the aggregate of farms. This latter aggregate or structural efficiency measure allows drawing conclusions about the efficiency of the region as a whole. Economic land rent is used as an indicator for the allocation of production factors on individual farms and the region.

7.4.1 Analysis of individual and structural efficiency

To derive efficiency scores, the DEA model is estimated as described in chapter 6. Assuming output-orientation and constant returns to scale technology, the density estimates of efficiency scores for each policy alternative at four different time periods are visualised in Figure 7-11 and Figure 7-12.[92] In the output-oriented model, a score of unity denotes efficiency, whereas inefficient farms receive a score greater one.

Figure 7-11: Kernel density estimates of output-oriented efficiency scores



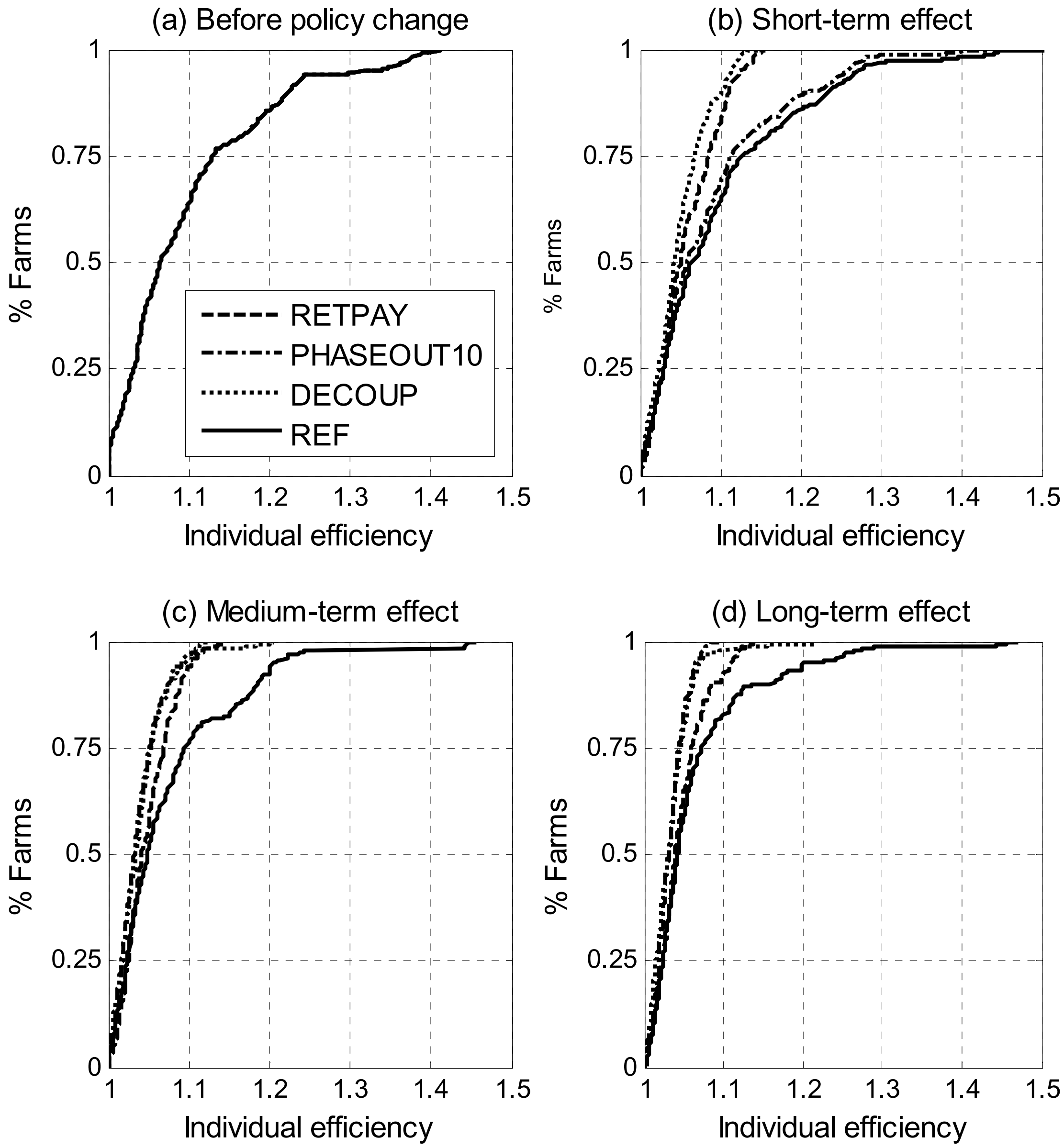
92 Units with an efficiency score of '1' are excluded from the density estimation.

Relative to the situation before the policy change, two main observations can be made in the short-run. One is that, scenarios RETPAY and DECOUP create strong incentives for inefficient farms either to quit farming or to become more efficient through investments and realisation of size effects. Because of this, the group of remaining farms becomes more homogenous with respect to individual efficiency. Greater homogeneity is also reflected in the majority of surviving farms following the same specialisation, which is pig and poultry production (see Table 7-4). In the other two scenarios (REF and PHASEOUT10) the upper tail of the efficiency distribution shows a slight, but minor change. Relative to the situation before the policy change, however, farms increase efficiency.

The second observation is that – except for policies REF and PHASEOUT10 – the peak of most distributions is not at the point of the highest efficiency in the short-run. Because of the assumed technological change and size effects, one should expect the peak of the distributions at the point of highest efficiency, particularly for policies RETPAY and DECOUP, where farms are more efficient in the short run (Figure 7-11). But technological change may also provide one possible explanation for this phenomenon. With every new investment that is technologically more advanced, a farm reduces variable production costs. Hence, it is likely to move closer to the frontier. Farms that invested in previous periods become relatively less efficient. Because of the assumed technological change and size effects, one should expect the peak of the distributions at the point of highest efficiency, particularly for policies RETPAY and DECOUP, where farms are more efficient in the short run (Figure 7-11). Regarding policies DECOUP and RETPAY, the peak phenomenon relates to the fact that in RETPAY and DECOUP, a few very large farms emerge causing a slight shift in the frontier, such that the majority of farms are located just below the frontier.[93]

[93] This phenomenon could also be related to a kind of inherent inefficiency originating from the random properties of the DEA estimator (KNEIP et al. 2003). But the fact that the peak does not appear consistently across all scenarios makes this rather unlikely.

Figure 7-12: Empirical cumulative density function of output-oriented individual efficiency scores



To further differentiate efficiency scores, Table 7-5 provides mean individual efficiencies and mean scale efficiency by revenue class. Accordingly, mean inefficiency of farm agents with revenue below 50,000 Euros is significantly higher than inefficiency of all other farm agents. However, depending on the policy, the group of low revenue farms is comparatively smaller. The main source of inefficiency with low output farms is scale inefficiency.

Table 7-5 Mean individual efficiencies and mean scale efficiencies by revenue class (all periods taken together)

Revenue class (1000 €)		REF	RETPAY	PHASEOUT10	DECOUP
<50	Indiv. eff.	1.2205 (352)	1.2235 (134)	1.2139 (237)	1.1834 (188)
	Scale eff.	1.144	1.132	1.140	1.103
50-200	Indiv. eff.	1.0629 (736)	1.0650 (504)	1.0609 (682)	1.0568 (634)
	Scale eff.	1.007	1.006	1.007	1.007
200-350	Indiv. eff.	1.0345 (415)	1.0396 (302)	1.0315 (399)	1.0315 (344)
	Scale eff.	1.004	1.004	1.004	1.004
>350	Indiv. eff.	1.0319 (151)	1.0390 (203)	1.0224 (170)	1.0243 (190)
	Scale eff.	1.003	1.005	1.003	1.003
Total average	Indiv. eff.	1.0865	1.0723	1.0730	1.0634
	Scale eff.	1.0350	1.0200	1.0270	1.0190

Note: Total number of farms in brackets.

Regarding the aggregate efficiency of the entire region, Table 7-6 presents a summary of results. In particular, it shows bias-corrected mean efficiencies (MeEff) and structural efficiencies (StEff) for the four policy scenarios.[94] Structural efficiencies are derived by weighting individual farm efficiency scores by output shares. Furthermore, the table shows efficiency ratios (RD) of both mean and structural efficiencies.

Policies inducing a strong immediate effect (DECOUP and RETPAY) increase mean efficiency in the short-run with a bias-corrected efficiency score of 1.0608 for DECOUP and 1.0728 for RETPAY. Relative to the reference, mean efficiency remains higher in all following periods. Because of the stepwise payment cut, the effect of policy PHASEOUT10 sets in later, such that differences only become apparent in the medium-run. This corresponds with results from the density estimation. Already in the medium-run, the situation changes with mean efficiency being highest for policy PHASEOUT10 (1.0446). This indicates that the stepwise removal of coupled direct payments and the subsequent adjustment of farms, leads to considerable efficiency increases with farms remaining in the sector while very inefficient farms quit (Figure 7-12). Only policy DECOUP yields comparable results on average, despite of the different policy design. Regarding DECOUP and PHASEOUT10, differences in mean efficiency to the reference and RETPAY are statistically significant at the 5% level in the medium and long-run. Regarding RETPAY, the difference to the reference is statis-

94 Bias-correction is required because the DEA estimator underestimates the true efficiency score (SIMAR and ZELENYUK 2003).

tically significant in the short and medium-run, but vanishes in the long-run. This is inline with previous observations, where it turns out that the policies affect farms in the region quite differently in the short-run whereas in the long-run, differences in the farm performances almost disappear.

Table 7-6: Bias-corrected mean efficiencies, structural efficiencies, and efficiency ratios of structural efficiencies and mean efficiencies CRS

Efficiency	Policy	Bef. policy change	Short-term effect	Medium-term effect	Long-term effect
MeEff	REF	1.1190	1.1277	1.0916	1.0786
	RETPAY	1.1187	1.0728	1.0582	1.0575
	PHASEOUT10	1.1190	1.1146	1.0446	1.043
	DECOUP	1.1185	1.0608	1.0491	1.0449
StEff	REF	1.0524	1.0595	1.0466	1.0581
	RETPAY	1.052	1.0595	1.0517	1.0491
	PHASEOUT10	1.0523	1.0563	1.0351	1.0394
	DECOUP	1.0521	1.0482	1.0374	1.0389
RD MeEff	REF/RETPAY	1.0002	1.0516*)	1.0317*)	1.02
	REF/PHASEOUT10	0.99993	1.0119	1.045*)	1.0342*)
	REF/DECOUP	1.0004	1.0634*)	1.0407*)	1.0323*)
	RETPAY/PHASEOUT10	0.99966	0.96178	1.013*)	1.0139*)
	RETPAY/DECOUP	1.0001	1.0113	1.0087	1.0121*)
	PHASEOUT10/DECOUP	1.0004	1.051*)	0.99575	0.9982
RD StEff	REF/RETPAY	1.0003	0.99997	0.99501	1.0086
	REF/PHASEOUT10	1.0001	1.003	1.0111*)	1.0181*)
	REF/DECOUP	1.0003	1.0108**)	1.0089	1.0185*)
	RETPAY/PHASEOUT10	0.99973	1.003	1.0161*)	1.0094
	RETPAY/DECOUP	0.99989	1.0108**)	1.0139*)	1.0098
	PHASEOUT10/DECOUP	1.0001	1.0077	0.99776	1.0004

Notes: *) Efficiency difference statistically significant at the 5% level; **) efficiency difference statistically significant at the 10% level; StEff = structural efficiency, MeEff = mean efficiency; RD of StEff = bootstrap-based ratio of structural efficiencies; RD of MeEff = bootstrap-based ratio of mean efficiencies; B=1000 bootstrap rounds, κ=0.7.

As mean efficiency does not account for the economic importance of individual farms but puts equal weights on all farms in the region, structural efficiency scores are computed. One immediately observes structural efficiencies to be lower than mean efficiencies, indicating that the region is generally more efficient than the mean would suggest.[95] This result does not surprise because larger

[95] It should be noted that efficiency is measured relative to all farms and scenarios in a single period, i.e., farms and policies were pooled in single sample in each time period. Because of this, it is not possible to compare structural efficiencies between time periods.

farms having a higher output share are generally more efficient due to technological change, size effects, and labour saving investments. However, when outputs are used as weights, it also appears that the differences between scenarios that existed for mean efficiency disappear in the short-run.

Referring back to Figure 7-11 and Figure 7-12 it also becomes apparent, that many inefficient farms can be neglected when it comes to the economic importance of these farms. Because inefficient farms mostly have a very low output weight, the contribution of inefficient farms to structural efficiency is very small. This explains why differences between structural efficiencies between scenarios are smaller than differences between mean efficiencies. Although it would have been desirable that agricultural policies increase structural efficiency significantly, none of the policies neither significantly increase nor decrease structural efficiency. Nevertheless, structural efficiency does not decrease after a policy change.

In general, efficiency scores in Figure 7-11 cover a relatively small range with maximum inefficiency in scenarios REF being around 1.5 in the short-run. Still, the bootstrap-based statistical test captures differences in mean and structural efficiencies at the 5% level. The test of the equality of mean efficiencies confirms the graphical results given in Figure 7-11. In case of scenarios REF and RETPAY, the null hypothesis of equal structural efficiencies has to be accepted. In other words, although these scenarios differ with respect to mean efficiency, considering economic importance, the efficiency of the entire region is not significantly different.

7.4.2 Economic efficiency

The second efficiency aspect considered in this section is economic efficiency. In other words, it addresses the question of the allocation of farm-owned production factors of individual farms and within the entire region. Figure 7-13 and Figure 7-14 show the evolution of average economic land rent in the region. In

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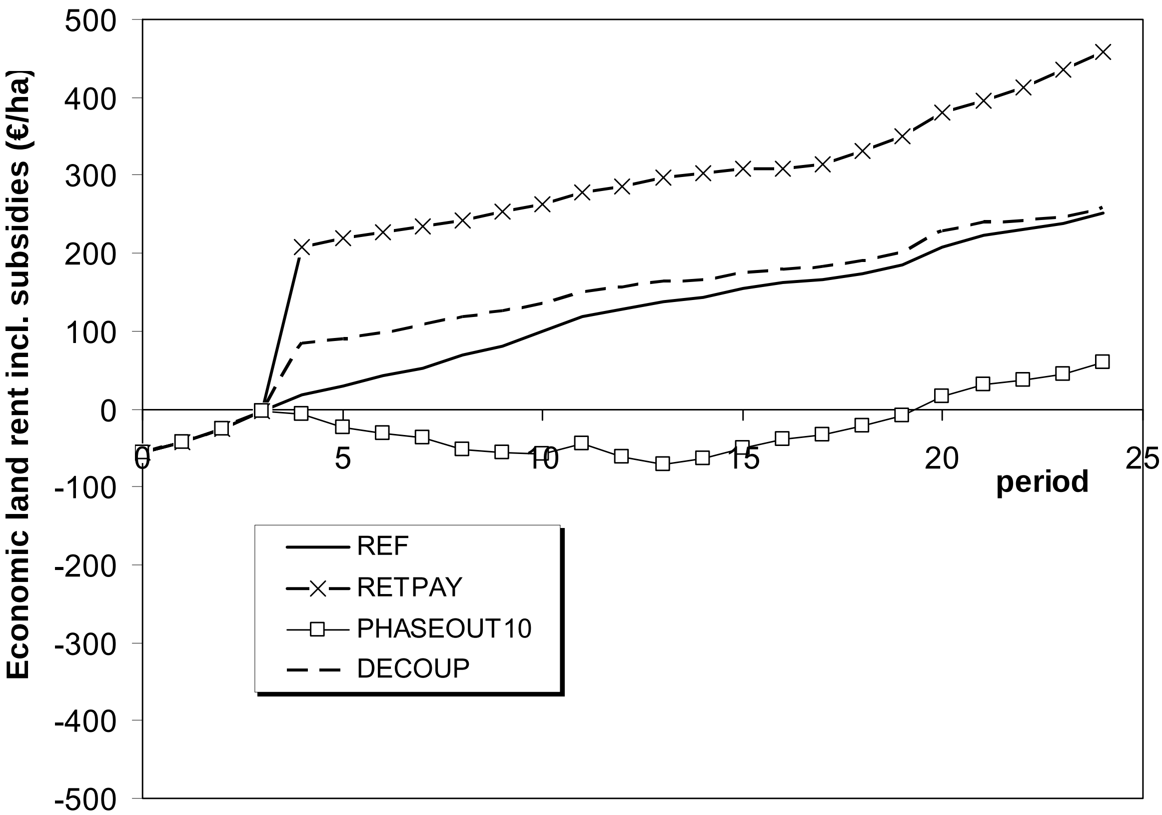
Because of this, it is not possible to compare structural efficiencies between time periods. This would require pooling farms, policy scenarios, and periods. A formal method for comparisons between time periods would be a Malmquist analysis (cf. COELLI et al. 1999) which allows identifying productivity change over time and the contribution of efficiency and technological change to productivity change. For the purpose of this study, a Malmquist analysis was not yet undertaken. In case of comparing structural efficiencies, the usual Malmquist approach needs to be augmented. This, however, is beyond the scope of this thesis. It is the subject of work in progress.

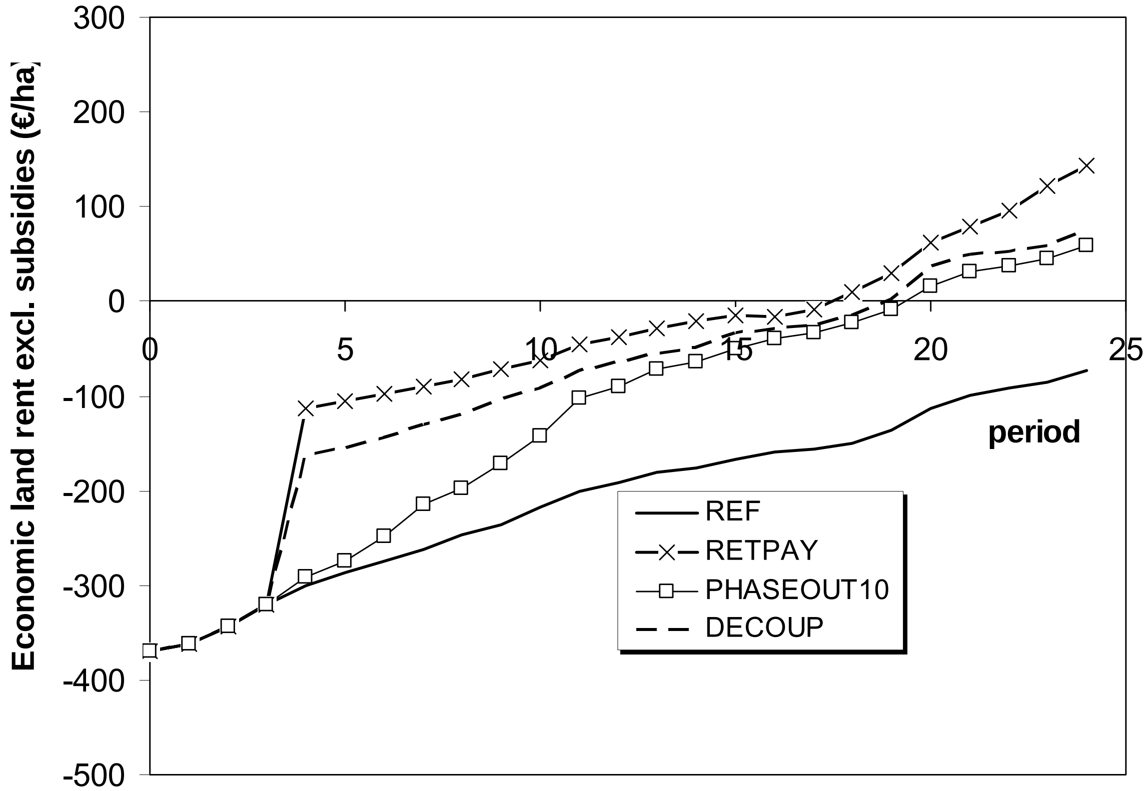
Figure 7-13, subsidies (coupled direct payments, single farm payment) are included, whereas Figure 7-14 excludes subsidy payments to compare and show how economic land rents would develop if subsidies were removed in any one period. Sunk costs of fixed assets are not included either (without sunk costs). It shows that economic efficiency is highest for policy scenarios RETPAY and DECOUP relative to the reference with and without subsidies. This result indicates that the efficiency gain induced by these policies in any case outweighs the influence of subsidy payment in the reference.

Figure 7-13: Evolution of average economic land rent incl. subsidies, without sunk costs



Regarding policy PHASEOUT10, average economic land rent in Figure 7-13 is considerably below the other policy scenarios and it declines while payments are cut successively. However, if subsidies are not included in the calculation, there is step-wise increase in economic efficiency in this scenario, pointing towards a gradual re-organisation of production. Moreover, Figure 7-14 demonstrates that in the medium-run average economic land rents of all alternative policy scenarios are closely together. In other words, regarding overall efficiency a similar situation is reached with three very different policy measures. But, this only holds in the medium-run. In the longer-run, the curves diverge slightly again.

Figure 7-14: Evolution of average economic land rent excl. sunk costs, without subsidies



To assess the respective adjustment costs associated with a policy change, Table 7-7 shows average economic land rents with and without sunk costs for labour and fixed assets. In the comparison, subsidies are not included to make the indicator comparable across all policy scenarios and time periods. Economic land rent is computed as defined in chapter 6.

Two aspects are most noteworthy about the table. First, economic land rent is negative in most time periods. This means that the initialised structure with data from the Hohenlohe region is highly inefficient with respect to the allocation of production factors unless subsidies are provided (Figure 7-13). That is to say, production factors are not necessarily used where productivity is highest. However, with structural change, economic land rent increases in all policy scenarios indicating that efficiency in the region increases. This can be observed best in Figure 7-14.

Table 7-7: Comparison of economic land rent including sunk costs and economic land rent without sunk costs excluding subsidies

Economic land rent	REF	RETPAY	PHASEOUT10	DECOUP
	(€/ha)			
Before policy change (t=3)	-430	-430	-430	-430
without sunk costs	*-319*	*-319*	*-319*	*-319*
Immediately after change (t=4)	-388	-2,360	-437	-1,259
without sunk costs	*-299*	*-112*	*-291*	*-162*
Short-term effect (t=6)	-336	-131	-374	-191
without sunk costs	*-274*	*-97*	*-247*	*-144*
Medium-term effect (t=14)	-194	-49	-108	-71
without sunk costs	*-176*	*-21*	*-63*	*-49*
Long-term effect (t=24)	-104	115	-3	21
without sunk costs	*-73*	*144*	*-60*	*75*
Capital value of economic land rent incl. sunk costs (base: t=3)[a)b)]	-4,021	-2,893	-2,859	-2,638
Ave. annual economic land rent incl. sunk costs[c)]	-221	-159	-157	-145

Notes: a) Interest: 5.5%; b) under the assumption that policy is not terminate; c) computed from capital value of economic land rent.

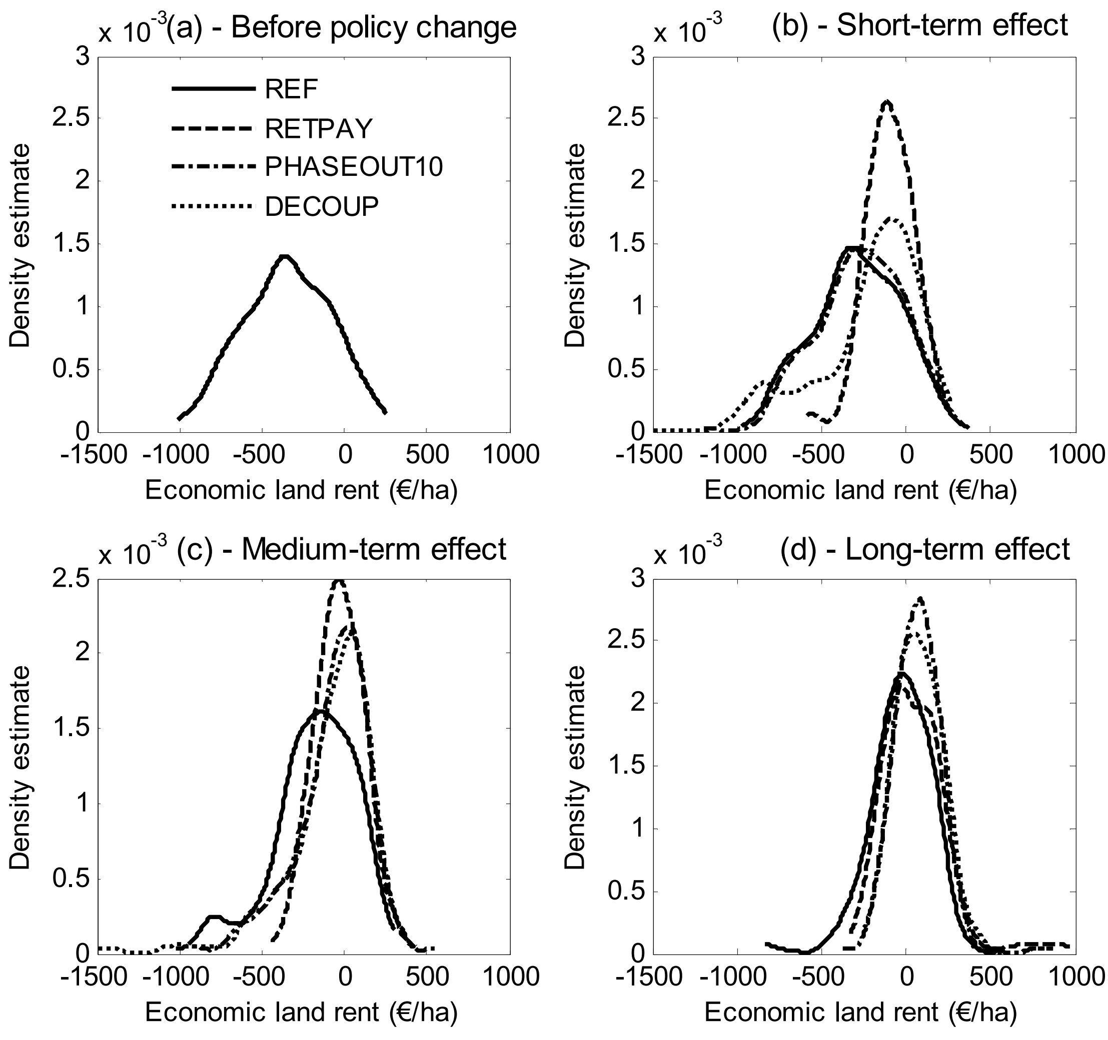
Second, structural adjustment leads to a massive devaluation of asset and human capital as represented by sunk costs. These can also be interpreted as the costs of structural adjustment. Initially, policies RETPAY and DECOUP are very costly in this respect. Accordingly, a large amount of productive capital is lost by farms leaving the sector. Despite of this short-term effect, farms in policy scenarios RETPAY and DECOUP generate a significantly higher economic land rent in all following periods as compared to the reference. To evaluate the total adjustment costs caused by the policy, the capital value of economic land rents including sunk costs is computed for an infinite number of periods.[96] Results show that capitalised adjustment costs per hectare are highest in scenario REF, and lowest in scenario DECOUP. Hence, compared to all other policies policy DECOUP creates the highest efficiency gains in the long-run which compensate for high adjustment costs incurred immediately after the policy change.

Although the previous figures provided some substantial information on the allocation of production factors together with advantages of individual efficiency, there are drawbacks with using averages. Due to a sample effect, the number of farms as well as the total amount of agricultural land managed by farms changes

96 It is assumed that the policies do not terminate, and the rate of structural change continuous after period t=24 at the average of periods 20 to 24.

over time and between scenarios (Figure 7-1 and Figure 7-2). Therefore, on average, economic land rent may increase, but the direction of change depends on the development of the sample of farms and the amount of land farmed. Furthermore, average economic land rent is calculated from aggregate values, i.e. it does not account for heterogeneity between farms. Because of this, density estimates of economic land rent calculated across individual active farms (Figure 7-15) allows for additional insights.

Figure 7-15: Kernel density estimates of individual farm economic land rent



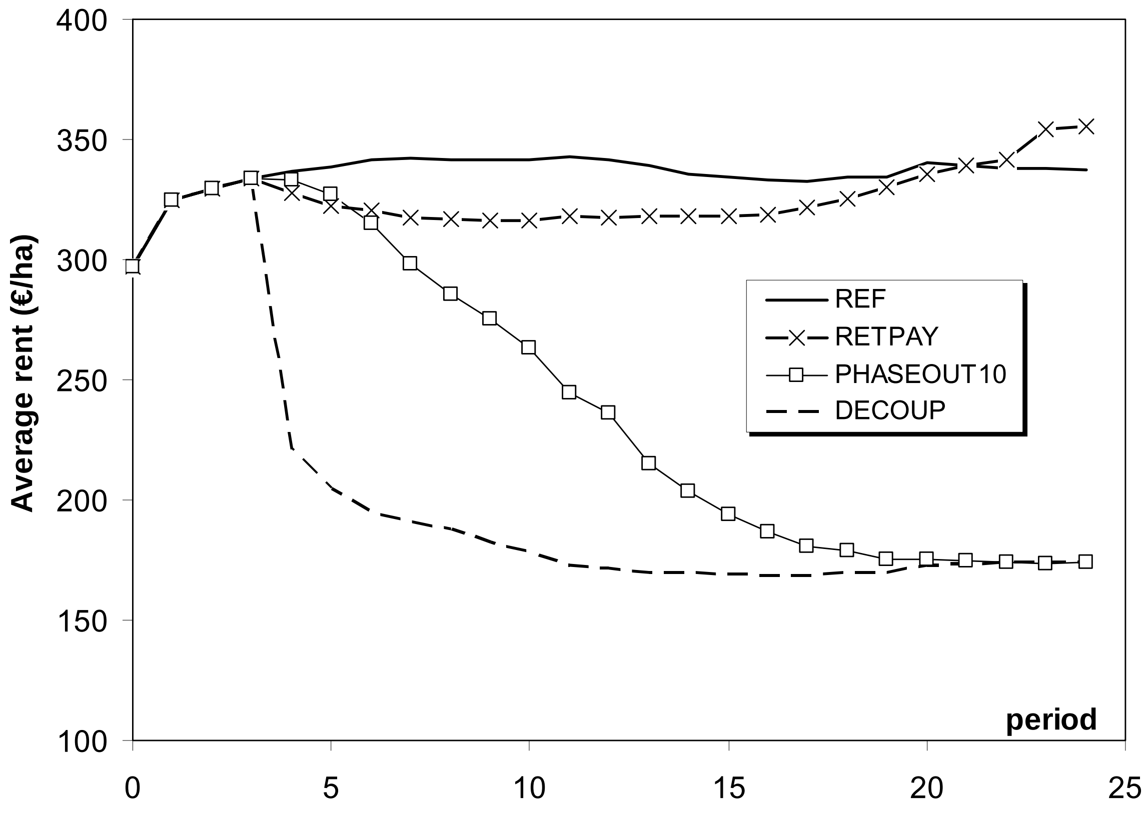
The density estimates highlight the fact that all alternative policy scenarios increase overall efficiency compared to the reference at least in the medium-run. Even though in all scenarios a significant and over time increasing share of farms generates a positive economic land rent, the question remains, why in all scenarios even in the long-run, the share of farms with a negative economic land rent is considerably high. A likely answer may be found in the specific exit dynamics generated by the different policy scenarios. In particular policies REF and PHASEOUT10, but also policy DECOUP create a policy environment that allows small, non-professional farms to remain in the sector in the short and medium-run even though the long-run opportunity costs of the farms are not covered. This issue has been discussed at several instances in this chapter. It also provides an explanation for differences at the lower end of the density curves.

The maximum economic land rent of policy scenarios RETPAY and DECOUP are about equal as well as the curves' peaks. But, the distribution of scenario DECOUP is significantly wider than that of RETPAY. The difference between the uniform retirement payment and a decoupled single farm payment may be explained by the fact that in case of the first policy more farms leave than under the latter policy (see section 7.3.1).

7.4.3 Impact on rental prices

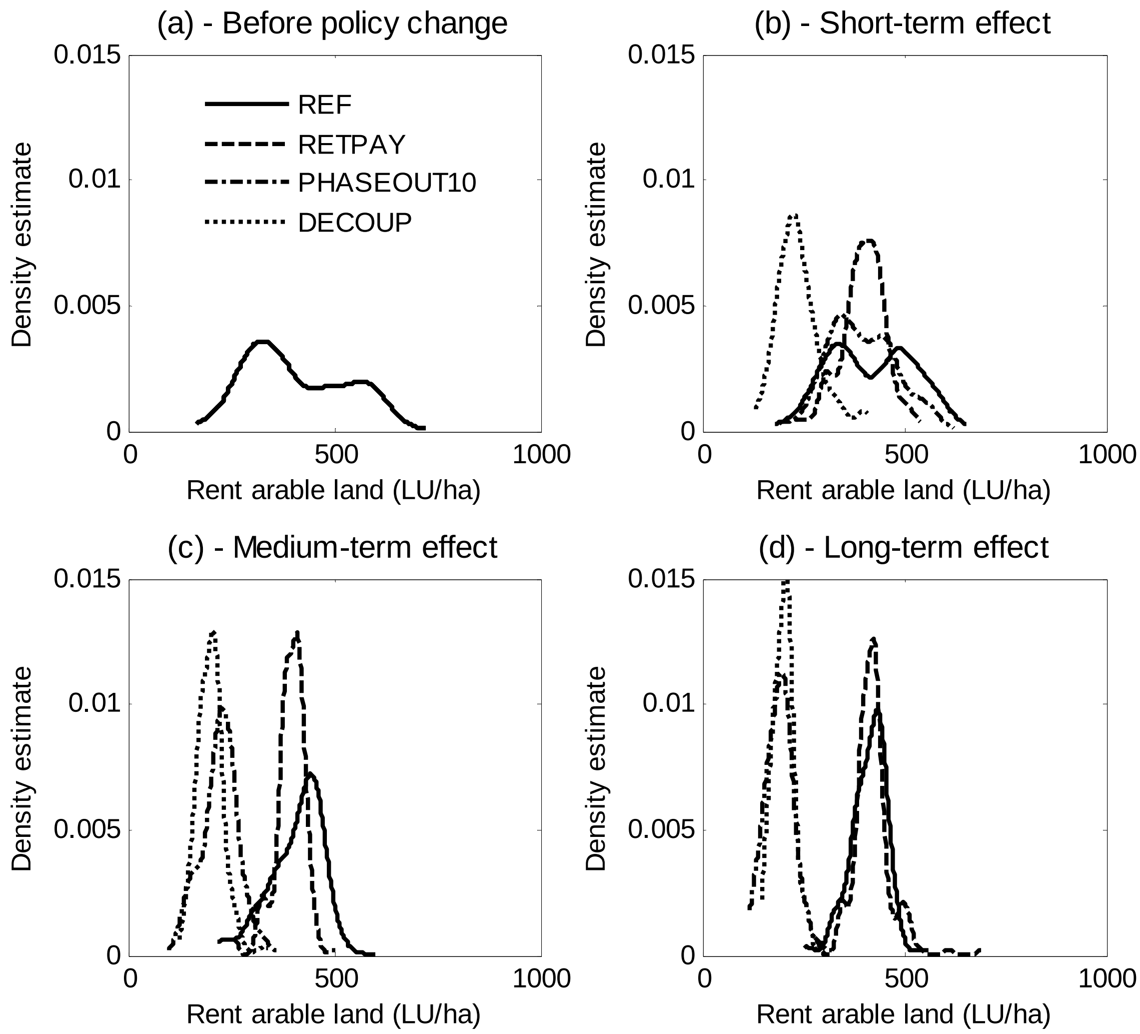
Surviving farms may also take advantage of some relaxations on factor markets and in particular the situation on the land market. As Figure 7-16 illustrates, rental prices decrease despite of increasing economic land rents. In particular, impact is greatest for fully decoupled direct payments.

Figure 7-16: Evolution of average rental price of farmland in the region



Apparently, a decoupled single farm payment leads to lower shadow prices for land, which immediately transfer into lower rental prices for arable land and grassland (Figure 7-17 and Figure 7-18).[97]

Figure 7-17: Kernel density estimates of arable land rental price at four time periods

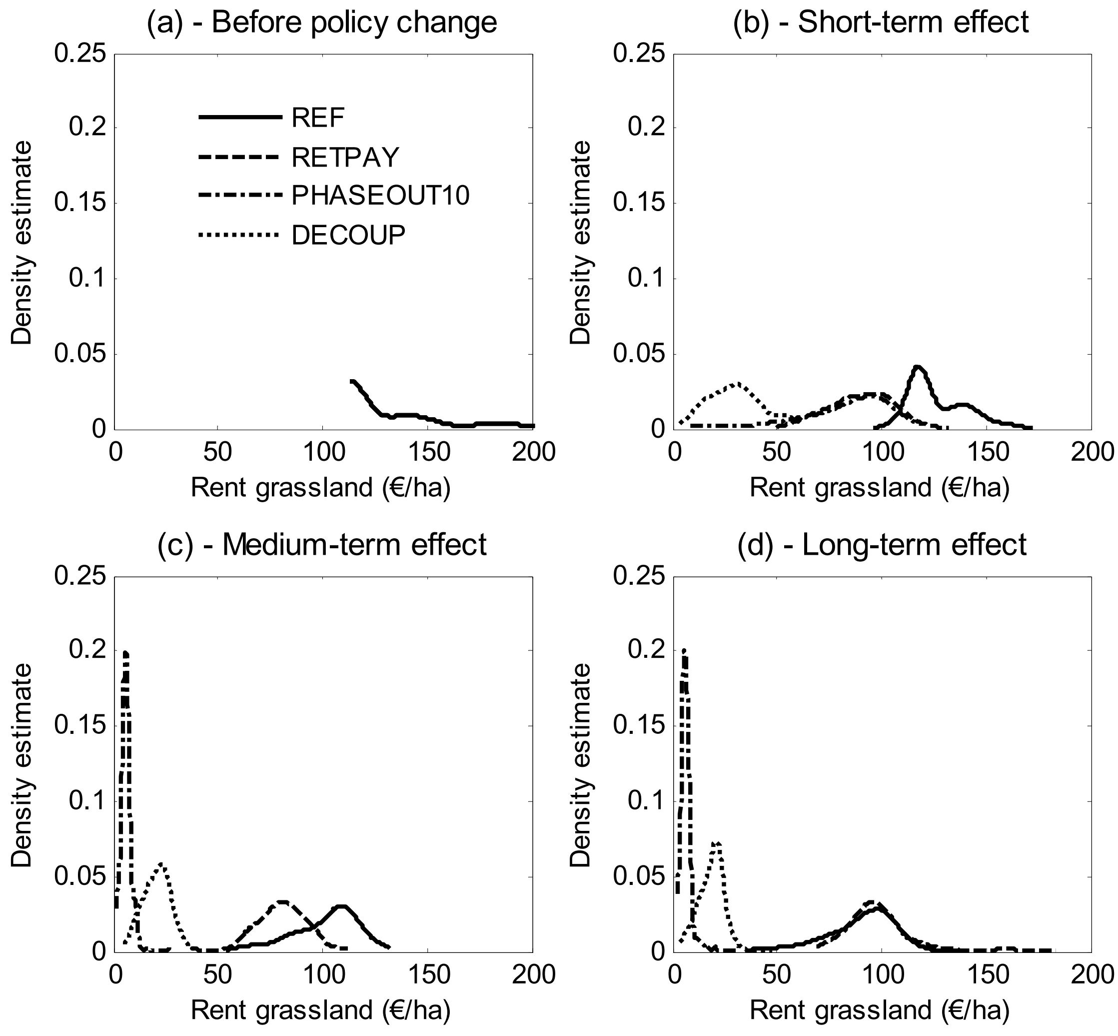


Policy RETPAY has only minor effects on rental prices: in the short-run and in the medium-run, rental prices for arable land and grassland decrease, mainly

[97] This effect was also aggravated because it was assumed that farms expect rental prices to decrease. Accordingly, they valued own land after the policy change at only 75% (arable land) and 50% (grassland) as compared to the reference. In scenario PHASEOUT10, a comparable expectation was not made. Different expectations were introduced into the model because it was assumed that farms are able to anticipate effects of policy changes in a very basic way.

because of land supplied by leaving farms (about 7000 ha). Since remaining farms receive coupled direct payments, in the longer-run, the situation gets tenser again. In particular, direct payments for suckler cows directly transfer into higher shadow prices – and therefore higher rental prices – for grassland (see Figure 7-18).

Figure 7-18: Kernel density estimates of grassland rental price at four time periods



Cutting direct payments (scenario PHASEOUT10) results in a continuous adjustment of rental prices to the rental price level of scenario DECOUP. Scenario PHASEOUT10 also leads to increased dynamics on the land market, as between 15 to 20% of the land is newly negotiated in each period (Table 7-8).

The decoupled rental price level is only reached in time period 20, six time periods after direct payments ceased. The reason is that existing rental contracts are continuously re-negotiated and adjusted towards the average rent paid in the region. Furthermore, with the absence of direct payments after 14 periods, the price of grassland drops nearly to zero (Figure 7-18).

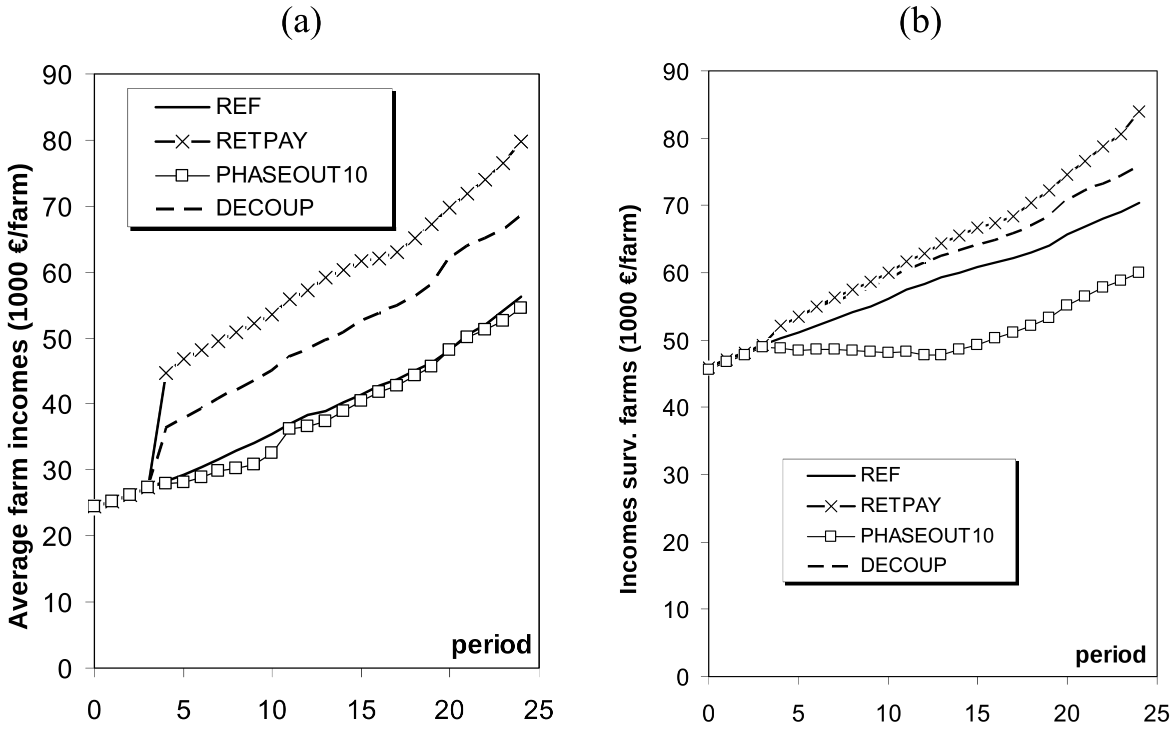
Table 7-8: Share of newly negotiated rental contracts for policy scenarios REF, RETPAY, PHASEOUT10, and DECOUP

Time period	REF	RETPAY	PHASEOUT10	DECOUP
Before policy change (t=3)	9.3%	9.3%	9.3%	9.3%
Immediately after change (t=4)	9.4%	59.5%	14.4%	61.4%
Short-term effect (t=6)	7.8%	6.4%	19.4%	13.8%
Medium-term effect (t=14)	5.3%	4.6%	19.9%	6.0%
Long-term effect (t=24)	3.6%	1.1%	12.4%	4.6%

7.5 Income implications

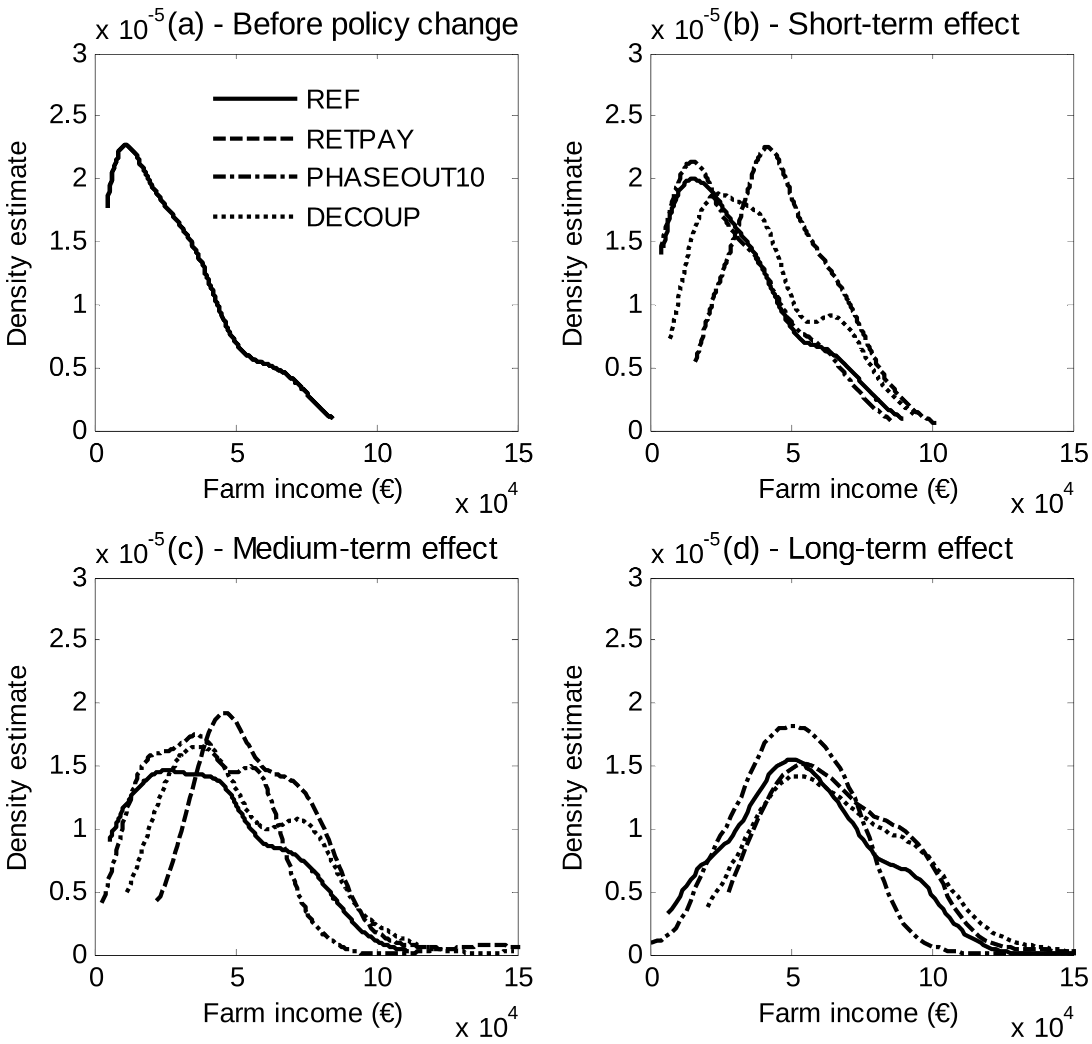
Before a policy change, about 40% of farmland is rented land. The share generally increases over time with structural change (refer back to Table 7-3). The increase is stronger for policies RETPAY and DECOUP which induce a strong and rapid structural change. As a result of this, the relation of rental prices to economic land rent changes in a way that average farm incomes are positively affected (Figure 7-19) as well as the distribution of farm incomes (Figure 7-20).

Figure 7-19: Evolution of average farm incomes for (a) all farms, and (b) farms surviving in all policy scenarios.



Based on the explanations and insights provided so far in this chapter, the specific income responses differ substantially between policies. In case of the retirement payment RETPAY, income grows as a combination of two effects. On the one hand, substantial structural change immediately after the policy change takes away pressure from the land market and provides the basis for surviving farms to grow and realise size effects. On the other hand, coupled direct payments favour certain production activities. However, despite of coupled direct payments less competition on the land market also reduces the degree to which direct payments transfer into rental prices. It should be stressed that these two effects weight higher than a fully decoupled single farm payment, which transfers fully into farm incomes.

Figure 7-20: Kernel density estimates of farm incomes at four time periods

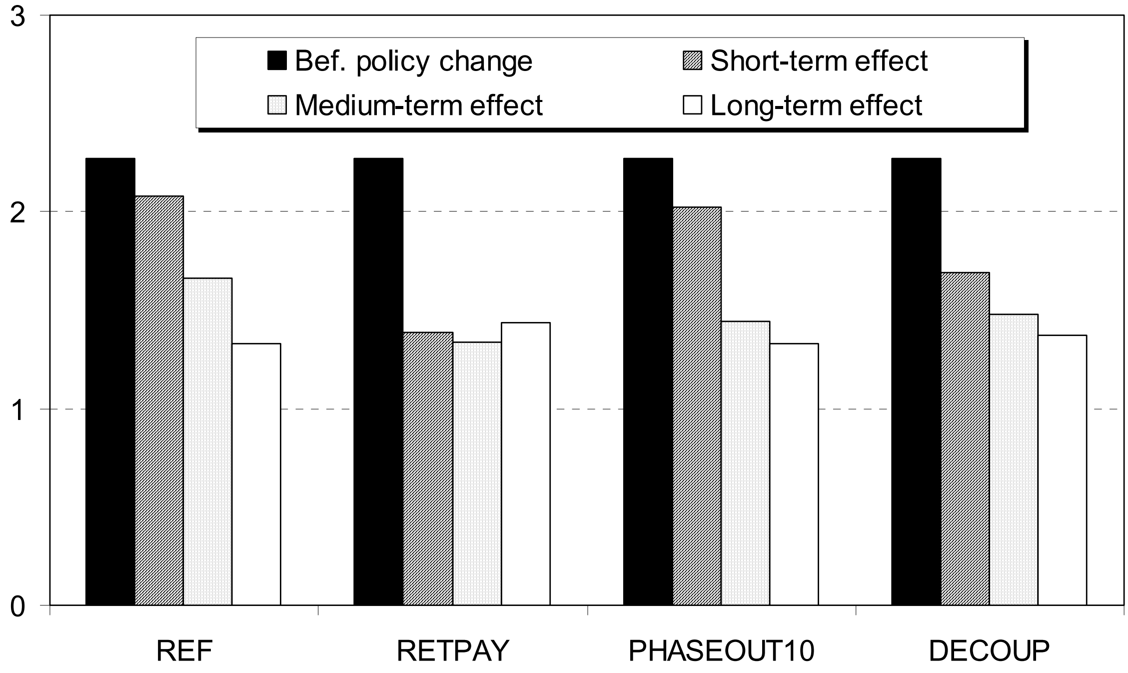


Policy PHASEOUT10 is particularly interesting because from Figure 7-19 (a) it could be concluded that, on average, efficiency gains (Figure 7-14) and lower rental prices compensate for income losses due to direct payment cuts. Against this, one may hold that the supposed efficiency gains may also result from a sample effect because the total number of farms in the sample changes over time. If instead of all farms, only farms surviving in all policy scenarios are analysed, Figure 7-19(b) shows that in scenario PHASEOUT10 farms on average incur income losses as compared to the reference scenarios DECOUP and RETPAY. With regard to stepwise payment cuts, the average income of surviving farms develops significantly below all other scenarios. Only when payments cease, restructuring leads to income increases.

7.5.1 Income differences by size and farm type

Before the policy change, the average farm income of the top quartile based on economic size is more than two times bigger than that of all farms (Figure 7-21). With structural change, income disparity decreases, though at varying degrees depending on the policy scenario.

Figure 7-21: Average farm income of the top quartile (25% largest farms based on ESU) as a ratio of the average of all farms.

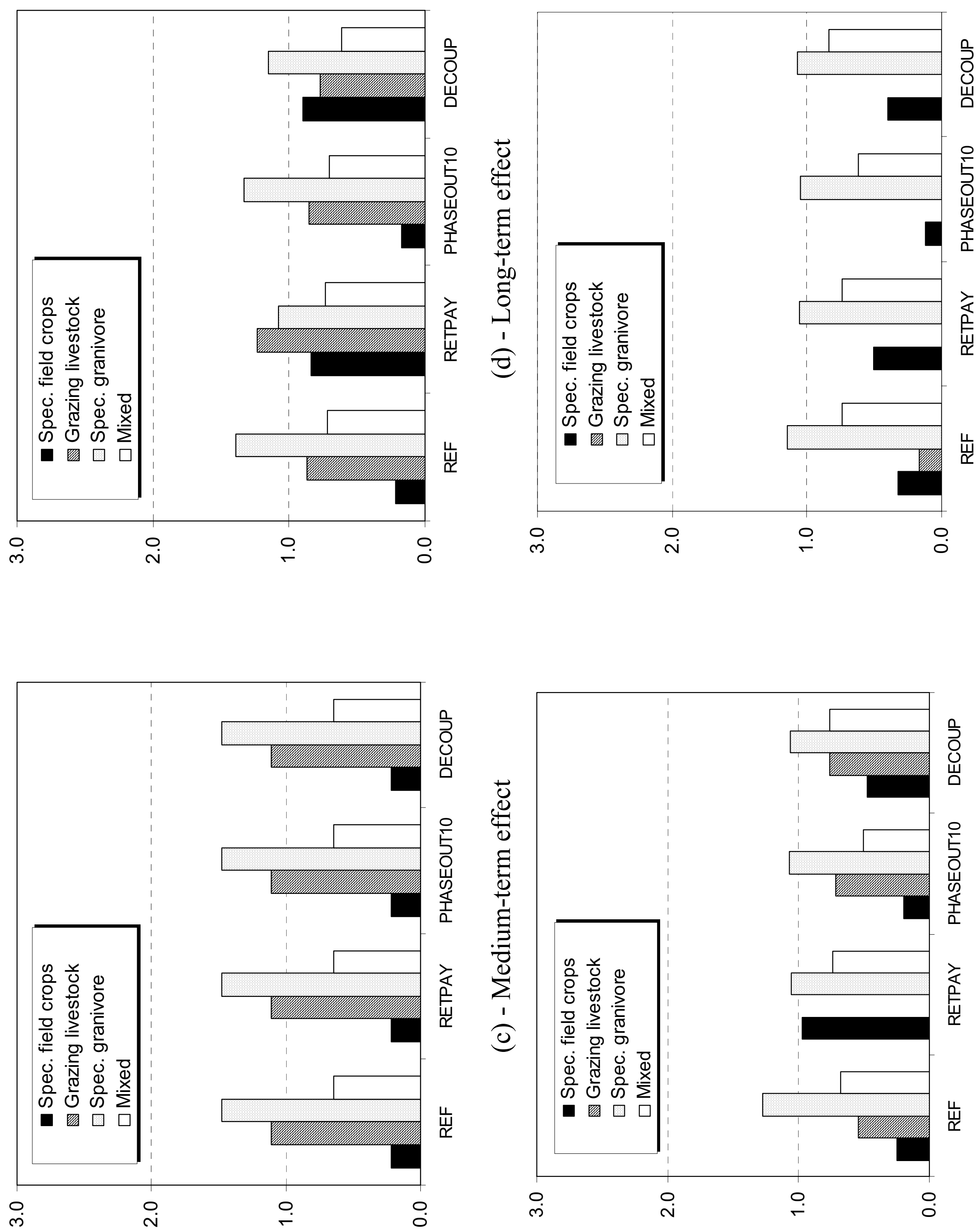


Differences become obvious in the short and medium-run, where for policy scenarios REF and PHASEOUT10, income disparity between the 25% best farms and the average of all farms remains quite high. Because of the large number of particularly small farms leaving in response to policies RETPAY and DECOUP, income dispersion in these scenarios decrease to their long-term level immediately after the policy change. From a long-term perspective, all policies narrow the dispersion of income by farm size and the farm income is therefore more equally distributed.

There are also income disparities between farm types, but they are not as large as between farms classified by economic size. This is shown in Figure 7-22. For example, in the short-run in scenario RETPAY, the average farm income of grazing livestock farms and specialised granivore farms, which account for 2% and 75% of all farms, is respectively 25% and 10% higher than that of all farms. However, already in the medium-run none of the farms specialises in grazing livestock production. Farms increasingly derive income from activities not affected by policy (Table 7-4).

Thus, the comparative income advantage of the grazing livestock farms in period 6 is not sufficient for the farms to keep their specialisation. Also specialised field crop farms are an exception in this scenario as only 1% of the farms in the region follow this specialisation. Overall, income differences are much higher in specialised granivore farms, which account for between 45% and 80% respectively of all farms in the region. It has to be taken into account that the majority of specialised field crop and mixed farms are operate as non-professional farms, that derive the major income share from off-farm employment opportunities.

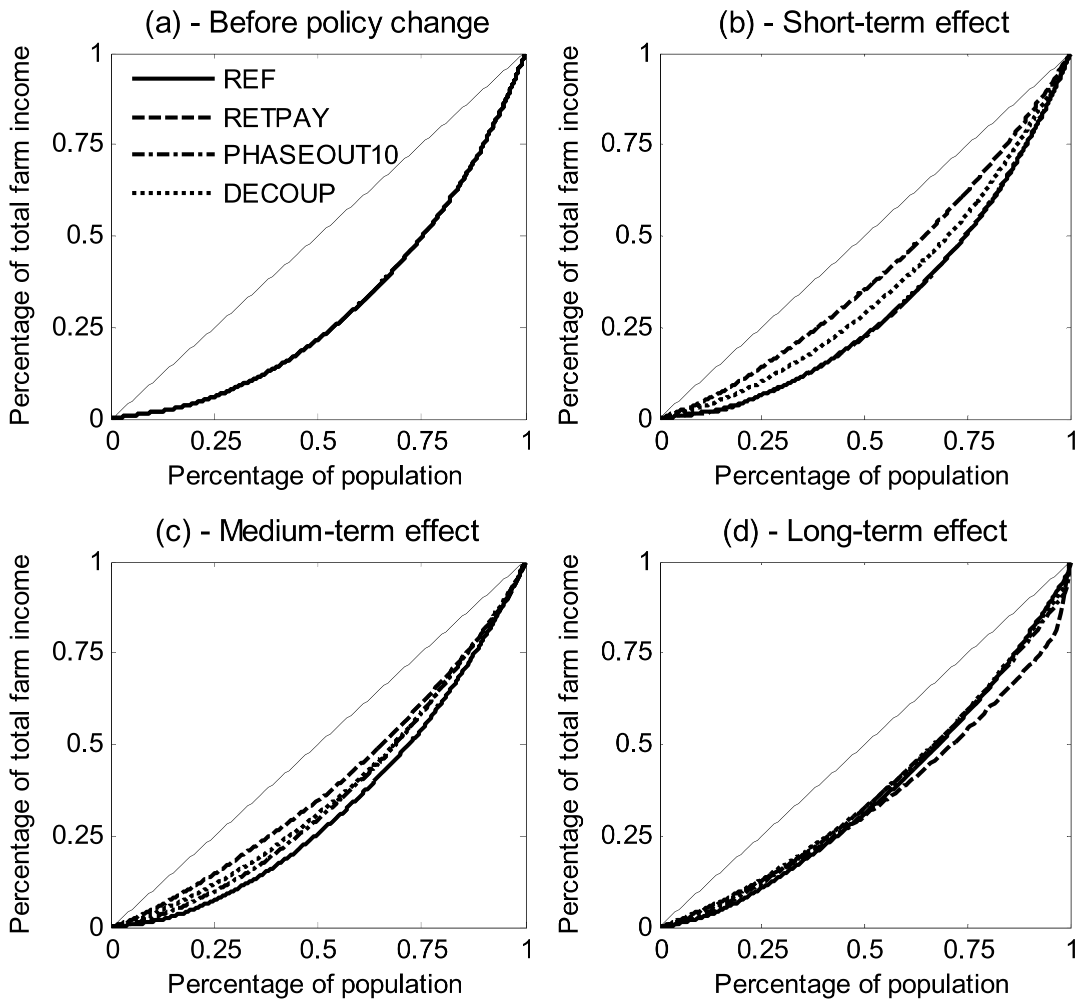
Figure 7-22: Average farm income of each farm type as a ratio of the average of all farms



7.5.2 Impact on income distribution

The distribution of farm incomes within the farm sector is an important issue. Based on simulation results, distributions of farm incomes are analysed for different time periods. Using the methodology introduced in chapter 6, the distribution of farm incomes is compared graphically in Figure 7-23 showing Lorenz curves and numerically in Table 7-9 using Gini indexes.

Figure 7-23: Empirical distribution of farm income at four time periods



Differences in distribution are highest shortly after the policy change. In the reference, farms in the lower quartile earn approximately 10% of total farm income (see Figure 7-20 for absolute values), whereas farms in the upper quartile account for more than 50% of total farm income. Over time, income inequality decreases in the reference scenario and scenarios DECOUP and PHASEOUT10.

Table 7-9: Gini indexes of income distribution

Time period	REF	RETPAY	PHASEOUT10	DECOUP
Bef. policy change	0.39	0.39	0.39	0.39
Short-term	0.38	0.21	0.38	0.30
Medium-term	0.34	0.22	0.28	0.26
Long-term	0.27	0.31	0.26	0.25

The introduction, in particular of a retirement payment (scenario RETPAY) has a significant impact on the distribution of incomes within the group. In particular, in the short-run, farm incomes are more equally distributed as about 75% of the farms accounted for about 65 % of the total income. The explanation for this is quite straightforward and follows a pattern that appeared already several times in this chapter: compared to the situation before the policy change a large number of low-income farms leaves the sector, such that the remaining farms can increase their income share. Right after the policy change, the group of farms remaining in the sector in scenario RETPAY is comparatively more homogeneous with respect to specialisation and economic size, which explains why the distribution of incomes is more equal. Note furthermore that inequality increases over time. This is quite surprising, as the agricultural structure quickly adjusts in response to the policy change, as was shown above. But, it confirms that, after the consolidation, the group of farms is getting increasingly heterogeneous.

Thus, retirement payments together with coupled direct payments decrease inequality in terms of income because of structural change in the short-run, but this is not a lasting effect. All other policies lead to a more lasting decrease in inequality. In comparison with these policy scenarios, the absence of direct payments in scenarios PHASEOUT10 affects incomes of all farms in the sample in that the distribution of farm incomes moved to the left (Figure 7-20). This implies that the average income decreases in the short-term.The absence of direct payments also affects the lower tail of the distribution as eventually some farms experience income losses. This influences the stability of a farm in a negative way because equity diminishes (Figure 7-24). In particular, in scenario PHASEOUT10, low profits transfer into very low or even negative change in equity capital, which puts the stability of the farm at risk.[98] This provides one further indication that farms in this particular scenario are driven out.

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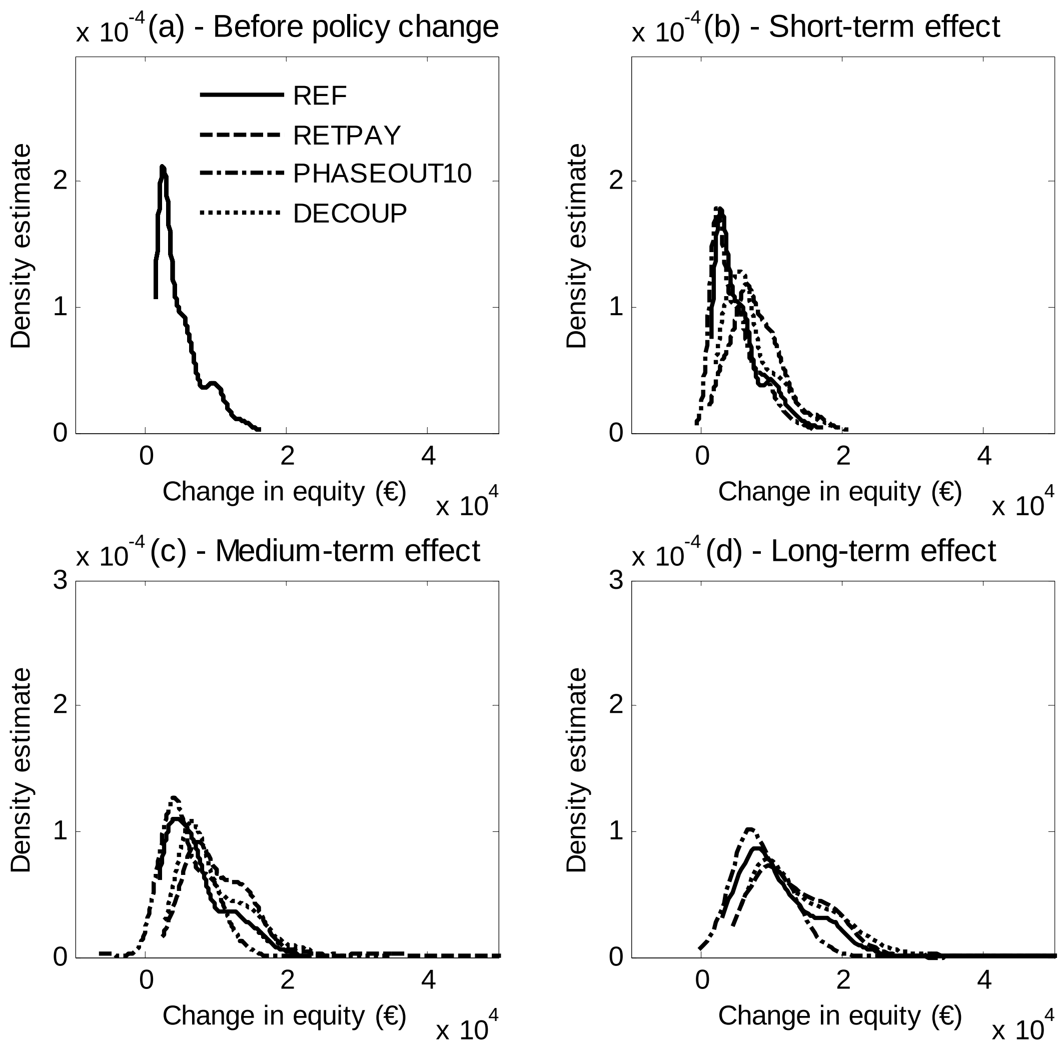
98 Change in equity capital is calculated as total household income including off-farm income minus total household consumption, which is at least 15,500 Euros per family labour unit.

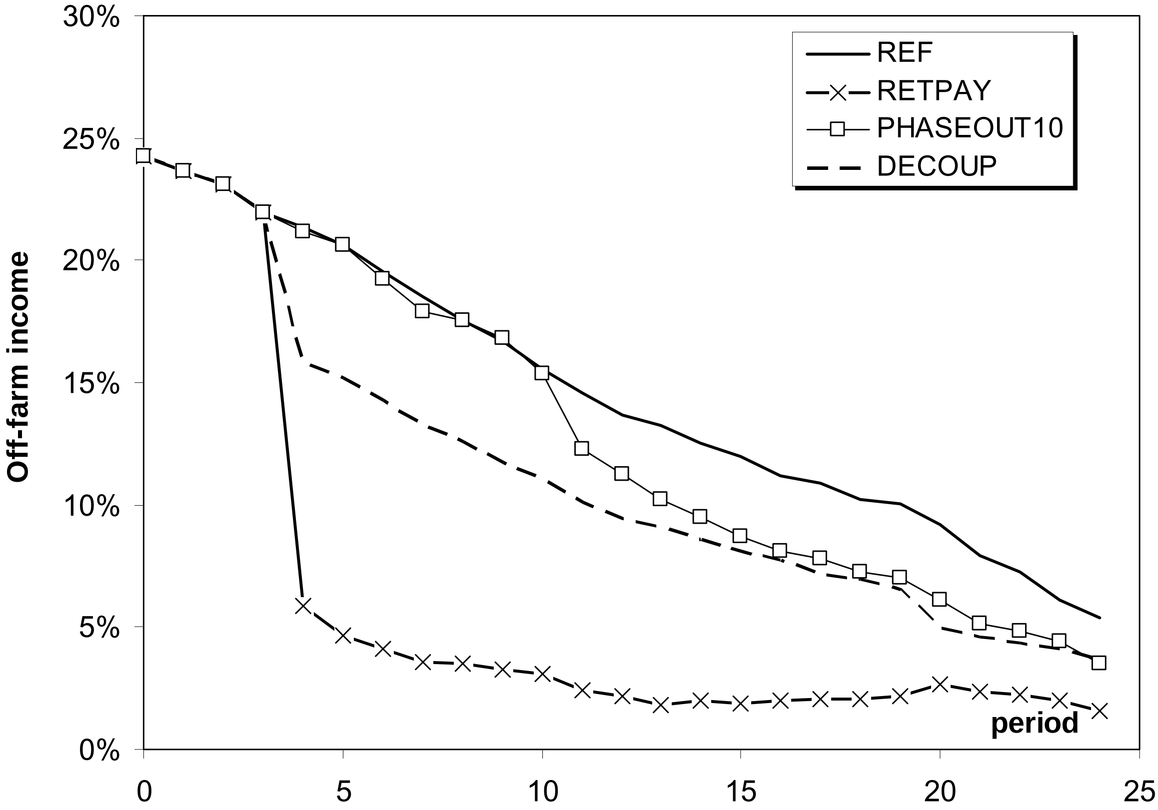
Figure 7-24: Kernel density estimates of change in equity at four time periods



7.5.3 *Off-farm income sources*

In view of equity change, it is interesting to observe the role that off-farm income sources play in the process of structural change in particular as non-professional farming is often considered as an adjustment strategy with respect to decreasing subsidy payment. The contribution of off-farm income sources to total household income (from which change in equity is calculated) is shown in Figure 7-25. Before the policy change, farms, on average, earn a quarter of total household income outside the farm. With structural change, the share of off-farm income decreases in all policy scenarios.

Figure 7-25: Evolution of average off-farm income share in total farm household income



The figure suggests that the contribution of non-professional farming as a source of income generation is declining significantly over time. This could be either because of the decreasing share of non-professional farms, or because of a growing share of on-farm incomes. A more differentiated view on this can be obtained from Table 7-10 which shows the contribution of off-farm income to total household income for farms with an economic size of less than 25 ESU.

Table 7-10: Off-farm income share of small farms < 25 ESU[a)]

Time period	REF	RETPAY	PHASEOUT10	DECOUP
Bef. policy change	65% (228)	65% (228)	65% (228)	65% (228)
Short-term	64% (189)	41% (6)	65% (167)	54% (80)
Medium-term	60% (100)	24% (1)	58% (30)	48% (34)
Long-term	47% (41)	28% (2)	90% (3)	42% (15)

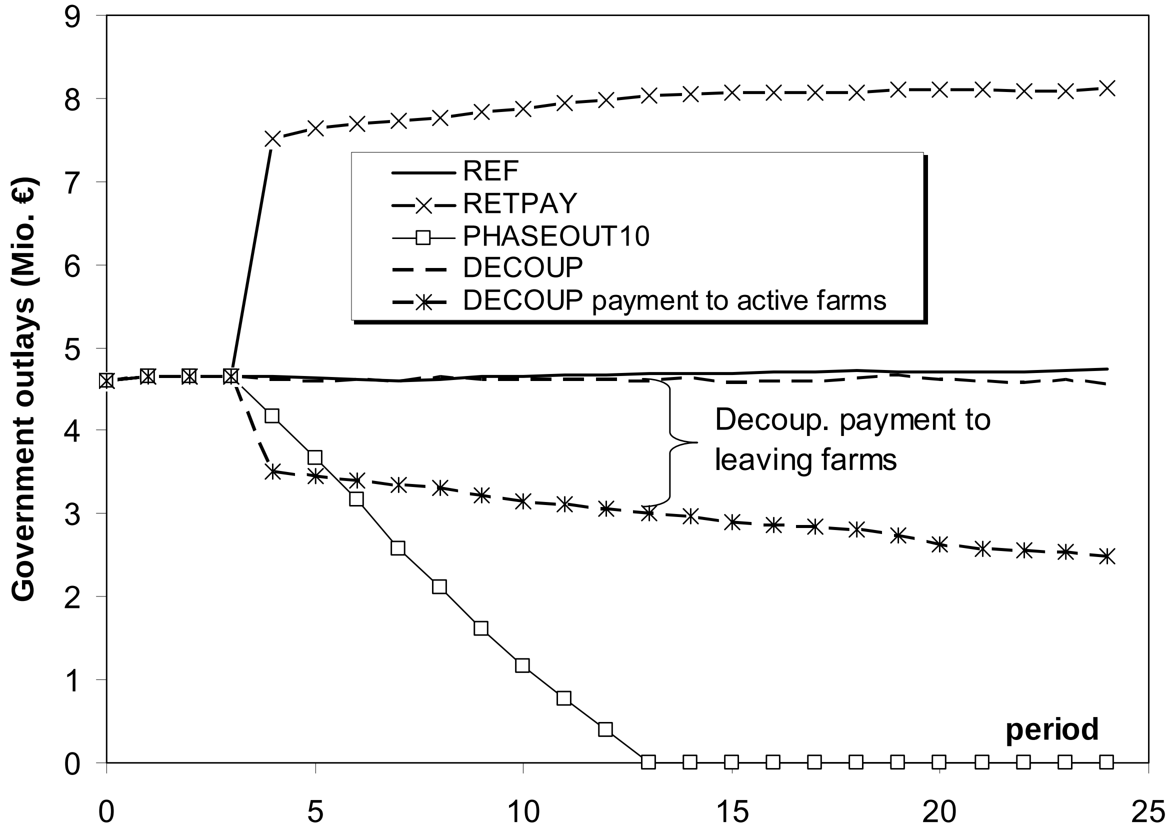
Note: a) Number of farms in parentheses.

The average off-farm income share is significantly above the average in the entire region. Despite of this, the number of very small farms also dramatically decreases over time, particularly in scenario RETPAY. This may explain the declining share of off-farm income in total farm household income.

7.6 Government outlays

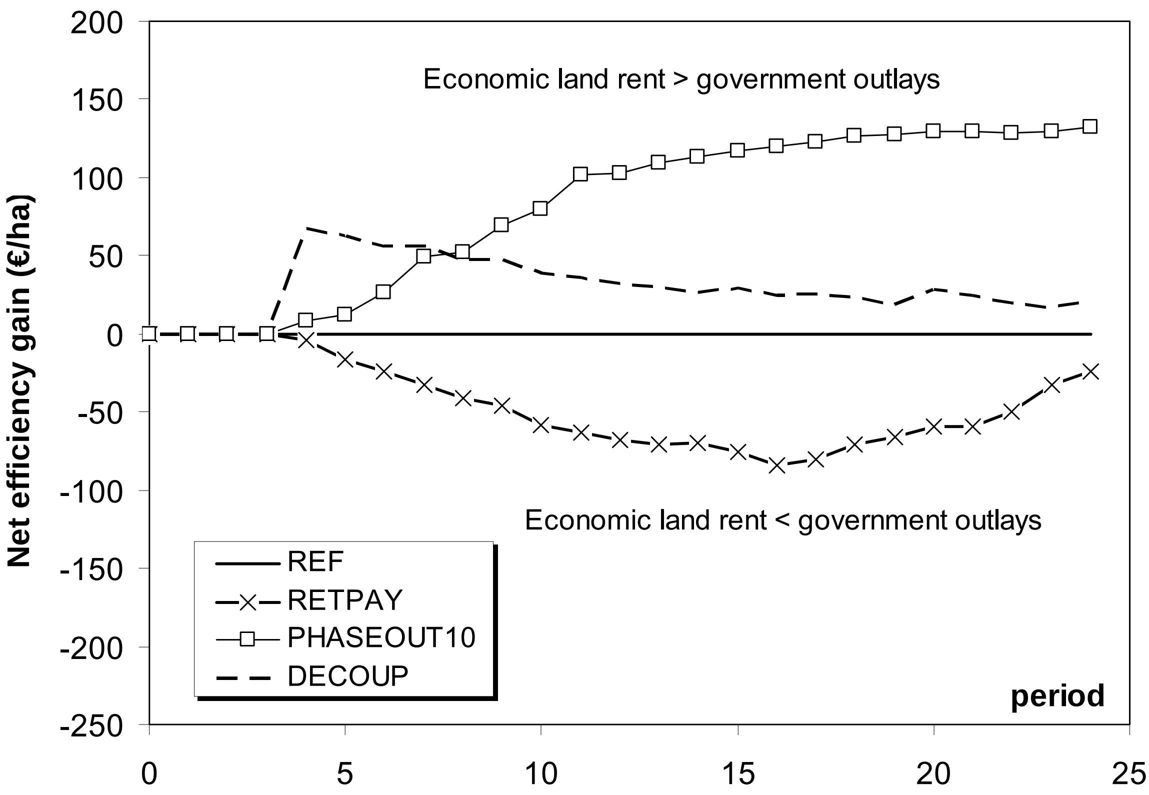
The last perspective from which the policy alternatives are analysed is the government's total expenditure (outlays) on policy. For this, Figure 7-26 shows total outlays going to active and farmers who have left the sector in the course of simulation. As expected, with the introduction of a retirement payment, total expenditure increases rapidly and substantially compared to the reference. Removing labour from the sector by means of an incentive payment – in this case paid as an annual rent of 10,000 € – thus turns out to be a very costly policy. Of course, the pull-effect of the incentive payment also depends on the amount, as it can be expected that a lower payment will draw less farms out of the sector.

Figure 7-26: Total government outlays granted to active farms and leaving farm agents



When contrasted with the achieved efficiency gains brought about by policy RETPAY, the net effect is in fact negative. Figure 7-27 illustrates that expenditure per hectare in each time period exceeds efficiency gains measured in economic land rent relative to the reference (see Figure 7-14). In this comparison, sunk costs of fixed assets are not included. If they were included, at least in scenarios DECOUP and RETPAY, the devaluation of fixed assets due to structural change (see Table 7-7) would be very large and outweigh any social efficiency gains in the short-run. In the long-run, efficiency gains from policy DECOUP outweigh the adjustment costs of the policy relative to the reference (see Table 7-7) at equal costs to the government.

Figure 7-27: Net efficiency gain measured as the difference between economic land rent per hectare farmland, and total government outlays per hectare relative to the reference



Note: Economic land rent including subsidies.

On the contrary, efficiency gains are highest for policy PHASEOUT10, which is not surprising as 10 periods after the policy's introduction costs to the state are zero and adjustment costs to the policy are not included here. However, the social efficiency gain has to be seen against lower incomes by farmers. Once payments are removed, equity change was negative for very few farms, putting some farms' stability at risk (Figure 7-24).

Whereas policies RETPAY and PHASEOUT10 represent two extremes in terms of policy expenditure, policy DECOUP takes a neutral position. Compared to the reference, total expenditure on the policy is positive remained at the same level, but efficiency gains are higher. Furthermore, as Figure 7-26 shows, in the short and medium-run the share of payments going to active farm is higher than the share going to farms withdrawing from the sector. However, the total amount going to active farms steadily decreases over time which is reflected in a decreasing efficiency gain in Figure 7-27.

7.7 Summary and discussion of results

The simulation experiments carried out and analysed in this chapter focussed on three policies. Table 7-11 provides a synopsis of key results for individual alternative policies.

While each policy affected the agricultural structure of Hohenlohe in a different way, the original intention behind each policy was to reduce impediments to structural change and increase the efficiency of production in the region. At this point, it should be stressed that the results obtained are limited by the assumptions on which AgriPoliS, the underlying data and the analysis methods are based. As stated in OECD (1994), *"any assessment of the implications of policy reforms will be complicated by the multitude of conflicting and contrasting forces that can be expected to exert adjustment pressures, particularly the overall state of the economy, changes in tastes and demographics changes."*

With regard to this application of AgriPoliS, it was assumed in particular that exogenous framework conditions do not change. In AgriPoliS, this applies to the labour market, interest rates, and the volatility of product prices not directly regulated by policy. Furthermore, results rest upon the assumption of technological change and size effects. Against this background, the results derived in this chapter have to be interpreted. Regarding the sections of this chapter, the following points shall be made.

7.7.1 Agricultural structure

- As expected, policies providing incentives for small farms to withdraw from the sector, lead to significantly larger farms that realise size effects and produce at lower costs.
- Depending on the definition of the respective policy, the speed of structural adjustment differs substantially between policy scenarios. Policies that provide incentive payments cause stronger adjustment reactions right after the policy change (DECOUP and RETPAY) than a policy introducing gradual changes (PHASEOUT10).

Table 7-11: Synopsis of alternative policies

	RETPAY	PHASEOUT10	DECOUP
Goal of policy	- Incentive payment for small farms to leave - Income transfer to non-competitive farms	- Gradual removal of assistance over 10 periods - Market signals determine farm decision-making	- Market signals determine farm decision-making - Decoupled single farm payment (SFP) income transfer to farmers
Effect of policy	- Strong reaction to policy change - 'Pull-effect': 50% of farms withdraw from sector after policy change → average farm size doubles - Short-term improvement of (individual) DEA efficiency - Significant increase in allocative efficiency of remaining farms - High incomes for remaining farms	- Gradual structural change: 'push-effect' - Efficiency increases (DEA+allocative) - Rental prices decrease with decrease in direct payments (almost no demand for grassland)	- Strong reaction to policy change - 'Pull-effect': A third of farms withdraw after policy change → non-production more profitable than farming - SFP → stays with farmer → rental prices cut by half - Efficiency increases (DEA + allocative + social)
but:	- High rental prices, causing capitalisation of direct payments in land value; share of payments go to land owners - High government outlays for leaving farms → efficiency losses, i.e., costs of policy outweigh efficiency gains - Coupled direct payments determine production → gradual re-intensification because of direct payments	- Incomes significantly lower than in other scenarios → lower rental prices, and efficiency gains do not compensate for complete removal of direct payments - Land is abandoned - Land assets loose value	- Over time, increasing share of SFP goes to leaving farmers - Land assets loose value → equity losses of land owners
Common to all policies	- Dairy production and beef cattle production ceases in the long-run independent of policy - Suckler cow production depends on provision of coupled direct payments - Dominant position of intensive livestock production increases with structural change		

- If payments are coupled to production, all land is rented in the region. If payments are either removed or decoupled from production, some land is abandoned, i.e., it is not demanded by farms. This results in very low rental prices, particularly for grassland. Even with very low rental prices for grassland, suckler cow production is not taken up at large scale. Hence, suckler cow production in this model is only profitable at a larger scale when there are coupled direct payments.
- Dairy production and beef cattle production cease in the long-run irrespective of the policy environment. On the one hand, this is owed to the fact that dairy and cattle are mostly held in small production units, most of which leave the sector over time. On the other hand, farms do not invest in dairy and cattle production because of high investment costs and high labour intensity.
- In all policy scenarios, the dominant position of specialised granivore farms grows despite of the downward trend in product prices. Farms operating as specialised granivore before the policy change have the highest chances to survive during structural change in any of the alternative policies. What does this mean? First of all, with structural change, production in the region moves away from low productivity production activities depending on grassland toward policy-independent production activities. This is because farms already operating as specialised granivore farms do not switch to dairy or cattle production. If the rental price for grassland is low, or direct payments are available, suckler cow production, which is less capital intensive than dairy production (policy RETPAY), is taken up by a few farms. Second, specialisation in intensive livestock production is also the result of the possible production activities defined in the model. The model only considered production activities, which were typical for the base year. Other alternative production options were not considered. If other alternatives were provided, farms could be expected to diversify more.
- A decoupled single farm payment leads to extensification of production in terms of stocking density. Scenarios REF and RETPAY eventually lead to an increase in the stocking density in the medium and long-run due to the combined effect of low rental prices for (mainly) grassland and coupled direct payments.
- Farms increasingly specialise and operate as professional farms, i.e., the decision of farms is increasingly a leave-or-stay decision. Non-professional farming as an option 'in between' is an adjustment reaction to some farms in the short and medium-run, but it becomes irrelevant in the long-run.

7.7.2 Efficiency

- Regarding individual DEA efficiency, they are statistically significant differences in means. Policies RETPAY and DECOUP increase mean efficiency in the short-run as structural change takes place and inefficient farms withdraw. In the medium and long-run, the impacts of policies DECOUP and PHASEOUT10 on mean efficiency is higher, though.
- Regarding the share-weighted structural efficiency, differences between scenarios are smaller, but remain significant. The output share of relatively inefficient farms is relatively small such that their contribution to total production can be neglected.
- Compared to the reference, policies DECOUP and PHASEOUT10 represent improvements regarding mean and structural efficiencies throughout the entire simulation. Although differences between these scenarios and the reference are small, they are statistically significant. Accordingly, the individual efficiency of farms increases.
- Taking adjustment costs into account, all alternative scenarios represent overall economic efficiency gains that compensate for adjustment costs. Overall efficiency gains are highest for policy DECOUP.

7.7.3 Income

- Under the assumed framework conditions (constant interest rates and wages, little downwards trend of product prices), farm incomes on average increase. However, there are income differences between farm sizes and farm types.
- If no direct payments are paid to farms (scenarios PHASEOUT10 after 14 simulation periods), a few farms generate a very low farm incomes eventually leading to negative equity change. Still, 98% of the farms operate at farm income levels of 20,000 € and above (including non-professional farms). Although average farm incomes of farms operating without direct payments are lower than in other policies, the stability of the great majority of farms is not at risk. Additionally, declining land values may also endanger farm stability as the land serves less as a loan security.
- As for off-farm income sources, mostly small farms derive income from off-farm sources. In general, the stronger the policy under consideration induces structural adjustment process (RETPAY, DECOUP), the lower is the share of off-farm income of total farm household income.

7.7.4 General

This last point not only holds for structural efficiency but also for other indicators (profit, farm size, economic land rent), namely that in the long-run differences between scenarios in terms of the distribution of indicators but also in the averages get smaller. What are the reasons for this? First of all, sudden and hard policy changes (RETPAY and DECOUP) lead to strong reactions on the side of the farms in the short-run. With a large number of farms leaving right after the policy change, the region is more or less consolidated with the remaining sample of farms being comparatively homogeneous. In the periods following the policy change, the heterogeneity of farms continuously increases, as for example the emergence of few but very large farms in the sample shows. In addition, the initial adjustment pressure created by policies RETPAY and DECOUP is strong. Following this, in policy RETPAY the retirement payment provides only little incentives for further structural change. This is fundamentally different in policy scenario PHASEOUT10 and even in the reference. In the latter case, the 'natural' structural dynamics inherent in AgriPoliS provide a constant, but slow adjustment pressure to farms. However, effects similar to a sudden policy change are only visible in the long-run.

Moreover, the simulation results have to be interpreted within the assumptions made. Several points appear especially relevant. *First*, AgriPoliS assumes economies of scale and technological change (cf. chapter 4) by way of lower costs which can be realised by all farms in the region by investing in assets, respectively. This assumption is in accordance with empirical observations on cost digressions (e.g., KUHLMANN 1999; KUHLMANN and BERG 2002) as well as theoretical considerations (e.g. BRANDES and ODENING 1992). *Second*, it is assumed that the rural labour market is capable of taking up all excess labour from agriculture as well as to meet farms' demand for hired labour. *Third*, farms face high sunk costs, as opportunity costs of farm-owned production factors are low, or zero in the case of fixed assets (cf. BALMANN 1995). Yet, one should not forget that opportunity costs between farms are heterogeneous and depend, e.g., on education and mobility. *Fourth*, rather moderate differences in the managerial ability of farms were assumed. That is, unit production costs of farms with high managerial ability and farms with low managerial ability differed by a 10% maximum. In reality, production cost differences between individual farms are potentially much larger. *Fifth*, labour-saving technical change and the assumed increase in costs of hired labour were considered comparatively low. Finally, *sixth*, as for off-farm labour opportunities, there are no differences in skills of individual farmers, i.e., farmers are equally smart and capable to work off-farm.

8 Decoupling direct payments

8.1 Introduction

In the previous chapter, the focus of analysis was on three different policies. Each policy directed at lifting some impediments to structural change caused by agricultural policies. From the analysis, some general conclusions were drawn regarding adjustment reactions to policy changes. This chapter takes one of the policies discussed in chapter 7, decoupled direct payments, and analyses different approaches to decoupling direct payments.

The agricultural sector has a long tradition of protection and support payments. For nearly half a century, the main motivation for payment and support has been to raise incomes to small family farms. However, this traditional way of agricultural policy making is associated with numerous negative effects. On the side of the farms, it has over the years lead farmers into a path-dependence in that support has stimulated farmers to invest and specialise in certain areas. Moreover, support is costly and not well targeted to the intended beneficiaries, which limits the acceptance of policy by society. If tied to the production of livestock or land, future support payments tend to be capitalised in land and paper assets (BEARD and SWINBANK 2001). At the more global level, support policies have depressed world market prices and reduced export shares of countries which do not support agriculture (BAFFES 2004). The central characteristic of all these policies is that they are coupled to production levels, input use, and prices.

Given the harmful effects of traditional support policies, it has long been advocated to decouple support from production, input use, and prices. (cf., BAFFES 2004; BEARD and SWINBANK 2001, DEWBRE et al. 2001; KOESTER and TANGERMANN 1976; LEWIS and FEENSTRA 1989; OECD 2001a; SWINBANK and TANGERMANN 2000; WISSENSCHAFTLICHER BEIRAT BMVEL 1997). A policy is fully decoupled if it *"… does not influence production decisions of farmers receiving payments, and if it permits free market determination of prices"* (CAHILL 1997). Assuming that a sudden move towards free market conditions will not be a socially and politically feasible alternative, the primary motivation for decoupling is to compensate farmers for the move to free markets with transitions adjustment assistance while at the same time making the policy transparent and palatable (BAFFES 2004; BEARD and SWINBANK 2001).

In the European Union, partly decoupled direct payments were first introduced as part of the MacSharry reforms in 1992, and they were further augmented by Agenda 2000. Regarding cereal production, payments were partly decoupled in that they combined a reduction of price support with compensatory payments. But, these compensatory payments still influenced the farmer's decision on how much land to plant. In that way, they were tied to the production of certain products, mainly cereals and cattle, such that decision making was not yet fully independent of support. As for headage payments, BAFFES (2004) mentions two reasons why these payments were coupled to production: first, because farmers were allowed to keep more cattle than are eligible for payments. Second, because the maximum number of cattle is not linked to numbers on farms prior to the introduction of the policy.

Decoupling of direct payments has been the predominant topic in European agriculture already before it has been brought into the discussion in the mid-term review of Agenda 2000 (EU COMMISSION 2002). The key element in the mid-term review proposal is the introduction of a decoupled 'single farm payment' which is not related to production but based on historical payments and cross-compliance rules. Although the 'single farm payment' was envisioned as the standard form of decoupling, the Commission granted member states the option to introduce a regionalised single area payment instead (COUNCIL REGULATION (EC) No 1782/2003). This single area payment is based on the total regional envelop of payments divided by the total number of eligible hectares. In response to political pressures from several member states, the final decision taken by the agricultural council in June 2003 offered even greater choice to individual member states as for specific provisions to decouple direct payments (COUNCIL REGULATION (EC) No 1782/2003). In particular, member states were allowed to maintain limited coupled elements to avoid abandonment of production. That is, for some products, direct payments remain coupled to production, though at varying degrees.

Hence, three principal ways of decoupling direct payments have been decided upon: a single farm payment, a regionalised single area payment, and partially decoupled direct payments.[99] Although all three alternatives are named 'decoup-

[99] It is generally also possible to combine the described approaches as, for example, the dynamic hybrid scheme to be implemented in Germany shows. Depending on the farm type

led', the direction of effects can be expected to differ. For example, whereas under a single farm payment the payment to farmers remains at the same level than before the policy reform, a single area payment is expected to lead to redistribution of payments between farms (KLEINHANß 2004). Starting from this, the goal of this chapter is to show and discuss adjustment reactions and adjustment patterns that could emerge from different ways of decoupling direct payments.

8.2 Policies considered

The alternative decoupled policy scenarios considered in this chapter are listed in Table 8-1. Although they do not exactly correspond to the proposals of the EU commission, the policies defined reflect the three main directions in which decoupling will be made possible in the EU after 2005.

The *first* policy is the decoupled single farm payment (DECOUP) which was introduced and defined in chapter 7. The analysis carried out in chapter 7 shows that a decoupled single farm payment (scenario DECOUP) leads to overall efficiency gains in terms of a better allocation of production factors across farms, and an increase in social efficiency. However, this comes at the expense of some land being abandoned. On average, about 7% of the total agricultural area in the region is abandoned after the policy change.

A key element of the new common agricultural policy of the EU, however, is to keep all agricultural land in good condition (COUNCIL REGULATION (EC) 1782/2003). To prevent the abandonment of agricultural land, the single farm payment in scenario DECOUP is adjusted by introducing a mixed payment.
This mixed payment, granted under the *second* policy DECOUPREG50, combines a decoupled single farm payment with a low area payment. In principle, the total payment granted to each farm after policy reform is at least as high as before the reform, since their calculation is based on a historical reference period. The decoupled single farm payment is paid to the person of the farmer. The area payment was chosen such that it covers the costs of maintaining grassland in minimum condition. A payment of 50 € per hectare proved sufficient for Hohenlohe. Moreover, to keep government outlays to finance the policy at the same level than the reference policy REF, the single farm payment component of the mixed payment is set at 84% of the single farm payment granted in policy

and location, the payment going to farmers is initially mixes a regional area payment, with elements of a single farm payment and coupled payments. Over time, the payment mix changes dynamically towards a regionalised single area payment.

DECOUP. If a farm withdraws from the sector, it continues to receive the single farm payment component. The area payment component is granted to active farmers to provide an additional incentive to farmland. A comparison of policies DECOUP and DECOUPREG50 is presented in appendix A-7. The comparison shows that results of these two scenarios are very similar. This is why scenario DECOUP is dropped from the further analysis in this chapter.

Table 8-1: Policy scenarios

Abbreviation	Scenario name	Scenario description
REF	**Agenda 2000**	- Full implementation of Agenda 2000 at the end of 2002 - No requirement to manage all land belonging to a farm
DECOUP	**Fully decoupled single farm payment**	- Each farm household receives a decoupled single farm payment based on the average direct payment paid to a farm during three periods before the policy change - Bound to person of the farmer and legal successor - Single farm payment is granted independent of farming, i.e. it is also paid if a farm leaves the sector, for the next 20 simulation periods after policy change - Farms are required to manage all farm land belonging to a farm at least in a very basic way (cutting)
DECOUP-REG50	**Fully decoupled single farm payment + low area payment**	- Combination of DECOUP and REGPREM - Total payment is split into single farm payment part and area payment part - Decoupled payments are set to 84% of the decoupled payment in scenario DECOUP[a)] - Low area payment of 50 €/ha that is granted if the plot is managed.
REGPREM	**Regional single area payment (310 €/ha)**	- Calculated based on average total payments granted to all farms over the last three time periods before the policy change in the region - Farms can only claim the payment for thei plots - Farms are required to manage plots belonging to the farm in the most basic way (cutting grass) - Farm s cannot claim a payment for land that is not managed or abandoned
PARTIAL	**Partly decoupled payment**	- 50% of the total amount of direct payments granted to farms in the reference period remains coupled - The remaining 50% are decoupled as an individual single farm payment - Payments is split into payment entitlements per hectare which are assumed to be transferred with the plot[b)]

Notes: a) It is equal to the historical reference payment minus 50 €/ha of average UAA before the policy change; b) It is assumed that all farmed land is eligible for payment entitlements.

The *third* policy considered, REGPREM, introduces a regional single area payment. The payment per hectare corresponds to the average payment in the last three periods before the policy change divided by all agricultural land in the region. This amounts to an area payment of 310 € per hectare. The single area payment is uniform across the entire region. It is implemented as a payment entitlement per hectare, which a farm receives for all its plots. Grassland and arable land are equally eligible for claiming the payment. Unlike policy DECOUPREG50, a single area payment does not guarantee that each farm in the region receives the same amount of payments as before the policy reform. Hence, it can be expected that there will be an immediate and potentially strong redistribution of payments between farms (ISERMEYER 2003).

Finally, the *fourth* policy, PARTIAL, introduces direct payments which are only partially decoupled from production. Policy PARTIAL is defined in a way that half of a farm's total coupled payment before the reform is paid as a decoupled single farm payment after the reform. Unlike policies DECOUPREG50 and REGPREM, coupled direct payments for cereals, suckler cows and beef cattle were kept, but cut by 50% each. The decoupled farm payment is granted to active farms, but not to the person of the farmer such as in policy DECOUPREG50. Furthermore, the decoupled payment component going to each farm is split into payment entitlements per hectare. Active farms, thus, can claim payments for each plot they manage. It is assumed that payment entitlements cannot be traded, but remain fixed to a plot of land, also when the plot is traded. This particular policy setup has three implications. One is that payment entitlements per hectare differ between farms depending on their historical level of direct payments and acreage. Second, support is paid only to active farmers. Third, because payment entitlements are not tradable, their value can be expected to transfer to higher land rental prices.

As mentioned in chapter 7, farms' expectations about the value of land after policy reform are exogenously given. In the decoupled scenarios DECOUP and DECOUPREG50 farms are assumed to expect rental prices (and hence opportunity costs of land) for arable land (grassland) to drop to 75% (50%) of the regional average. In scenarios REGPREM and PARTIAL, the decrease of rental prices is assumed lower (90% for arable land and 50% for grassland) respectively because farm agents expect a greater share of the direct payment to transfer into land prices.[100]

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[100] Different values for the expected decrease of rental prices were tried out, but results are

The following sections present results using the analytical framework of chapter 6. The summary at the end of the chapter gives synoptically an overview of key results. As the previous chapter introduced more general adjustment patterns to policy changes, these will not be developed again in this chapter. Rather, special focus is put on differences between decoupling alternatives. The discussion in this chapter will focus exclusively on the issue of decoupling direct payments. It will not touch issues such as cross-compliance, rural development, market regulations, or modulation, which are also key elements of the 2003 EU policy reform package.[101]

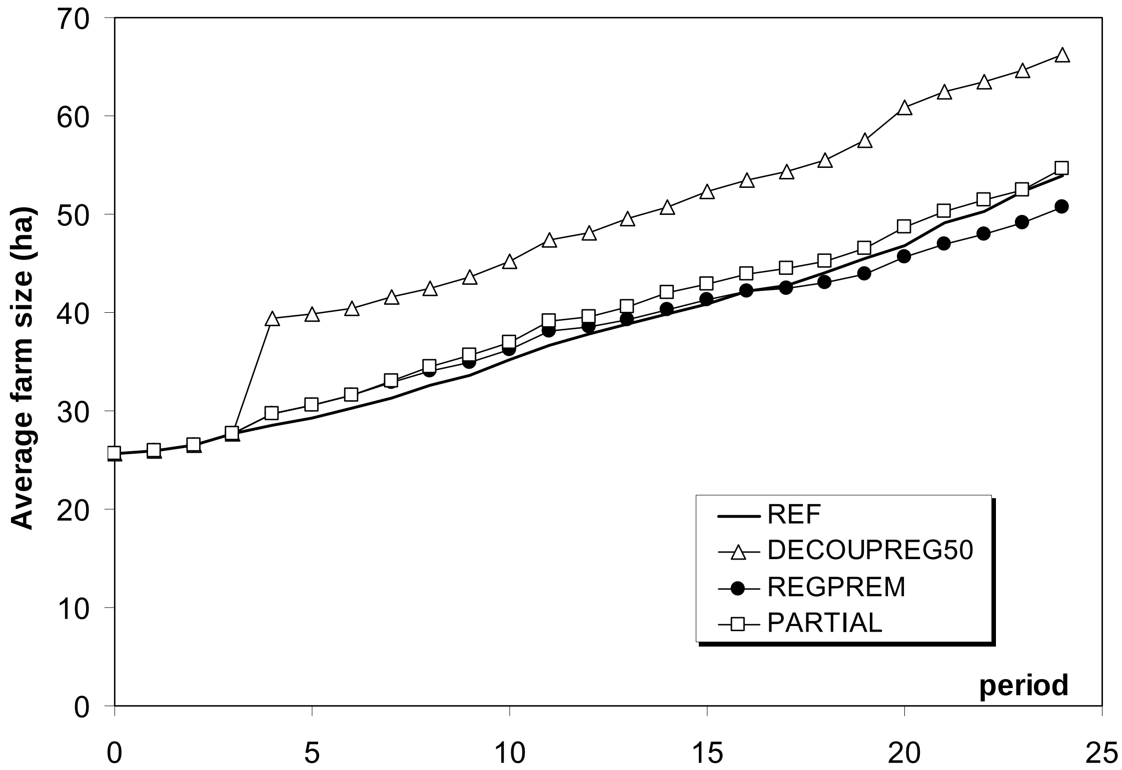
8.3 Impact on farm size

The development of the region with respect to farm size measured in hectares and economic size measured in ESU is depicted in the following figures (Figure 8-1, Figure 8-2, and Figure 8-3). The figures give an impression about the speed of structural change under the defined policy conditions. Structural change takes place in all policy scenarios, but a significant shift right after the policy change can only be observed, where direct payments are bound to the person of the farmer and decoupled from production and land (except for the low area payment). Two aspects attract particular attention. On the one hand, over time there is a development towards larger farm sizes. This is not surprising as with farms quitting production, remaining farms take over the land and grow in size. Furthermore, irrespective of the prevailing policy environment, the share of small farms decreases with time either because farms grow or withdraw (Figure 8-2).

not reported here.

[101] Indirectly, the maximum stocking density of 2.5 LU per hectare can be considered as one way to implement cross-compliance.

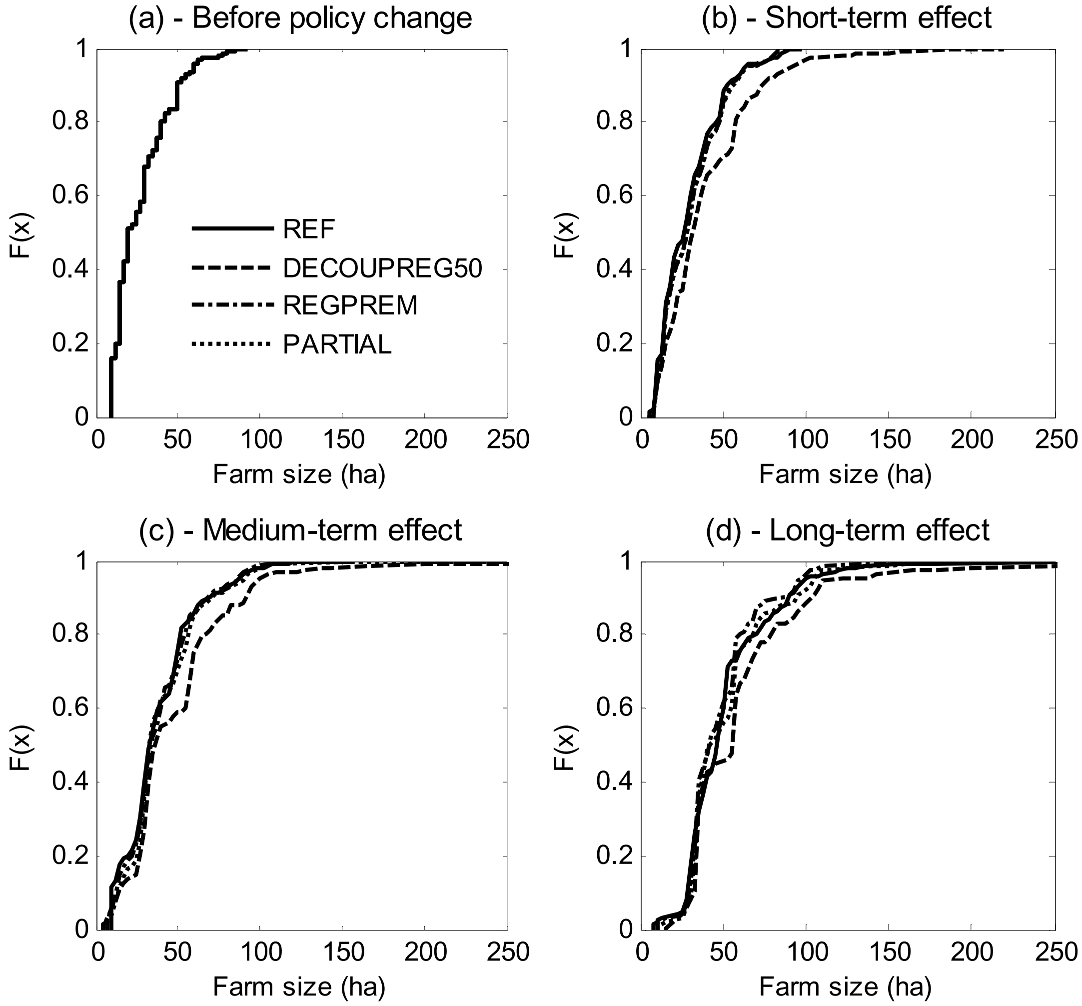
Figure 8-1: Evolution of average farm size



Showing the empirical cumulative distribution of farm size at four points in time, Figure 8-2 also underlines the strong impact of a decoupled single farm payment. It shows that the share of farms above 50 hectares of farmland is persistently higher in scenario DECOUPREG50. However, with the exception of scenario REGPREM, the gap between scenarios closes over time. This means that also without a policy change, structural change under the reference Agenda 2000 would have led to a similar farm size distribution in the long-run.

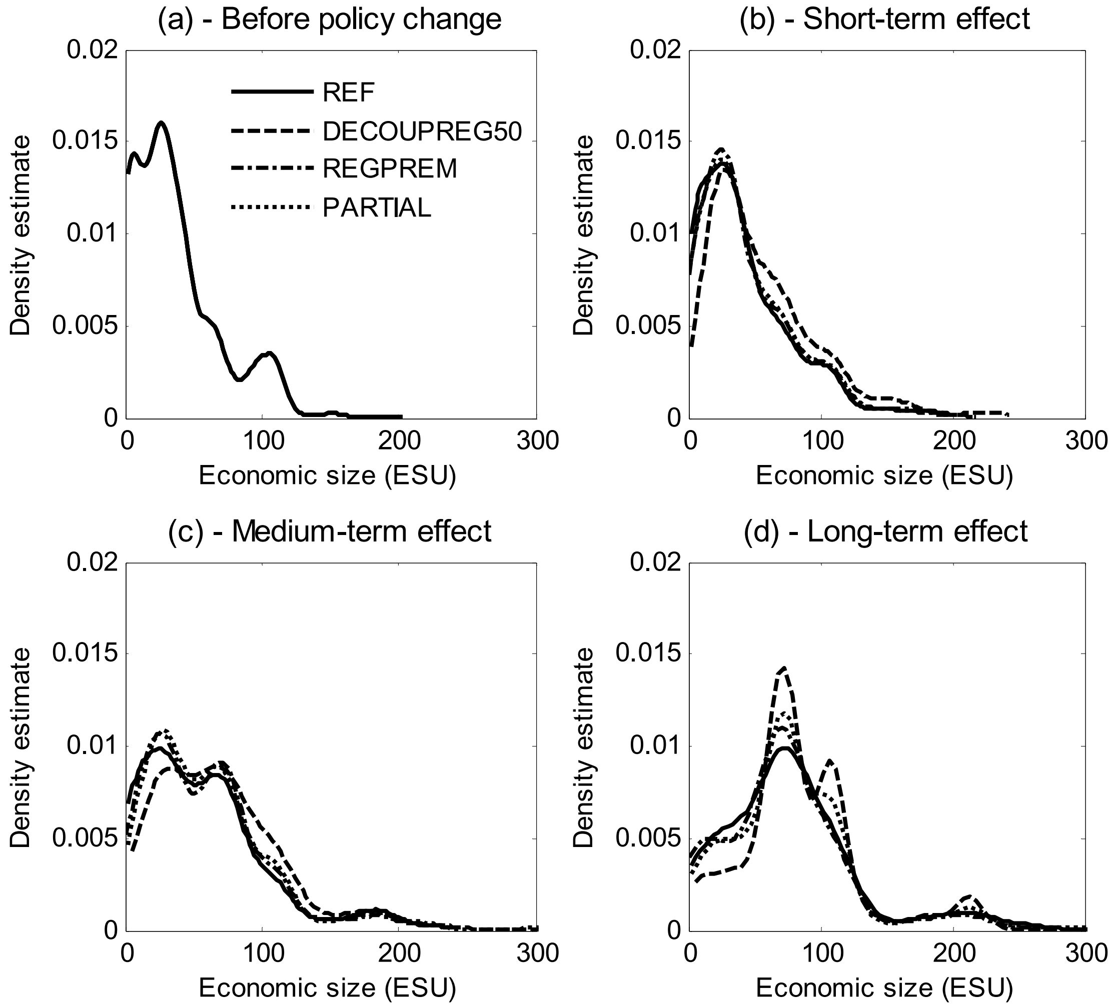
Regarding the distribution of the economic size of farms and the shift of the distribution over time, one can observe that in the medium-run, the distribution is slightly bimodal with a peak around 40 and 80 ESU. In the long-run, this bimodality mostly disappears in scenarios REGPREM and PARTIAL, although a significant shift to the right can be observed with a peak around 80 ESU. In scenario DECOUPREG50 the distribution is three-peaked in the long-run with very large farms around 200 ESU, a concentration of farms with around 100 ESU, and farms with a size of 80 ESU.

Figure 8-2: Empirical cumulative density functions of farm size at four time periods



It shows that scenarios REF, REGPREM, and PARTIAL are similar with respect to farm size in hectares and economic size. In other words, unless direct payments are fully decoupled from production, i.e., granted also when the person of the farmer is no longer engaged in farming, the size distribution of farms does not differ significantly between scenarios. Compared to the reference, alternative policy scenarios REGPREM and PARTIAL provide no additional incentive for farms to leave the sector. Only scenario DECOUPREG50 grants an explicit financial incentive for farms to leave the sector. This was analysed in detail in chapter 7. It is hence interesting to investigate in what ways and where exactly policy scenarios REGPREM and PARTIAL affect farms in the region. As these policies do not lead to significant changes in both the economic and physical farm size, other starting points for an analysis of policy effects would be profits, land rental prices, the organisation of production, specialisation of farms and efficiency impacts. These will be analysed next.

Figure 8-3: Kernel density estimates of economic size at four time periods



8.4 Impact on production

Table 8-2 illustrates how production capacities of selected production activities change after a policy change. The table shows the change in production capacities immediately after the policy change (t=4) and change in the medium-run (t=14). Compared to the reference scenario, suckler cow production ceases immediately after the introduction of payments, which are decoupled from livestock production. Dairy production also shows a steady decrease, which is independent of the prevailing policy environment. Dairy farms do not re-invest in dairy production or quit farming altogether. Intensive livestock production is more dependent on the policy environment. Whereas in the reference scenario, fattening pig production decreases, this could be reversed or slowed down in the decoupled scenarios. A reason for this is the easier accessibility of land due to lower rents, which alleviates manure restrictions (see section 8.5.2).

Table 8-2: Change of production capacity relative to the situation before the policy change; immediately after the policy change (t=4) and medium-run change (t=14)

Products		REF Before policy change	Change relative to reference before policy change (%)							
			REF		DECOUP-REG50		REGPREM		PARTIAL	
		t=3	t=4	t=14	t=4	t=14	t=4	t=14	t=4	t=14
Cereals	ha	8,547	0.5	2.5	13.9	19.0	4.2	11.5	3.0	14.0
Rape seed	ha	1,152	-1.6	14.0	-82.6	-96.4	-21.4	-54.7	-20.1	-69.1
Sugar beet	ha	282	0.0	0.0	-17.2	20.3	14.2	18.3	3.5	12.8
Dairy	places	2,659	-10.7	-70.0	-9.7	-78.1	-6.8	-59.2	-9.4	-65.4
Suckler cows	places	2,117	4.1	35.5	-95.5	-96.2	-92.0	-92.4	-20.6	-54.5
Beef cattle	places	880	-14.2	-85.5	-100	-100	-100	-100	-14.7	-83.9
Fatt. pigs	places	19,537	1.2	21.3	66.1	121.0	4.0	-10.4	1.2	20.4
Sows	places	27,547	2.5	22.0	0	4.2	4.6	33.8	4.9	31.3
Turkeys	places	85,000	17.7	100	76.5	70.6	23.5	58.8	2.5	41.2

Table 8-3 shows revenue shares of different product groups. The table thus provides some information on the relative contribution of a production activity to total produce in the region. Two points are worth noting here. First, intensive livestock farming, i.e., sows for breeding, fattening pigs and turkeys, accounts for 70% to 85% of total revenue in all policy scenarios. Scenarios differ, though, with respect to specialisation within intensive livestock farming.

For example, in line with the previous table, the revenue share of fattening pigs in policy scenario DECOUPREG50 triples over the 20 periods after the policy change. At the same time, the revenue share of sows for breeding decreases. The reverse can be observed for policy scenarios REGPREM and PARTIAL in which sows for breeding account for up to 65% of total revenue in the medium to long-run. Likewise, revenue shares of production activities related to grassland (dairy cows, cattle, suckler cows) show only minor changes.

Table 8-3: Revenue shares of different product groups for policies REF, DECOUPREG50, REGPREM, and PARTIAL at different time periods

Policy		Total	Crops	Sows	Fatt. pigs	Suckler cows	Tur-key	Beef cattle	Dairy cows
		%							
REF	Bef. change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	15.0	56.7	11.5	2.4	6.0	0.7	7.7
	Medium-term	100	14.2	58.1	13.3	2.7	8.6	0.2	2.8
	Long-term	100	13.1	49.1	23.6	2.8	11.4	0.0	0.0
DECOUP-REG50	Bef. change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	15.2	51.3	20.0	0.1	7.3	0.0	6.1
	Medium-term	100	15.2	50.6	24.6	0.1	7.5	0.0	2.1
	Long-term	100	14.0	41.8	36.7	0.3	7.2	0.0	0.0
REGPREM	Bef. change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	15.6	59.4	11.3	0.2	5.2	0.0	8.4
	Medium-term	100	14.8	64.4	9.9	0.2	6.9	0.0	3.8
	Long-term	100	14.2	63.6	15.0	0.1	7.0	0.0	0.0
PARTIAL	Bef. change	100	15.7	53.4	12.2	2.3	4.8	1.3	10.3
	Short-term	100	14.9	57.1	11.7	1.6	5.9	0.8	8.1
	Medium-term	100	14.5	62.1	13.1	0.9	6.0	0.2	3.2
	Long-term	100	13.4	58.2	21.2	0.7	6.5	0.0	0.0

A similar line of reasoning applies to suckler cow production. Although one could have initially expected that a single area payment would lead to a higher revenue share of suckler cows, the results show the opposite. Again, the reason is related to the special management requirement that was implemented in policy REGPREM. When direct payments are decoupled from specific production activities, it is more profitable for the majority of farms to manage grassland in a very basic way than to use it as an intermediate input in grassland-related livestock production.

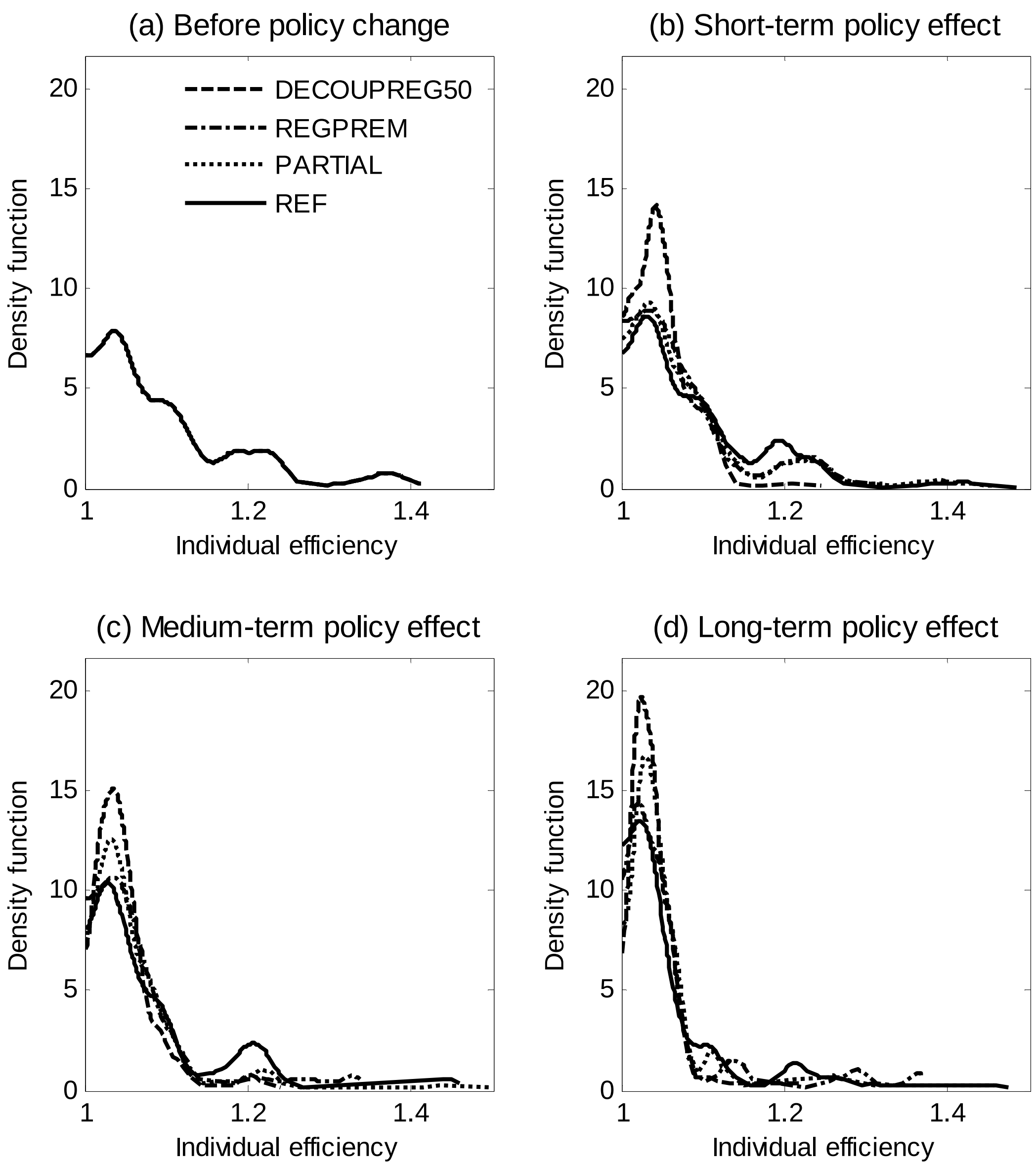
8.5 Efficiency implications

The next step is to analyse the impact of the decoupling policies on efficiency utilising the methods in chapter 6.

8.5.1 Analysis of individual and structural efficiency

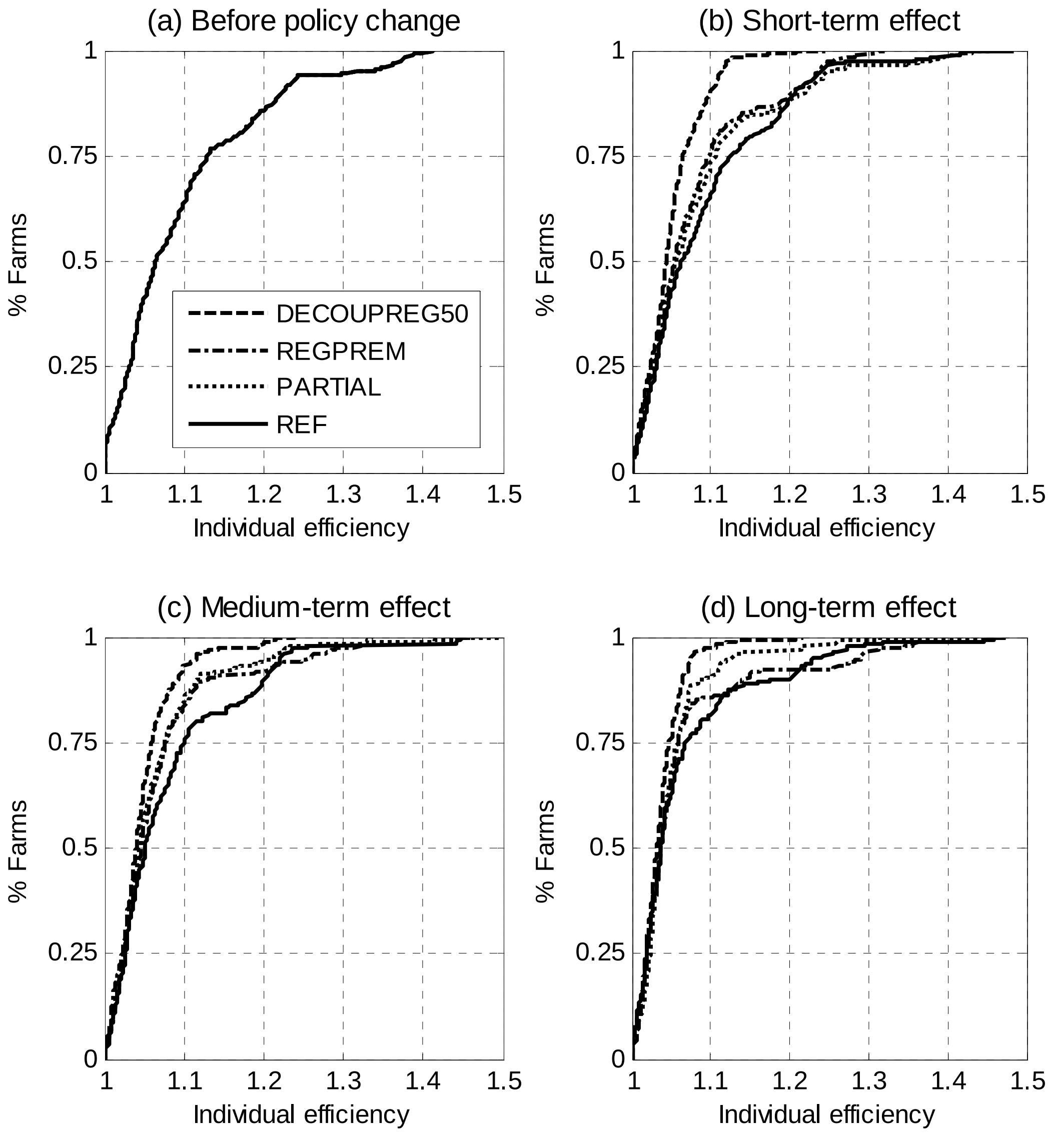
To assess the production efficiency of individual farms and the region as a whole, the DEA model specified in chapter 6 was estimated assuming output-orientation and constant returns to scale technology. The density functions of individual efficiency scores shown in Figure 8-4 underline the outstanding position of policy DECOUPREG50 that became already apparent in the analysis of structural change indicators.

Figure 8-4: Kernel density estimates of efficiency scores at four time periods



Accordingly, policy DECOUPREG50 leads to an overall increase in the individual efficiency of farms. The reason is that farms remaining in the sector increased individual efficiency by investing or by re-organising production while, at the same time, inefficient farms leave the sector. Alternatively, one can conclude that with the policy change, farms become more homogeneous with respect to production efficiency (Figure 8-5). In subsequent periods (medium and long-term effects), mainly farms at the lower end of the distribution increase their efficiency over time. For example, whereas in the short-run about 90% of the farms in the sample have an efficiency score below 1.1, in the long-run nearly 98% of the farms in the sample had scores below 1.1.

Figure 8-5: Empirical cumulative density function of output-oriented efficiency scores at four time periods



As regards policies REF, REGPREM, and PARTIAL efficiency increases gradually with time for the majority of farms. But, these policies also provide the ground for a few number of inefficient farms to stay in business.

In addition, Figure 8-5 shows a dichotomy of farms in all policy scenarios. Whereas the distribution of the 50% most efficient farms is very similar between scenarios (there are hardly any differences in individual efficiency scores), the 50% least efficient farms, differ considerably regarding efficiency scores.[102] More clearly, this can be seen in Table 8-4. On average, individual efficiency of the 50% most efficient farms hardly changes in response to a policy reform. In contrast, mean individual efficiency in the group of the 50% least efficient farms changed considerably.

Table 8-4: Mean efficiencies of best 50% and worst 50% farms

	Policy	Bef. policy change	Short-term effect	Medium-term effect	Long-term effect
Best 50 %	REF	1.0293	1.0296	1.0258	1.0185
	DECOUPREG50	1.0293	1.0228	1.0217	1.0181
	REGPREM	1.0293	1.0263	1.0228	1.0175
	PARTIAL	1.0293	1.0279	1.0238	1.0209
Worst 50 %	REF	1.1640	1.1529	1.1341	1.1096
	DECOUPREG50	1.1640	1.0762	1.0733	1.0554
	REGPREM	1.1640	1.1265	1.1099	1.1042
	PARTIAL	1.1640	1.1440	1.1028	1.0774

Mean efficiencies (MeEff) for the entire region are reported in Table 8-5, which shows a summary of results. On average, the introduction of alternative policy schemes improves mean efficiency in all cases in the short-run. In correspondence with observations made in the graphical analysis of Figure 8-4, Figure 8-5 and Table 8-4, mean efficiency is highest in case of policy DECOUPREG50. Moreover, it is interesting to observe that in the long-run, differences in the mean between the reference and scenario REGPREM almost disappear despite of the different nature of the policy. Regarding policy PARTIAL results show that impact on mean efficiency is greatest in the long-run. However, compared to the reference, only policy DECOUPREG50 leads to statistically significant differences.

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[102] It should be stressed that samples and, in particular, sample sizes underlying the estimates differ.

Table 8-5: Bias-corrected mean efficiencies, structural efficiencies, and efficiency ratios of structural efficiencies and mean efficiencies CRS

Effi-ciency	Policy	Bef. policy change	Short-term effect	Medium-term effect	Long-term effect
MeEff	REF	1.1190	1.1151	1.0961	1.0779
	DECOUPREG50	1.1187	1.0606	1.0582	1.0469
	REGPREM	1.1190	1.0993	1.0801	1.0726
	PARTIAL	1.1185	1.1055	1.0758	1.0602
StEff	REF	1.0524	1.0576	1.0496	1.0536
	DECOUPREG50	1.0520	1.0475	1.0408	1.0362
	REGPREM	1.0523	1.0515	1.0432	1.0392
	PARTIAL	1.0521	1.0561	1.0460	1.0442
RD MeEff	REF/DECOUPREG50	1.0002	1.0516*)	1.0359*)	1.0297*)
	REF/REGPREM	0.99993	1.0144	1.0148	1.0049
	REF/PARTIAL	1.0004	1.0088	1.0189	1.0168
	DECOUPREG50/ REGPREM	0.99966	0.96421*)	0.9796*)	0.97587*)
	DECOUPREG50/ PARTIAL	1.0001	0.95899*)	0.98357	0.98741
	REGPREM/PARTIAL	1.0004	0.99447	1.004	1.0117
RD StEff	REF/DECOUPREG50	1.0003	1.0097	1.0085	1.0169*)
	REF/REGPREM	1.0001	1.0058	1.0062	1.0139*)
	REF/PARTIAL	1.0003	1.0015	1.0035	1.0091
	DECOUPREG50/ REGPREM	0.99973	0.99617	0.99766	0.99708
	DECOUPREG50/ PARTIAL	0.99989	0.99188	0.99498	0.9923
	REGPREM/PARTIAL	1.0001	0.99569	0.9973	0.99519

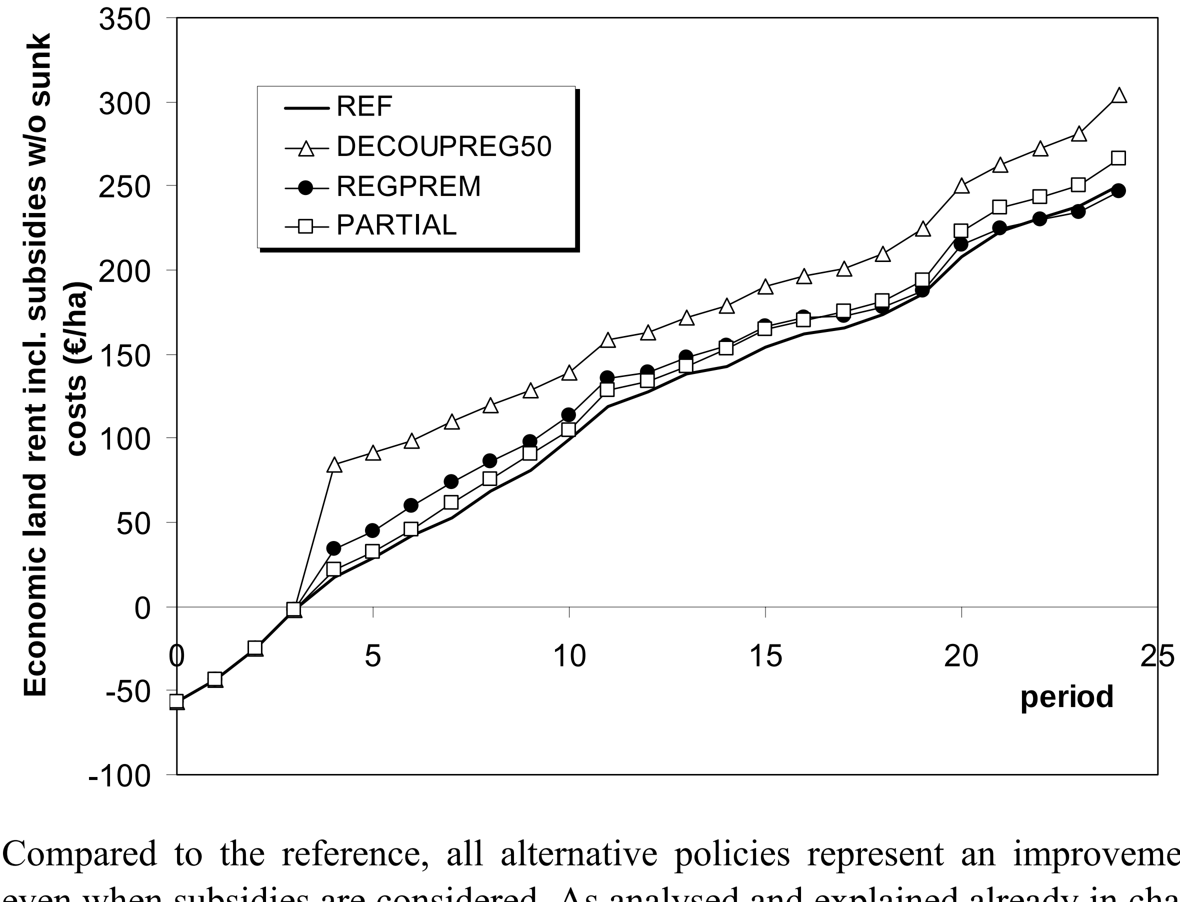
Notes: *) Efficiency difference statistically significant at the 5% level; **) efficiency difference statistically significant at the 10% level; StEff = structural efficiency, MeEff = mean efficiency; RD of StEff = bootstrap-based ratio of structural efficiencies; RD of MeEff = bootstrap-based ratio of mean efficiencies; B=1000 bootstrap rounds, κ=0.7.

To account for the economic importance of farms, structural efficiencies (StEff) are calculated and shown in Table 8-5. Two observations shall be discussed at this point. First, structural efficiency scores of all scenarios are generally below mean efficiencies indicating that the region is in fact more efficient than the unweighted mean efficiency would suggest. This particular result is not surprising as larger farms save costs and labour due to larger operations. This creates an efficiency advantage. Second, if output shares are used as weights, statistically significant differences between scenarios, which were apparent in the mean, almost disappear. This can be explained by the fact that the output share of inefficient farms is comparatively lower than output shares of efficient farms. This is reasonable because of the mentioned size effects of efficient farms. Only in scenario DECOUPREG50, differences between mean efficiencies and structural efficiencies are small as in this scenario, farms are generally larger after the policy change (see Figure 8-3). However, in comparison with the reference, the structural efficiency in scenario DECOUPREG50 is only statistically significant in the long-run. Also in case of scenarios REF and REGPREM, the null hypothesis of equal structural efficiencies has to be rejected in the long-run. This is in contrast to the test on mean efficiencies, were no statistically significant differences could be observed.

8.5.2 Economic efficiency

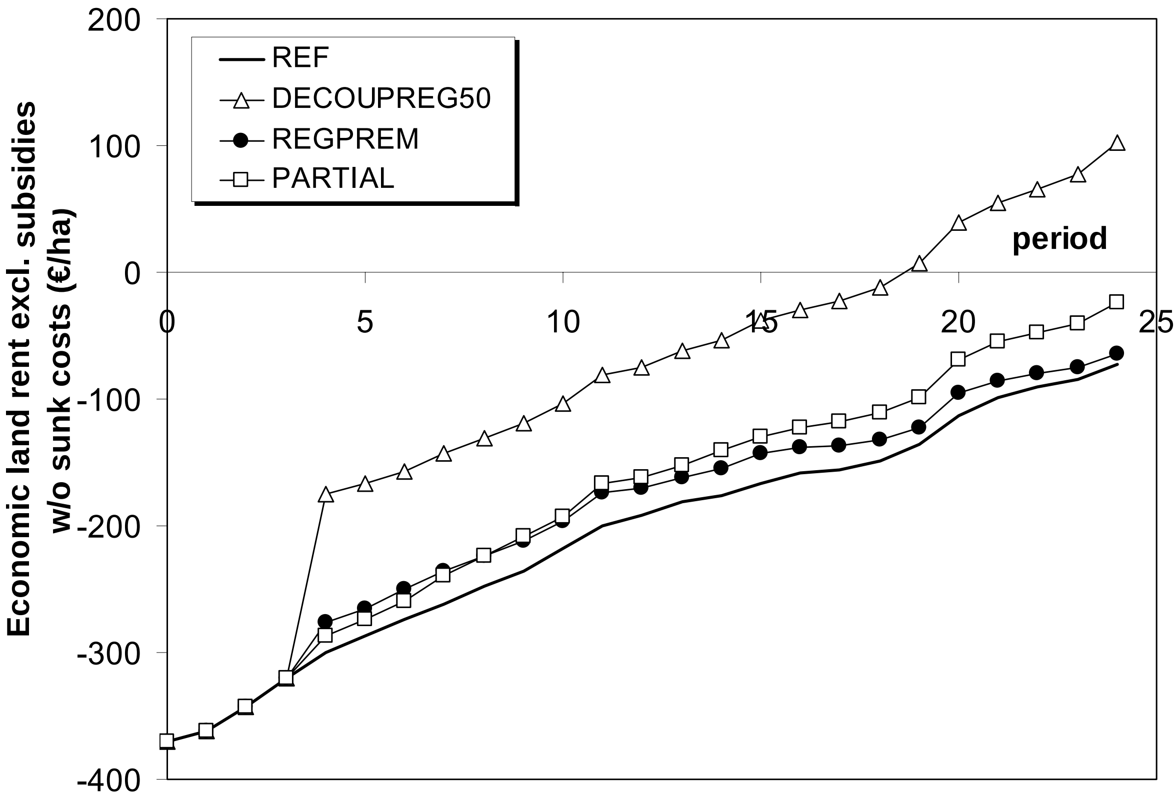
The efficiency of agricultural production in the region, measured as the economic land rent with and without subsidies, increases in all policy scenarios (Figure 8-6 and Figure 8-7).

Figure 8-6: Evolution of average economic land rent with subsidies, without sunk costs



Compared to the reference, all alternative policies represent an improvement even when subsidies are considered. As analysed and explained already in chapter 7, fully decoupled payments lead to a strong immediate increase in efficiency initiated by a re-allocation of production factors right after the policy change.

Figure 8-7: Evolution of average economic land rent with sunk costs, without subsidies



However, if sunk costs of leaving farms are taken into account, the strong reallocation immediately after the policy change in scenario DECOUPREG50 generates high adjustment costs (Table 8-6). Even though economic land rent is highly negative in policy DECOUPREG50 right after the policy change, throughout the remaining periods of the simulation a significant increase can be observed. Thus, despite of high adjustment costs in the short-run, in the medium and long-run efficiency gains in policy DECOUPREG50 as expressed by the capitalised value of economic land rent including sunk costs are significantly higher than in the other policies in which adjustment takes place more gradually.[103]

[103] If compared to policy DECOUP in chapter 7, the mixed payment scheme introduced in policy DECOUPREG50 generates additional efficiency gains because of the higher share of land farmed. Policy DECOUP generated a capitalised economic land rent including sunk costs of -2,638 €/ha.

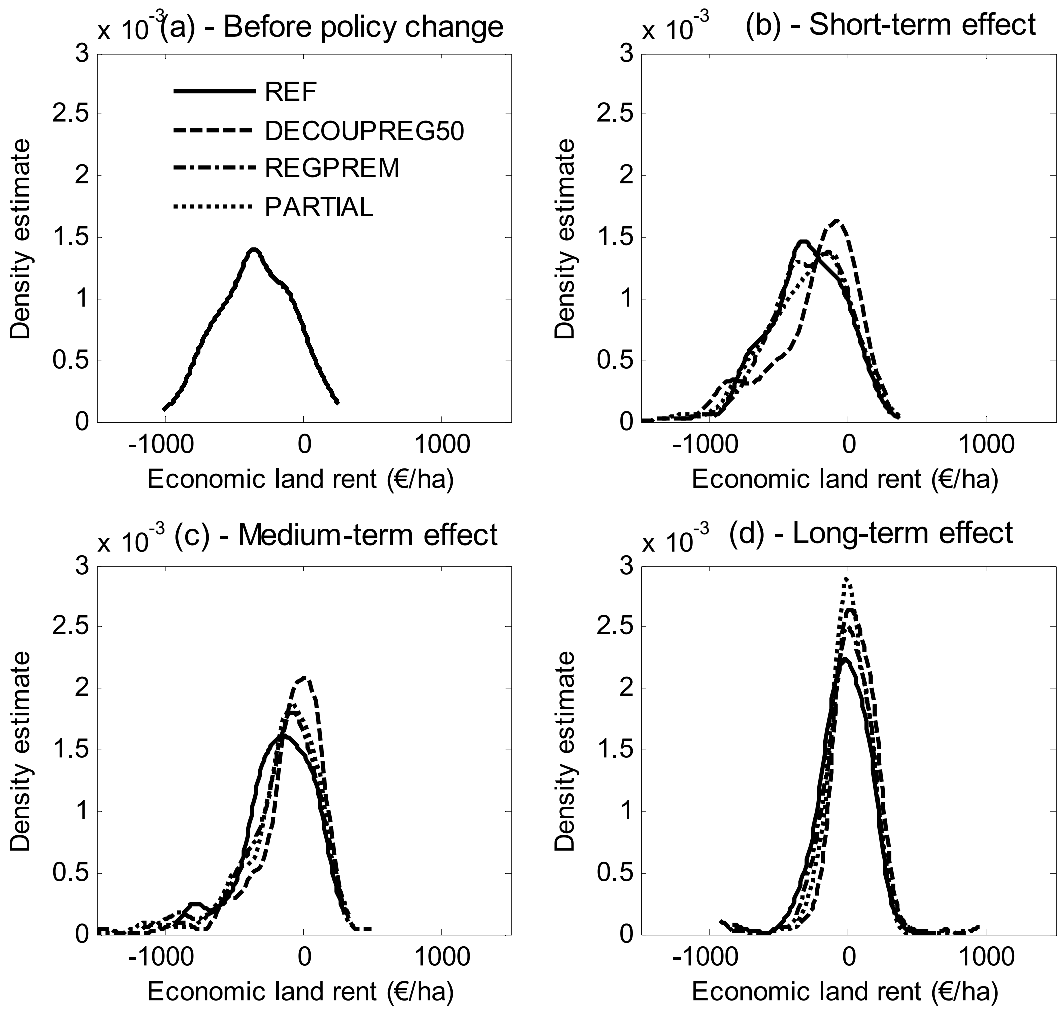
Table 8-6: Comparison of economic land rent including sunk costs and economic land rent without sunk costs excluding support

Economic land rent	REF	DECOUP-REG50	REGPREM	PARTIAL
	(€/ha)			
Before policy change (t=3)	-430	-430	-430	-430
without sunk costs	*-319*	*-319*	*-319*	*-319*
Immediately after change (t=4)	-388	-1,121	-428	-420
without sunk costs	*-299*	*-174*	*-276*	*-287*
Short-term effect (t=6)	-336	-178	-312	-324
without sunk costs	*-274*	*-157*	*-251*	*-259*
Medium-term effect (t=14)	-194	-79	-176	-190
without sunk costs	*-176*	*-53*	*-15*	*-141*
Long-term effect (t=24)	-104	40	-93	-91
without sunk costs	*-73*	*102*	*-64*	*-23*
Capital value of economic land rent incl. sunk costs (base: t=3)[a)b)]	-4,021	-2,478	-3,672	-3,575
Ave. annual economic land rent incl. sunk costs[c)]	-221	-136	-201	-197

Notes: a) Interest: 5.5%; b) under the assumption that policy is not terminate; c) computed from capital value of economic land rent.

In Table 8-6, economic land rent is calculated as an average of the whole region, which abstracted from the actual economic land rent of individual farms. Figure 8-8, therefore illustrates the distribution of individual farm economic land rents. On the one hand, the distributions of alternative policies are to the right of the reference, indicating an efficiency improvement. On the other hand, differences between scenarios are apparent at the lower tail of the distributions. This corresponds to what was observed in the analysis of individual DEA efficiency estimates, where differences between scenarios were evident mainly with respect to inefficient farms.

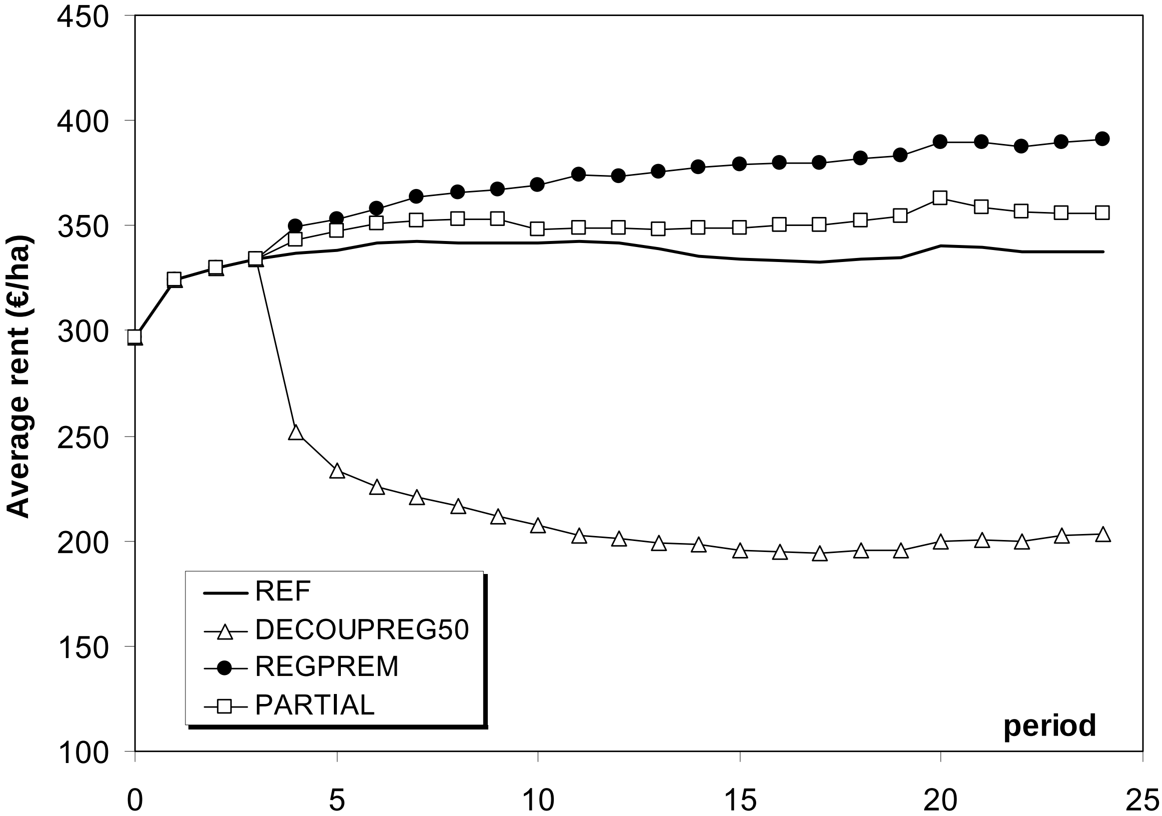
Figure 8-8: Kernel density estimates of individual farm economic land rents excluding support at four time periods



Despite of their increasing trend, economic land rents do not correspond with the rental prices paid by the farms (Figure 8-9). Particularly scenario DECOUPREG50 shows a sharp contradiction. While the productivity increases sharply, the rental price for land falls dramatically by about 50 % shortly after the policy change. This shows that the lower shadow prices for land resulting from decoupled payments are transferred quickly into lower rents.[104] Vice versa, scenario REGPREM that couples premiums to land use leads to significantly increasing rental prices while the efficiency increase is only modest.

[104] In reality, this process can be expected to last longer as lease contracts are usually made for a fixed time period. However, it has to be noticed that rental contracts often include clauses that allow for the adjustment of rental prices to reflect changes in overall supply and demand on the land market.

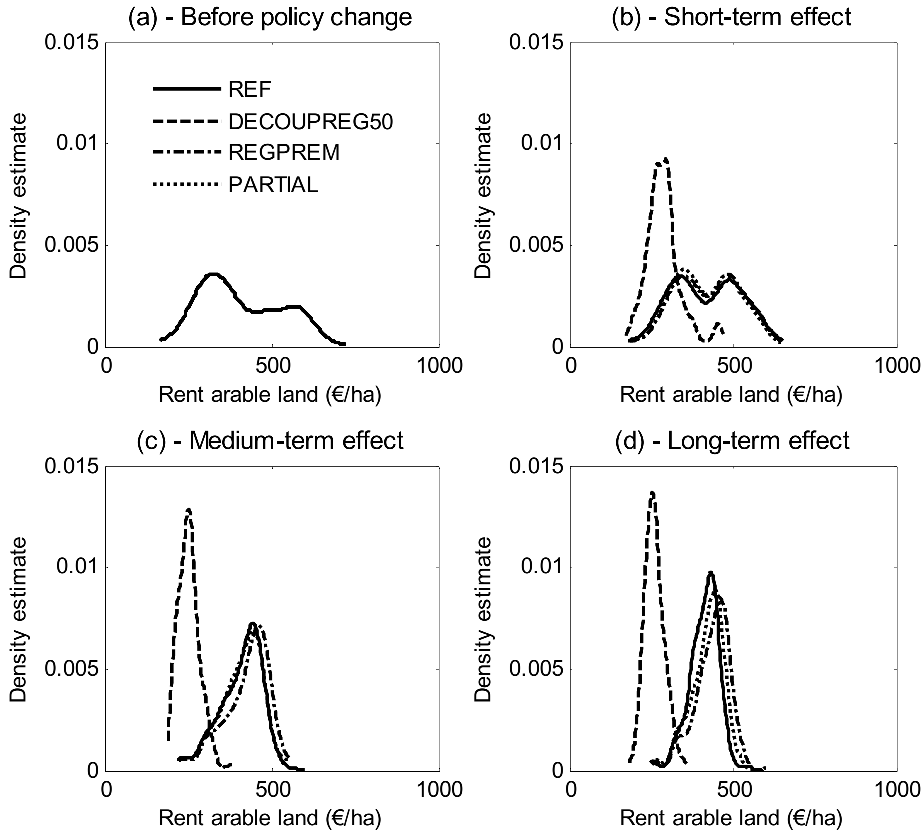
Figure 8-9: Evolution of average rental prices for land



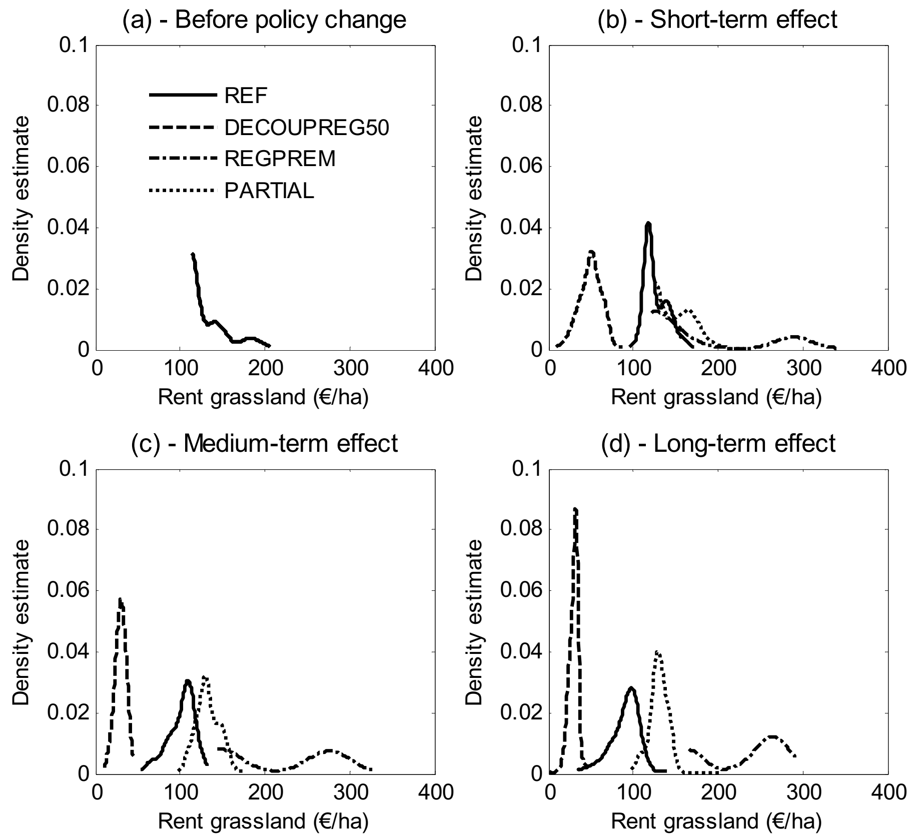
Also in scenario PARTIAL, rental prices increase because of coupled payments on the one hand, and decoupled payment entitlements, on the other hand. As argued in the introduction, these payment entitlements were expected to affect rental prices, which can, in fact, be observed in the figure. However, as payment entitlements in PARTIAL are generally below the single area payment, average rental prices are below those in scenario REGPREM. The coupling to land use increases the shadow prices, particularly of grassland, as the kernel density estimates in Figure 8-10 (a) and (b) show. Results thus show that payments coupled to production and/or land lead to rents for land owners. The intended positive income effect on the producers' side is therefore lost.

Figure 8-10: Kernel density estimates of rental prices

(a)



(b)

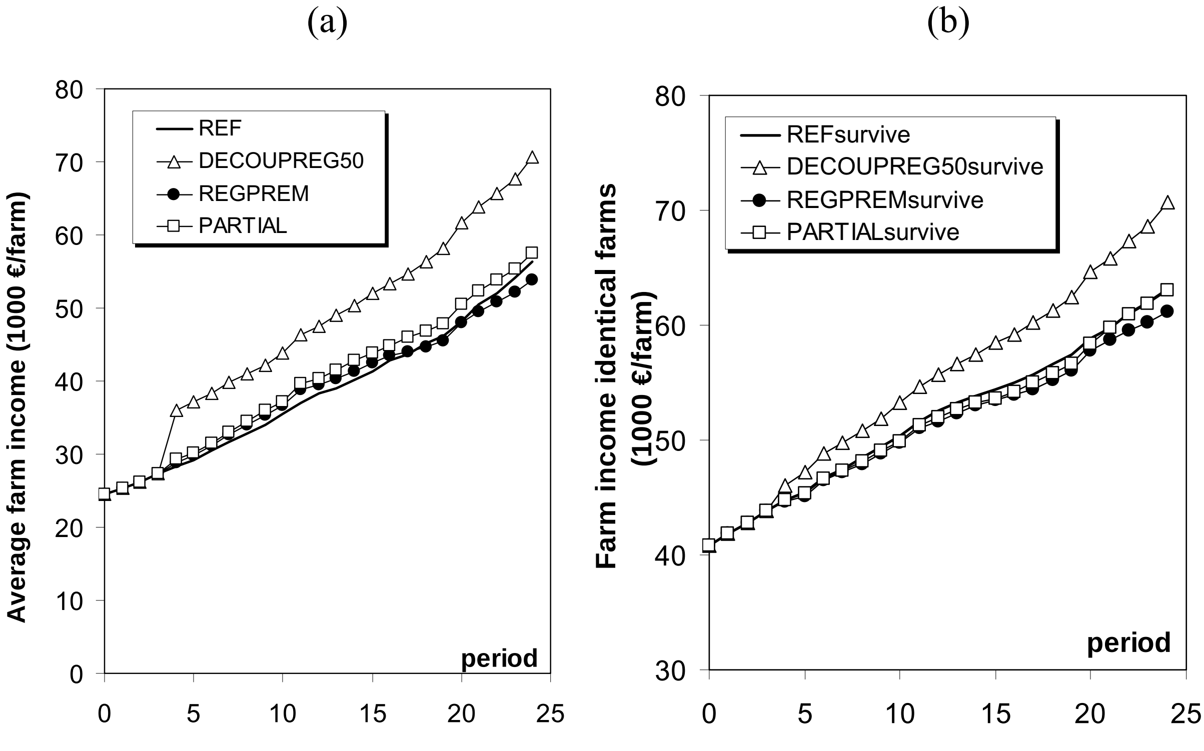


8.6 Implications for incomes and farm specialisation

8.6.1 Impact on farm incomes

Taking into account that rental prices for land are at a high level unless direct payments are fully decoupled, it could be expected that high rental prices have negative effects on farm incomes in case of policies REGPREM and PARTIAL. However, Figure 8-11 (a) illustrates that the average effect on farm incomes is marginal compared to the reference.[105] As for scenario REGPREM, the result implies that the direct payment for grassland introduced with a single area payment on average compensates for possible income losses due to higher rental prices. It could therefore be expected that particularly grazing livestock and mixed farms benefit from policy REGPREM.

Figure 8-11: Evolution of average farm income of (a) all farms and (b) farms surviving in all policy scenarios



More significant, though, is the impact of a fully decoupled single farm payment. Taking into account that already before the policy change nearly half of the total agricultural land was rented, it is farms with a higher share of rented land that benefit most from lower rents. This is supported by Figure 8-11 (a)

[105] Kernel densities are shown in Figure A-1 in appendix A.6.

which illustrates that particularly scenario DECOUPREG50 leads to higher farm incomes, while farm incomes are lower if rental prices are higher. One could argue that this interpretation is also the result of a sample effect as the composition of the farm sample changes over time and depending on the policy. However, an analysis of the farms surviving under all policy conditions (Figure 8-11 (b)) shows that these farms can generate persistently higher farm incomes in any case. Hence, farms with a growth potential high enough to guarantee the farm business to operate also in the long-run, benefit most from fully decoupled payments. To investigate the income effects in a more differentiated way, farm incomes are differentiated by farm types and by policies and shown in Table 8-7.

Table 8-7: Average farm income by farm type and time period

Time period	**Farm type**	**REF**	**DECOUP-REG50**	**REGPREM**	**PARTIAL**
		€/farm			
Bef. policy change	*Total average*	*27,349*	*27,349*	*27,349*	*27,349*
	Spec. field crops	5,871	5,871	5,871	5,871
	Grazing livestock	30,381	30,381	30,381	30,381
	Spec. granivore	40,340	40,340	40,340	40,340
	Mixed farms	17,589	17,589	17,589	17,589
Short-term effect	*Total average*	*30,461*	*38,365*	*31,247*	*31,514*
	Spec. field crops	6,532	13,081	6,993	7,471
	Grazing livestock	26,463	29,503	28,747	27,310
	Spec. granivore	42,278	44,720	40,838	42,212
	Mixed farms	21,874	24,573	21,345	19,928
Medium-term effect	*Total average*	*40,221*	*50,393*	*41,384*	*42,854*
	Spec. field crops	10,068	20,932	13,007	15,429
	Grazing livestock	21,873	34,589	26,863	27,085
	Spec. granivore	51,167	54,502	48,785	49,457
	Mixed farms	27,364	33,815	27,892	25,027
Long-term effect	*Total average*	*56,261*	*70,739*	*53,858*	*57,452*
	Spec. field crops	18,486	24,847	18,980	17,897
	Grazing livestock	9,510	-	-	-
	Spec. granivore	64,646	75,483	62,338	64,062
	Mixed farms	41,848	63,512	37,708	36,389

In comparison with the reference, for policies REGPREM and PARTIAL, average farm income after the policy change is higher in absolute terms for grazing livestock farms and specialised field crop farms in the short and medium run, whereas specialised granivore farms, on average, experience income losses. There is no considerable change in the number of farms per farm type compared to the reference (see Table 8-8). In the long-run, policy REGPREM neither holds up the decrease in the revenue share of dairy and cattle, nor prevent cattle production from ceasing. Once dairy and cattle production facilities reach their useful lifetime, farms do not re-invest in dairy and cattle production but rather re-organise towards intensive livestock production or leave the sector.

As regards policy DECOUPREG50, farms of all farm types, on average, increase farm incomes compared to the reference. However, it has to be noted that the number of farms of each farm type also changes drastically compared to the reference due to farms leaving the sector. The ratio of income by farm type to average income of all farms gives a measure of income disparity (cf. OECD 2003). Although farm income disparities increase for grazing livestock farms in general, relative to the reference, the alternative policies slightly narrowed income disparities for grazing livestock farms in the short and medium-run. Only specialised granivore farms, on average, earn incomes persistently above the average of all farms.

8.6.2 Farm specialisation

The following Table 8-8 shows the share of non-professional farms and professional farms by farm type and time periods. Before the policy change, about half of the farms in the region operate as professional farms, specialising mainly in granivore production or grazing livestock farming. Non-professional farms mainly specialise in field crops or operate as mixed farms. Over time, with structural change proceeding, up to 84% of all farms operate as full professional farms.

Although the importance of specialised granivore farms is common to all policy scenarios, the relative importance of intensive livestock farming is pronounced in policy scenario DECOUPREG50. The adjustment patterns induced by this policy have been discussed at before in this chapter, but Table 8-8 sheds some additional light on this policy. Shortly after the policy change, almost 70% of all farms in the region are specialised granivore farms; 46% of all farms are operating as professional farms increasing to 82% 20 periods after the policy change. In other words, half of the farms in the region have a size such that at least one full-time labour unit can be employed. This result could also indicate that the assumed labour-saving technological progress is underestimated (see also chapter 7).

Table 8-8: Share of non-professional farms (NPF) and professional farms (PF) by policy, farm type, and time period

Period	Farm type	REF			DECOUPREG50			REGRPEM			PARTIAL		
		n[a)]	NPF	PF	n	NPF	PF	n	NPF	PF	n	NPF	PF
			% of n			% of n			% of n			% of n	
Bef. policy change	*Total*	*530*	*55.1*	*44.9*	*530*	*55.1*	*44.9*	*530*	*55.1*	*44.9*	*530*	*55.1*	*44.9*
	of which												
	Spec. field crops	91	17.2	0.00	91	17.2	0.0	91	17.2	0.0	91	17.2	0.0
	Grazing livestock	68	1.5	11.3	68	1.5	11.3	68	1.5	11.3	68	1.5	11.3
	Spec. granivore	236	13.8	30.8	236	13.8	30.8	236	13.8	30.8	236	13.8	30.8
	Mixed	135	22.6	2.8	135	22.6	2.8	135	22.6	2.8	135	22.6	2.8
Short-term	*Total*	*483*	*54.3*	*45.7*	*361*	*44.8*	*55.3*	*462*	*55.9*	*44.1*	*462*	*53.8*	*46.2*
	of which												
	Spec. field crops	77	15.9	0.0	4	1.1	0.0	68	14.7	0.0	51	11.0	0.0
	Grazing livestock	56	5.0	6.6	29	4.7	3.3	56	6.9	5.2	52	5.8	5.4
	Spec. granivore	249	16.5	34.9	243	21.0	46.1	263	20.7	36.3	251	17.5	36.9
	Mixed	102	16.9	4.1	86	18.0	5.8	75	13.6	2.6	108	19.4	3.9
Medium-term	*Total*	*368*	*42.7*	*57.3*	*286*	*32.9*	*67.1*	*363*	*42.4*	*57.6*	*348*	*40.2*	*59.8*
	of which												
	Spec. field crops	54	14.7	0.0	13	4.6	0.0	41	11.3	0.0	28	8.1	0.0
	Grazing livestock	26	4.6	2.5	8	1.8	1.1	28	4.7	3.0	23	4.3	2.3
	Spec. granivore	244	14.1	52.2	237	19.9	63.0	265	20.7	52.3	263	20.1	55.5
	Mixed	44	9.2	2.7	28	6.6	3.2	29	5.8	2.2	34	7.8	2.0
Long-term	*Total*	*272*	*24.4*	*75.7*	*220*	*16.4*	*83.6*	*289*	*27.8*	*72.2*	*268*	*24.3*	*75.7*
	of which												
	Spec. field crops	31	11.4	0.0	18	8.2	0.00	49	17.0	0.00	30	11.2	0.00
	Grazing livestock	2	0.7	0.0	0	-	-	0	-	-	0	-	-
	Spec. granivore	208	5.2	71.6	192	5.5	82.2	228	7.3	71.9	225	9.7	74.5
	Mixed	30	7.0	4.1	9	2.7	1.4	11	3.5	0.4	12	3.4	1.1

Note: a) n = number of farms in group.

Fully decoupled direct payments lead to a strong decrease of specialised field crop farms and grazing livestock farms already in the short-run. Whereas the share of specialised non-professional field crop farms slowly increases with time, mixed farming and in particular grazing livestock farming did not turn out to be viable specialisations in the long-run. With respect to policies REGPREM and PARTIAL, changes are not as evident as in scenario DECOUPREG50. Viewed across all time periods, a single area payment as well as partially decoupled payments show to have no great impact on results despite of the different setup of the policies. Differences such as the high share of non-professional mixed farms in scenario PARTIAL turn out to be a short-term reaction as the share of mixed farms in scenario PARTIAL decrease strongly in the medium-run. In the long-run, the specialisation of farms and the shares of professional and non-professional farms do not change considerably.

8.7 Redistribution effects of a single area payment

When policy REGPREM was introduced in section 8.2, it was already mentioned that the policy could potentially lead to a redistribution of direct payments. This can be analysed based on Figure 8-12. The figure shows the change in direct payments per hectare before the policy change relative to a single area payment of 310 €/ha.

Accordingly, in comparison with the single area payment, ceteris paribus, approximately 20% of the farms benefit from the new policy.[106] These farms are predominantly engaged in dairy production. At the other end of the spectrum, the level of direct payments per hectare would be significantly lower for about 20% of the farms; 10% of the farms will even experience dramatic losses in direct payments per hectare, which are mainly specialised granivore farms and mixed farms (Table 8-9). Above all, farms producing suckler cows and beef cattle suffer most from the policy change. Hence, with the introduction of a single area payment, payments are redistributed from farms producing suckler cows and beef cattle to dairy farms.[107] Note, that this redistribution takes place between

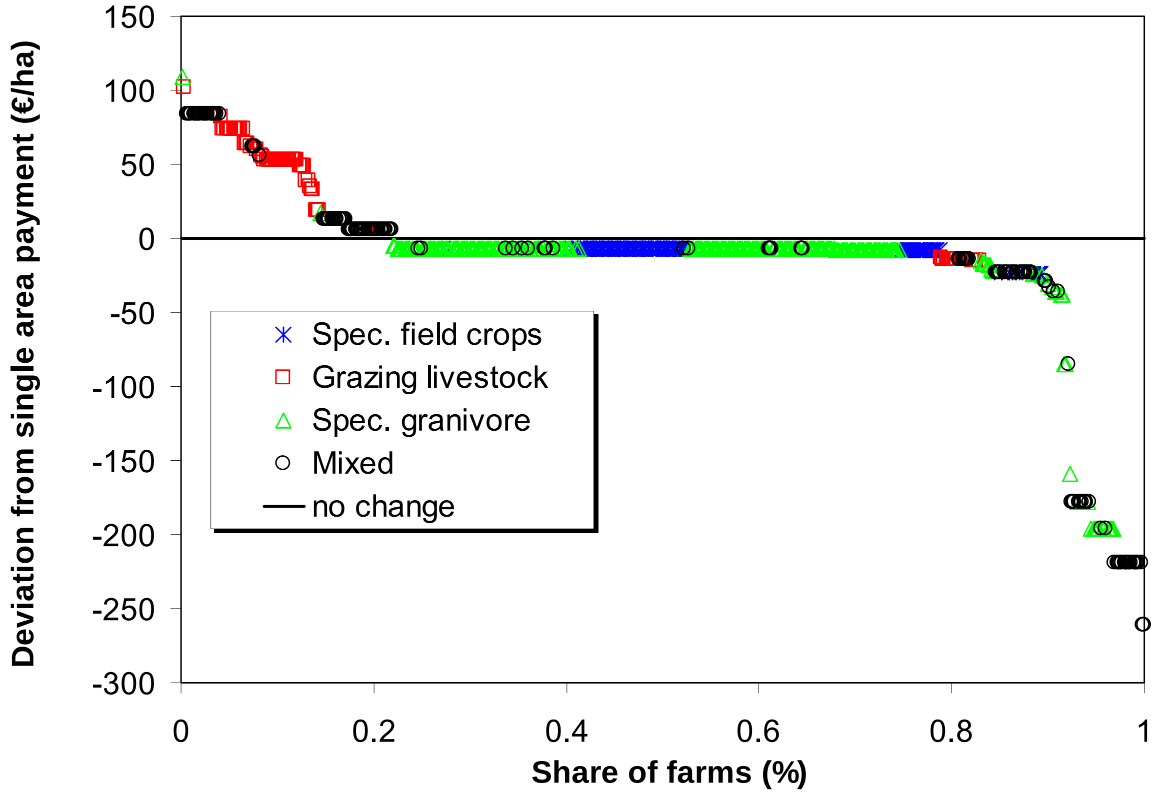
[106] Calculation of the single area payment is based on a three-year reference period. This explains why there are slight losses in direct payments for the majority of farms in Figure 8-12, where only the last period before the policy change considered.

[107] This result has to be interpreted within the assumptions made; in particular, the assumption on milk prices. The simulations assume constant milk prices. If milk prices were further cut, as foreseen by Agenda 2000 from 2002 onwards, then some dairy farms would also not benefit from the introduction of a single area payment.

farms engaged in production activities depending on grassland.

Still, the question his how much farms really suffer? An analysis based exclusively upon Figure 8-12 would suggest significant income losses with some farms. Yet, when adjustment reactions are taken into account, income loss due to the policy change is – on average – only a temporary phenomenon for farms remaining in the sector. This can be seen in Table 8-9, which shows the development of production for the 20% farms (105 farms in t=3) suffering from the policy and the 20% farms benefiting from a single area payment.

Figure 8-12: Deviation of direct payments per hectare and farm before policy change (t=3) from single area payment



Based on this, it cannot be concluded in general that all farms incurring losses in direct payments will automatically loose income, despite of losses in direct payments of up to 250 € per hectare. Rather, a single area payment induces farms to adjust livestock production by giving up suckler cow and cattle production and expand livestock operations and arable farming.

Inevitably, a lower production of suckler cows and cattle has consequences for the use of grassland. Since policy REGPREM requires that land should not be abandoned to claim the payment, it is more profitable for farms to manage grassland in a basic way (e.g. cutting grass) than to keep livestock.

Table 8-9: Characterisation of groups of farms benefiting and suffering from change to policy REGPREM at different time periods

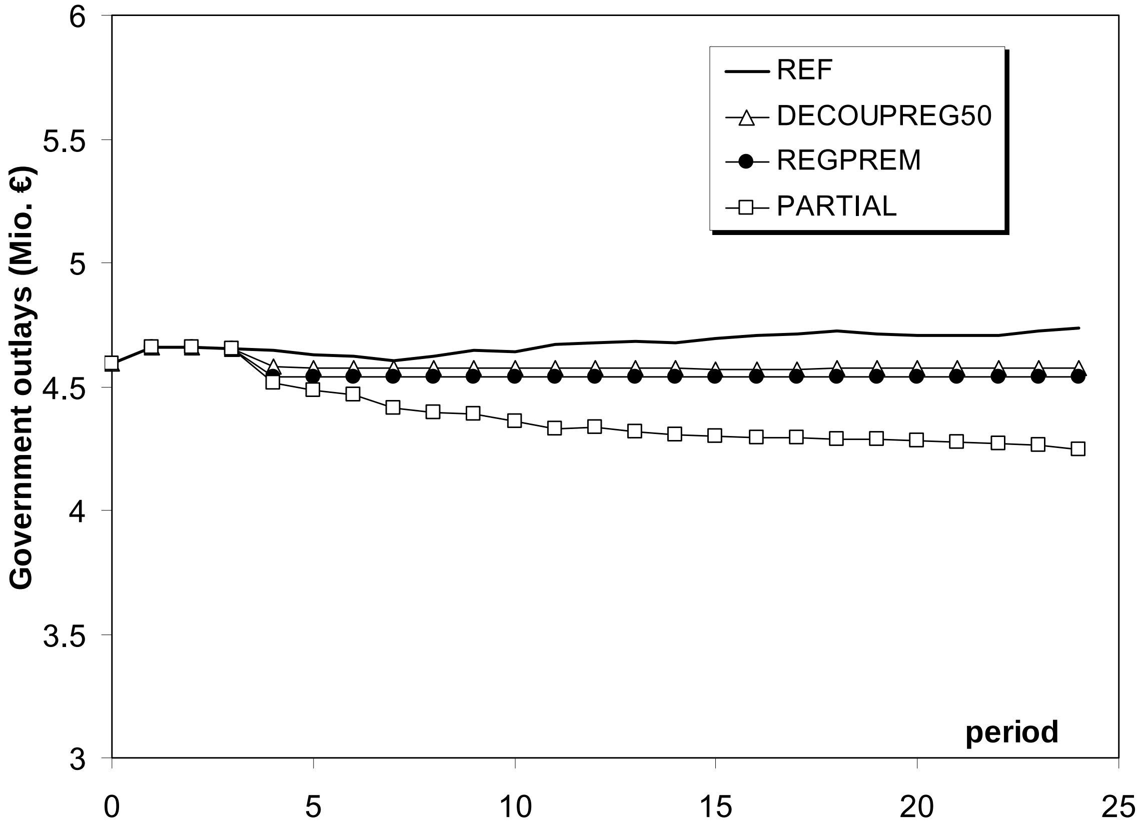
Time period	Farms	Farm income	Average farm size	Production activities				
				Dairy	Beef cattle	Suckler cows	Sows	Crops
	(N)	(€/farm)	(ha)	(places)	(places)	(places)	(places)	(ha)
20% farms benefiting from policy REGPREM								
t=3	105	23,778	25.7	8,974	0	1,878	1,786	850
t=4	103	25,011	27.1	8,397	0	271	2,061	962
t=6	101	25,709	28.1	7,867	0	243	2,493	1,017
t=14	77	33,118	35.0	3,757	0	239	4,152	1,234
20% farms suffering from policy REGPREM								
t=3	105	21,347	28.9	1,547	1,800	3,081	3,461	1,336
t=4	100	19,486	30.8	1,350	0	124	3,846	1,638
t=6	87	22,058	32.9	1,161	0	134	3,868	1,526
t=14	67	28,823	37.3	631	0	138	3,812	1,379

8.8 Government outlays and social efficiency

Regarding the total government outlays on the policies, the following picture emerges (Figure 8-13). Considering the scale of the figure, differences between scenarios are moderate. Total government expenditure in policy scenarios REGPREM and DECOUPREG50 remains at a level slightly below outlays on the reference. Outlays for policy DECOUPREG50 are only slightly above policy REGPREM. This is remarkable in view of the fact that under policy DECOUPREG50, outlays also include payments going to farms who have withdrawn from the sector.

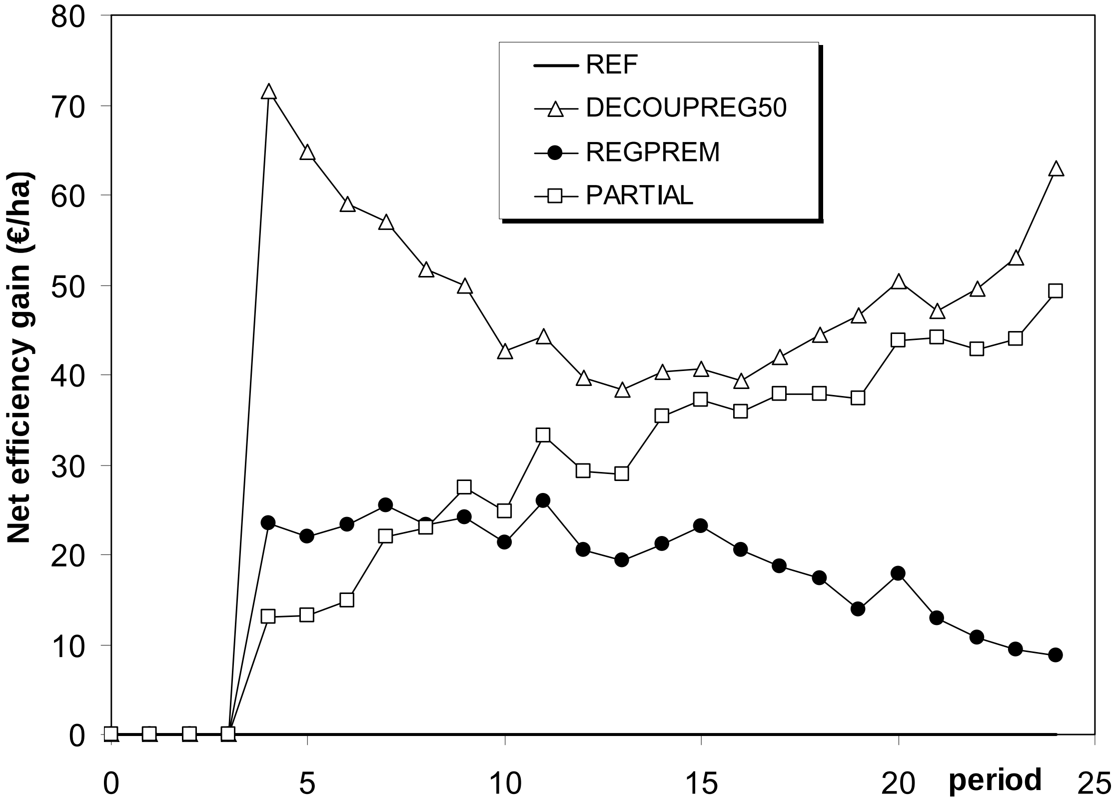
In addition, the positive effects of a decoupled single farm payment with respect to efficiency, rental prices, and income, gives evidence that this policy is also efficient of expenses are contrasted with efficiency gains in the sector. This can be seen in Figure 8-14, which balances efficiency gains relative to the reference with differences in outlays. The figure clearly illustrates, that the net effect of policy DECOUPREG50 is highly positive and increasing with time. In other words, efficiency gains due to a better allocation of production factors in the region outweigh the costs of the policy. Although adjustment costs in policy DECOUPREG50 are high in the short-run (Table 8-6), this phenomenon is only temporary.

Figure 8-13: Total payments granted to farms and leaving farms



Finally, the third alternative policy, PARTIAL, is the only policy that shows a steady decrease in total government outlays. At first sight, this may be surprising taking into account that payments are partly coupled to production. The following point may give an explanation. Policy PARTIAL grants coupled direct payments to production activities such as suckler cows, or beef cattle, the profitability of which is not only dependent on the provision of direct payments as such but on their amount. Hence, it appears that the amount of direct payments per produced unit is not high enough to keep up production at the same level than in the reference. And indeed, referring back to Table 8-3, revenue shares of suckler cow production decrease over time, and therefore the total amount of direct payments granted to farms.

Figure 8-14: Net efficiency gain measured as the difference between economic land rent per hectare farmland, and total government outlays per hectare farmland relative to reference



Note: Economic land rent including subsidies.

8.9 Summary and discussion of results

Central results of the policy simulations in this chapter are presented in Table 8-10. Of course, these need to be seen within the assumptions stated in chapter 6. In particular, it should be stressed that results assume labour-saving technological change. Moreover, farms are equally smart with regard to seeking off-farm labour. From a purely economic point of view, the results presented in this paper support the demand for a decoupling of direct payments.

Table 8-10: Synopsis of alternative policies

	DECOUPREG50	REGPREM	PARTIAL
Goal of policy and implementation	- Single farm payment (SFP) decoupled from production and land paid to person of farmer; based on historical records - Incentive to allocate factors according to market signals - Low single area payment (50 €/ha) to insure management of most marginal land	- Equal distribution of payments across all agricultural land - Redistribute payments between farms - Single area payment based on total average payments divided by total agricultural area - Payment entitlement can be claimed for managed farmland	- Prevent cattle production from ceasing - Direct payments remain 50% coupled to production - Other 50% paid as single farm payment, but split into payment entitlements which can be claimed for managed land
Effect of policy	- Immediate strong reaction to policy change - 'Pull-effect': Farmers take SFP and withdraw from sector - Rental prices cut by half, alternative uses of capital and labour - Low percentage of abandoned land - Overall efficiency increases	- Little change in farm and production structure; no impulse for structural change - Rental price for grassland increases → basic management to claim payment necessary - Low efficiency increase compared to other policies	- Little change in farm and production structure; no impulse for structural change - Differences to REF and REGPREM in the long-run
but:	- Over time, increasing share of SFP goes to leaving farmers - Land assets loose value	- In the short-run, higher incomes for granivore farms, but decrease of dairy and cattle cannot be prevented - Redistribution of payments - Lower efficiency gains than DECOUPREG50 - Inefficient farms remain in sector	- Cattle production ceases in the longer run as re-investments are not profitable → lower government outlays - Inefficient farms remain in sector
Common to all policies	- Dairy production and beef cattle production ceases in the long-run independent of policy - Suckler cow production depends on provision of coupled direct payments - Dominant position of intensive livestock production increases with structural change		

8.9.1 Policies

Fully decoupled direct payments, granted independent of agricultural production show to have landslide effects. Shadow prices for production factors such as land, fall dramatically because of the policy. Thus, farms spend less on leasing land and look for alternative uses of the complementary factors labour and capital. This accelerates structural change. To prevent that marginal land will fall completely out of use, a basic land management premium of 50 € per ha is enough to prevent land from falling idle. As much as a single farm payment granted independently of farming increases the efficiency of agriculture in the region, their general acceptance by society can be questioned as it will be difficult to justify why farmers should still receive payments if they quit farming (Swinbank and Tangermann 2000). Food quality and environmental aspects that form another pillar of agricultural policy-making have also been left out. But, it can be expected that these policies have an indirect effect on agricultural structures and production efficiency, too.

If payments are no longer attached to production, but to land use only (scenario REGPREM), this results in little change in the production structure compared to the reference. Efficiency and profits, on average, are only affected in a minor way. An exception is the rental price for grassland, which experiences an increase over time as well as a re-distribution of payments between farms in the region. Conditional on the assumptions made on milk prices, the policy induces payments to be redistributed away from small mixed and specialised granivore farms producing beef cattle and suckler cows toward dairy farms. But, as mentioned above, this depends crucially on the assumption of constant milk prices.

Yet, the extent of the redistribution depends on the level of the single area payment, the region's farming structure, and – very importantly – the farms' ability to adjust to the changing policy framework. Regarding the first issue, a different payment level would necessarily lead to a different percentage of farms that would, ceteris paribus, win or loose. As for the specific farming structure in the region, Hohenlohe's structure is comparatively heterogeneous region with many intensive livestock farms on the one hand, and a comparatively high share of smaller grazing livestock and mixed farms, on the other hand. Depending on their specialisation and size, farms in a region are affected differently. The analysis in this chapter also shows that farms suffering most from a single area payment are those who adjust to the changing policy conditions.

The high demand for grassland in this scenario is related to the fact that arable land and grassland are eligible for the single area payment already if the land is managed in a very basic way. In this study, this requirement is interpreted as a basic plot management that involves cutting grass. Because of this, it is only rational that farms rent plots in order to claim the payment. As long as payments are higher than the marginal costs of plot management, land will not be abandoned. Furthermore, keeping grassland in good condition appeared to be more profitable for farms than to engage in grassland-dependent livestock production activities.

Regarding partially decoupled direct payments (scenario PARTIAL), both the farm structure and the production structure do not change significantly with the introduction of the policy. Production activities that highly depend on the provision of coupled direct payments such as suckler cows decrease as 50% of the direct payment is changed to a decoupled payment. Most notably, scenario PARTIAL (and less so REGPREM), cannot prevent dairy production and cattle production from ceasing. Once dairy and cattle production facilities reach their useful lifetime, farms do not re-invest in dairy and cattle production but rather re-organised towards intensive livestock production or leave the sector.

8.9.2 Winners and Losers

As for the winners and losers of a policy change towards decoupled income payments, the model results produce a clear answer. Considering that farms maximise household income, both unprofitable farms and farms with a growth potential, benefit from fully decoupled payments (DECOUPREG50). Unprofitable farms profit because farms are rewarded for leaving the sector, despite of significantly lower opportunity costs of land. This takes away some strain on the land market, as more land is available for lease. The remaining farms have the opportunity to lease land at lower prices and to realise size effects more easily. As these farms' share of leased land is already higher at initialisation, farms remaining in the sector earn additional incomes from lower rental prices. Losers of policy DECOUPREG50 will be land owners, as a fall in rental prices is reflected in lower land values (cf. BEARD and SWINBANK 2001). This, however, has consequences for the use of land as a security, which in return could endanger the stability of capital-intensive production activities. Moreover, it would make it more difficult for farms to exploit the growth potential that results from the decoupling.

9 General discussion

9.1 Introduction

This study viewed agricultural structural change as an evolving (complex) system. This specific point of view guided the identification of objectives of the study. The overall objective of this study was to gain more insight into the interplay of agricultural policy measures and regional structural change in a family-farm dominated region. The emphasis was put on policy measures granting direct payments to farmers. Moreover, the study aimed to contribute to a deeper understanding of farm-type specific adjustment reactions in response to a policy change.

The research objectives were approached in three steps. First, agent-based systems were discussed as an approach to model structural change in agriculture. Based on this discussion, the agent-based spatial and dynamic model AgriPoliS was developed building upon previous research by BALMANN (1995). In AgriPoliS, structural change takes place endogenously in response to individual farms' factor endowments, behavioural foundations of farm-decision making, political and technical framework conditions as well as competition for land between farms. In the second part of the thesis, AgriPoliS was calibrated to the regional agricultural structure of the region 'Hohenlohe' in southwest Germany. The third part of the thesis was devoted to policy analysis with a focus on structural development, efficiency and income effects. This last chapter is dedicated to the elaboration of different emergent issues resulting from the three parts of the thesis. The methods used and data issues will be discussed in sections 9.2 and 9.3. Section 9.4 discusses policy implications before in the final section; a brief outlook on further research is undertaken in section 9.5.

9.2 Methodological implications

9.2.1 AgriPoliS

A core component of this study was the development and application of the agent-based model AgriPoliS. The set-up of AgriPoliS concentrates on modelling core components of family-farm dominated agricultural structures: farms, product and factor markets, land as well as interactions between them. Inevitably, AgriPoliS rests upon many specific assumptions about agent behaviour, interactions between agents and parameters (chapters 3 and 4). Because of this, results and possible consequences ought to be interpreted and questioned against the assumptions made. For example, individual farm agents' sole objective is to maximise farm household income in addition to a very limited foresight of one period. Because of this, farm agents make decisions based on income expectations about the next period and do not account of changes in following periods. Assumptions are necessary to keep the model tractable, i.e., to make it computable and to ensure the co-ordination of agents (chapter 2). Although they should be carefully chosen, assumptions are always subjective in nature. Nevertheless, simulations of the reference scenario (chapter 4 and 5) show plausible results compared to actual empirical observations and economic reasoning.

The subjective nature of assumptions equally applies to the decision on the definition of core components of agricultural structures. Unavoidably, many other influencing factors that may be regarded important (by others) have been left out and not taken into consideration. For example, one could envisage extending the model by considering companies along the process and value chain. Besides the definition of core model components, the definition of adjustment possibilities defined in AgriPoliS can be considered relatively narrow, in particular, as alternative production activities are defined exclusively based on typical production activities undertaken in the past (e.g. intensive livestock production or crop production). Moreover, real-world adjustment reactions such as possibilities to merge farms or co-operative resource use of farms were not considered.

Hence, with respect to further extension, a dilemma opens up. On the one hand, there is the attempt to find a good, precise and valid representation of real agricultural structures that includes important phenomena and components of the system. On the other hand, there are limits set by the complexity of a respective model. Although AgriPoliS maps basic components and adjustment reactions (but by far not all), the model itself has reached a level of complexity and specificity that makes it increasingly difficult to comprehend the implications of the model and to connect causes and effects. Further extensions may bear the danger that the model becomes so complex that it cannot be comprehended in itself is of no explanatory use (HANNEMAN and PATRICK 1997). Hence, authors writing on simulation generally ask for models to be as simple as possible (e.g., BANKES 1993; HANNEMAN and PATRICK 1997; MANSON 2002). In addition, time restrictions have to be considered. This relates to the computing time necessary to simulate a region over a specified number of periods and to the time devoted to model development and validation. The actual modelling and calibration is even more time consuming.

A lesson learned with regard to modelling structural change in agriculture is that as much as structural similarity between the model and reality is desirable, the modeller needs to be able to communicate the model, its assumptions, limitations and results, openly to an audience consisting of colleagues, knowledgeable experts, students and policy makers. This is mostly relevant because formal validation procedures cannot be applied in a straightforward manner to agent-based simulation as discussed in chapter 2 and certain assumptions such as size effects have been a subject of heavy disputes among experts. So, critical discussion and exchange also represent a part of the validation process.[108]

Nevertheless, simulation results with AgriPoliS are comparatively robust to parameter variations, as shown by the sensitivity experiments with AgriPoliS presented in chapter 5. Although the sensitivity analyses represented only a limited attempt at investigating the behaviour of AgriPoliS in a formal manner, the obtained results are in line with results obtained from simulation experiments carried out before this study using AgriPoliS or precursors of AgriPoliS. Moreover, results fit empirical observations such as slow structural change, persistently unexploited economies of scale, and income disparities (BALMANN 1999).

To conclude, a model such as AgriPoliS offers many opportunities to look at the dynamics of agricultural structural change from new and different perspectives using a range of analysis methods. AgriPoliS, therefore, can be considered a promising tool for further policy analysis. To overcome the limitations posed by complexity, modellers will have to carefully extent AgriPoliS and conduct

[108] These challenges are not solved by the steady increase in computing capacity. More computing power might shift problems related to the computability of complex models. But, ever powerful computers cannot solve problems relating to cognitive capacities of the modeller and the audiences as well as the fact that complex models are prone to errors. Finally, yet importantly, data availability becomes restrictive the more differentiated the models become.

intensive test periods at each new development step. This also extends to the implementation of different policy scenarios. Overcoming the shortcomings of complex simulation models will depend to some extent on further progress in information technology, methodological progress, the resourcefulness of its users, and continuous training of future researchers.

9.2.2 Design of Experiments

In general, it was found that the application of formal analysis procedures such as Design of Experiments (DOE) to study the behaviour of AgriPoliS contributed to a better understanding of AgriPoliS, especially under extreme conditions. Based on the analysis it turned out that AgriPoliS is most sensitive to changes in interest rates. The results, however, have to be taken with care. The reason is that the DOE specified in chapter 5 was of a very basic nature because only five factors out of the large number of parameters were selected to be included in the DOE. If more parameters had been chosen, different results concerning factor importance and interactions of factors would have potentially arisen. Moreover, in DOE no rules are defined as to the appropriate factor level settings. Because of this, the importance of factors is partly based on what was defined in the experimental setup. In view of this, it has to be seen that the primary intention behind the approach followed in chapter 5 was to become acquainted with various, complementary ways of sensitivity analysis.

9.2.3 DEA-model and structural efficiencies

This study used a data envelopment approach to analyse differences in efficiency between farms operating under different policy conditions. DEA was used because of its ability to compare a large number of farms with regard to inputs and outputs using different units of measurement (CURTISS 2002). DEA furthermore does not impose any functional form on the underlying production technology. Two kinds of analyses were carried out. First, kernel density functions were estimated for each policy scenario showing the distribution of efficiency scores also between time periods. Based on individual efficiency scores, for each policy scenario the measure of structural efficiency was derived as the output-share weighted mean efficiency. Unlike an application of DEA to real empirical data which includes noise into the measure of efficiency, the simulated data does not contain noise which could deter the efficiency estimates. This made DEA particularly suitable for the analysis.

Unexpectedly, the DEA-modelling had a positive side effect with regard to the validation of AgriPoliS. While carrying out and testing AgriPoliS and subsequently applying the DEA-model to the simulated data, it turned out that the DEA-model actually could also be interpreted as a meta-model just as the one applied in the DOE procedure. This offers some scope for further linkages between simulated data and efficiency analysis.

9.3 Data issues

With regard to data, one needs to distinguish between the output and the input side of AgriPoliS. On the input side, the research in this thesis was based on data collected for the region Hohenlohe in the reference year 2000/2001. Many different kinds of data from different sources were required to calibrate AgriPoliS to the specific agricultural structure of Hohenlohe (chapter 4). In general, model results are conditional on data availability and the assumptions made.[109] Although the financial year 2000/2001 was chosen as the base year, not all data was available for this year. The main reason is that statistical offices do not conduct surveys on an annual basis. For example, the agricultural survey providing data on the total number of farms and the distribution of farm types is conducted only every 5 years; the last available was from 1999. An exception is the farm accounting data, which is collected annually for the German agricultural report and for the European Farm Accounting Data Network (FADN). Another problem encountered is that data is not necessarily available for homogeneous regions. It is more likely that data is available for administrative regions, which in many cases show very heterogeneous production conditions.

On the output side, AgriPoliS generates a large panel data set based on the specified input data and the rules and assumptions governing the programme flow (see chapter 3). The development of each farm during the simulation can be traced based on a number of indicators (see table A-8 in the appendix). As shown in this study, different analytical techniques could be applied to the simulated data sets. In particular, analysis techniques could be used that usually require a large number of observations such as Kernel density estimation.

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[109] A restriction, which should not be underestimated, is data availability. In the first place, this concerns the accessibility of individual farm accountancy data which often is only available as aggregates of selected farm variables. Moreover, regional statistical may not be available for the considered regions. Whenever the required data is not available, one has to resort to a second-best solution. Obviously, data availability thus influences the quality of results.

9.4 Policy implications

Before discussing results and implications from the individual policy simulations presented in chapter 7 and 8, some general remarks shall be made. In the introduction in chapter 1, structural change was introduced as being an integral part of any economic process, as being a 'natural' process, inherent to any economic activity. All too often structural change has a negative connotation and policy makers have aimed to work against it, e.g., by introducing subsidies. However, the simulation results presented in this study as well as practical experiences from many decades of policy analysis show that policies cannot entirely hold up structural adjustment such that all actors benefit from the policy. If policy slows down structural change, many problems accumulate and lead to high costs incurred at later time periods. Another key insight gained from this study is that agricultural policies affect individual farms in different ways depending on the specific situation of the farms. It seems that policy makers underestimating the power of market signals in structural adjustment, overestimate their own abilities to create policies that sustainably yield the desired results.

Regarding the specific results from the policy simulations, in particular, the following points shall be pointed out:

- A policy directed at removing unprofitable and inefficient farms from the sector (policy RETPAY in chapter 7), would lead to strong and immediate structural adjustment with many farms leaving the sector. Although this leads to a relaxation of the situation on the land market in the short-run, the link between direct payments and production is upheld such that in the medium-run, competition for scarce resources and production increases. Thus, the policy does not increase the market orientation of production. Moreover, under welfare considerations this policy, which tries to correct distortions with another distortion, is costly. Efficiency gains in factor re-allocation are outweighed by the total costs of the policy.
- More efficient from a societal point of view is a policy in which direct payments are not tied to production and production takes place in response to market signals. Three aspects are most noteworthy with regard to a real decoupling of transfers (policy DECOUP): First, inefficient and unprofitable farms have stronger incentives to withdraw from farming. Although leaving farms would not benefit from the growth possibilities of remaining farms, they would no longer be forced to engage in production activities unprofitable without support. In this sense, leaving farms have advantages at least in the short-run (cf. SWINBANK and TANGERMANN 2000). Second, fully de-

coupled direct payments would lead to significantly lower shadow prices of land, labour, and capital at the farm level. Hence, farmers are no longer willing to pay high rental prices for land. As much as lower rental prices may be an advantage for farmers with a high share of rented land and for growing farms, land owners could experience a devaluation of land and quotas, which could in return have a certain negative effects. The reason is that land is an important credit security, particularly in family-farm dominated agriculture. Devaluation could therefore reduce the financial stability of farms.110 Third, the study showed that on marginal sites, some land might be abandoned if direct payments are fully decoupled. If society demands that all land is managed, the results indicate that in the case of Hohenlohe's structure, a policy combining a low single area payment (50 €/ha) and a single farm payment prevents most land from being abandoned.

- It was found that a stepwise reduction of direct payments (PHASEOUT10) had no such strong immediate effects on structural change unlike a retirement payment or fully decoupled single farm payment. The particular effect of the policy is that it slowly, but surely increases structural adjustment pressure with every payment cut. However, this effect has to be seen in relation to the assumptions made with regard to expectation formation and prices. As for the first issue, farms were only able to plan one period ahead in each case taking the next payment cut into account. In this way, farm agents are more inclined to invest in assets as compared to a situation where they took payments cuts in further periods into account.111 The second issue relates to the observation that without price fluctuations, the stability of a few farms is increasingly at risk. Assuming that price fluctuations are present in reality, the impact of equity will even be stronger. Moreover, farms need to spread price and production risks.
- The different types of decoupling analysed in chapter 8 showed that unless payments are fully decoupled from production and land use, the effect on structural change, factor use and rental prices in Hohenlohe is comparatively small. As shown in the simulation, a single area payment induces a redistri-

[110] This problem is particularly relevant for family-farm dominated regions in which farms generally own a significant share of land. Furthermore, the problem arises mainly for capital-intensive investments into livestock production because costs of stables and equipment are sunk in most cases as there are hardly any alternative uses (BALMANN 1995, HAPPE and BALMANN 2002)

[111] In the AgriPoliS version used for this thesis, no account is taken of the timeliness of policies in the process of expectation formation.

bution of payments away from small mixed and specialised granivore farms producing also beef cattle and suckler cows toward dairy farms under the assumption that lower milk prices are not transferred into dairy premia. Only a minority of farms was affected by the redistribution and it could not hold up dairy production to cease in the longer-term. The results obtained are not general, but specific to the agricultural structure of Hohenlohe and the underlying assumptions. Hence, depending on the region, redistribution effects will differ. What is more, structural adjustment in any case will depend on the individual farms' ability to adjust to changing framework conditions. The impact of policy measures depends on the circumstances and reactions of the farmers who respond to them.

One obvious conclusion from the results is that a full decoupling of direct payments creates the greatest potential for increasing factor mobility and making production more responsive to market signals. Even though the results obtained with AgriPoliS are subject to a number of assumptions that influence the behaviour and interactions of farm agents, and hence model results, the majority of the findings are plausible from a theoretical and empirical point of view and are consistent with other studies (e.g. BERTELSMEIER 2004).

Whether or not the results obtained by the simulations can be transferred to real systems depends on a number of factors. One aspect is that the specific impact of a policy should not be seen independently of other policies such as social policies or tax policies as well as developments in other sectors. This concerns above all the labour market. Furthermore, as much as fully decoupled payments granted independent of farming make sense from an economic point of view, their general acceptance by society can be questioned, as it will be difficult to justify why farmers should continue to receive payments after they have left agriculture (FENNEL 1997; ISERMEYER 2002; SWINBANK and TANGERMANN 2000). However, the positive income effects of decoupling and the evolution of the sector as such create scope for a stepwise reduction of the payments. Food quality and environmental aspects, which form another pillar of agricultural policy making, have also been left out. But it can be expected that these policies have an indirect effect on agricultural structures and production efficiency, too. Finally, subsidies not only provide incentives, but also form farmers' thoughts and actions in a way that farmers over time get used to agricultural policies and subsidies in particular. In many cases, agricultural policies have led to a degeneration of a kind of 'entrepreneurial spirit'. If production is to be more market-oriented, farmers will need to acquire or relearn an entrepreneurial approach to farming. With AgriPoliS, it is not possible to reflect this particular issue, but other behavioural models other than linear programming may offer new possibilities.

9.5 Implications for further research

Based on the work presented in this thesis, a broad range of research directions opens up, some of which are being followed already. Starting directly from the work presented in this thesis, the most obvious step in further research is to calibrate AgriPoliS to regions other than Hohenlohe. In fact, at the time of writing this thesis, work on applying AgriPoliS to 17 regional agricultural structures in the enlarged EU had already started as part of two EU-funded projects. In addition to modelling different regions, the projects also involve further refinements of AgriPoliS with regard to environmental impact assessment, explicit consideration of space in a GIS-type framework, a more detailed representation of decoupling options as well as Mediterranean agriculture.

The policy simulations presented in this study assumed framework conditions (interest rates, managerial ability, etc.). The impact of agricultural policies is – amongst other issues - subject to the uncertainty about the development of the system to which the policy is applied. Uncertainty exists with respect to a number of framework conditions of agricultural production such as interest rates, wages, innovation, prices, managerial ability, farm succession, just to mention a few. In this study either selected framework conditions are varied or policies. It therefore would be of interest in future policy analyses to study the relationship between policy dynamics and varying framework conditions. Computer simulation experiments to explore the implications of many plausible formulations of a problem are helpful in devising policies that come close to achieving a set of defined policy goals, whilst being reasonably effective given different versions of the future.

Moreover, in this study, the consequences of structural adjustment are analysed exclusively from the farms' point of view and – in a very basic way – that of the state. BOEHLJE (1999) argues, though, that the process of structural adjustment is multi-dimensional including the whole supply and value chain, i.e., food production, processing and distribution industries as well as society are equally affected. Based on this, one could envision refocusing the analysis of structural change starting with supply and value chains rather than firms and markets.

In chapter 2 of this thesis, different behavioural foundations of agents were addressed. In the process of understanding the behaviour of economic agents, other goals than income maximisation and optimisation could be explored. As many applications in the field of sociology and communication sciences have shown, it is furthermore possible to explicitly introduce different, not necessarily economic, behavioural patterns into agent-based models. Another alternative, which is increasingly winning grounds in agent-based systems, is to introduce artificial intelligence methods, either to create completely artificial societies, or to replace behavioural assumptions as done, e.g., by BALMANN and MUßHOFF (2004), or BALMANN and HAPPE (2001a). Moreover, learning is increasingly introduced in to agent-based models.

To summarise, AgriPoliS offers an opportunity to look at the dynamics of agricultural structural change from new and different perspectives. In this sense, it may represent a fruitful approach complementary to more traditional econometric and normative modelling approaches. From the author's perspective, AgriPoliS offers some scope for further uses in policy analysis as well as in other fields of research. Last, but not least, the future of agent-based modelling in agricultural economics will be subject to a critical and careful further development of existing models or the development of new models. Crucial in this regard is an open discussion of assumptions and model structures with an audience consisting of colleagues, knowledgeable experts, students and policy makers, as well as the creativity and resourcefulness of future modellers and users.

Summary

Agricultural structures have been shaped by a variety of factors including economic, cultural, historical, political, technological, and geographical conditions. Moreover, agricultural structures are not static. Structural change can be characterised as an evolutionary process consisting – among other things – of constant adjustment to changes in demand, supply, and technological progress.

The development of competitive and efficient agricultural structures has been one of the central goals of agricultural policy making in addition to ensuring a fair standard of living for farmers. To achieve these goals, the agricultural sector in most industrialised nations has long been the subject of government interventions. However, many agricultural policies have worked counteractively to these goals by creating distortions in the use of resources. Against this background, the emergence of new and innovative modelling methods such as agent-based models, in addition to ever-increasing computing capacities has offered new possibilities to model adjustment reactions and to quantify the impact of agricultural policies.

This thesis takes up these new methodologies and applies them to the modelling and evaluation of agricultural policy impacts on regional structural change in Baden-Württemberg. The thesis contributes to a deeper understanding of structural change dynamics and factors causing structural change. The starting point of the analysis is the hypothesis that Hohenlohe's agricultural structure displays structural inefficiencies and that structural adjustment in the past has been impeded by existing agricultural policies. Based on these assumptions, it is studied whether and to what extent policy changes can facilitate structural adjustment towards a more efficient and competitive agricultural structure.

At the centre of the thesis is the development of the spatial and dynamic simulation model of regional agricultural structures AgriPoliS (Agricultural Policy Simulator). The core of AgriPoliS is the understanding of a regional agricultural structure as an agent-based system, i.e., a system of interacting heterogeneous agents. The model extends previous work by BALMANN (1995, 1997). AgriPoliS is a normative spatial and dynamic model in which a number of individually acting farm agents interact with each other subject to their actual state and to their individual environment. Farms can engage in a number of production activities,

invest into buildings and machinery, operate as part-time farms, or leave agriculture altogether.

The initial situation of the model is calibrated to the agricultural structure of the region 'Hohenlohe' in Baden-Württemberg in the reference year 2000/2001. The calibration aims to map the farming structure in the region and the variety of prevalent farms and production activities. The main data sources used are accountancy data (FADN), regional statistics, investment data, as well as technical production coefficients. The full implementation of the Agenda 2000 by the end of 2002 is taken as the reference scenario.

In a first set of simulations, AgriPoliS' behaviour in the reference scenario is investigated. In particular, parameter values for technological change, interest rates, region size, and managerial ability are varied. Accordingly, high interest rates together with heterogeneous managerial ability and high technological change induces a particularly strong structural change in the region. Moreover, results show no strong variations in response to different initial conditions. Finally, an impact analysis of managerial ability on farm survival shows that farms with higher managerial ability are more likely to survive structural change.

In the policy simulations, emphasis is put on policies that are likely to support the development towards more efficient and competitive agricultural structures. In particular, a retirement payment, a stepwise cut of coupled direct payments, as well as several scenarios with decoupled direct payments are simulated (decoupled single farm payment, single area payment, and partially decoupled payments). Key results are the following:

- Structural effects: A fully decoupled single farm payment granted independent of agricultural production shows to have strong effects in the short-run. Shadow prices for production factors fall dramatically. Thus, farms have stronger incentives to spend less on leasing land and to look for alternative uses of the complementary factors labour and capital. This means accelerating structural change. In addition, marginal land may no longer be managed. A basic land management premium of 50 € per ha prevents most land from falling idle. A stepwise reduction of payments leads to a gradual increase of adjustment pressure resulting in land prices falling over time. On the other hand, a single area payment if implemented as payment entitlements per hectare results in no significant changes compared to the reference scenario. However, in the long-run, results do not differ greatly between scenarios.

- Income effects: As for the single farm payment and the retirement payment, unprofitable farms, and farms with a growth potential, benefit already in the short-run. Farms in the first group benefit because they are rewarded for leaving the sector. This takes away pressure from the land market, as more land is available for lease. Surviving farms benefit because they have the opportunity to lease land at lower prices and to realise size effects more easily. Most of all, farms with a high share of rented land benefit from falling land prices. Over time, a stepwise reduction of direct payments also transfers into lower rental prices. In case of this policy, farms that previously existed because of direct payments are successively pushed out of the sector. Losers of policies leading to lower rental prices will be land-owners as a drop in rental prices implies land values to decline.
- Efficiency: A Data Envelopment Analysis shows that on average efficiency increases significantly, if an incentive is provided to unprofitable and inefficient farms to leave the sector. If no incentive is provided or direct payments are coupled to production, inefficient farms remain in production. This is also the case for a uniform area payment. However, since inefficient farms are relatively small, the production share of inefficient farms is also relatively small, such that the output-weighted structural efficiency shows only small differences between policy scenarios. To assess the efficiency of production in the region, economic land rent is used as a measure for the allocation of factors. In all scenarios, average economic land rent increases with time despite of lower rental prices in the case of fully decoupled payments. Considering adjustment costs, efficiency gains are highest and adjustment costs lowest for decoupled single farm payments.

The results show agricultural policies to affect structural change in many ways. A full decoupling of direct payments creates the greatest potential for increasing factor mobility and making production more responsive to market signals. Even though the results obtained with AgriPoliS are subject to assumptions that influence the behaviour and interactions of farm agents, and hence model results, the majority of the findings are plausible from a theoretical and empirical point of view. Results point out that the individual farm's scope for adjustment depends on the specific circumstances of the farm and the conditions of the region within which the farm is situated.

Zusammenfassung

Agrarstrukturwandel ist geprägt durch eine Vielzahl ökonomischer, kultureller, historischer, politischer, technischer und geographischer Faktoren. Er ist gekennzeichnet durch konstante Anpassungsprozesse an Angebots- und Nachfrageänderungen sowie an technische Fortschritte. Die Entwicklung wettbewerbsfähiger und effizienter Agrarstrukturen ist seit je her ein Hauptziel der Agrarpolitik neben der Erzielung eines angemessenen Einkommens. Zur Erreichung dieser Ziele ist der Agrarsektor in den meisten industrialisierten Ländern einer Reihe von Politikmaßnahmen unterworfen. Allerdings hat es sich gezeigt, dass viele der Politiken den gesetzten Zielen eher entgegengewirkt haben, indem sie zu Verzerrungen bei der Allokation von Ressourcen geführt haben. Vor diesem Hintergrund bieten neue und innovative Modellierungsmethoden, wie z.B. die agentenbasierte Modellierung, neue Möglichkeiten, die Wirkungen von Agrarpolitiken auf den Agrarstrukturwandel zu modellieren und zu quantifizieren.

Die vorliegende Arbeit wendet die genannten neuen Methoden an auf die Wirkungsanalyse von Agrarpolitiken auf den regionalen Strukturwandel in der Region Hohenlohe in Baden-Württemberg. Die Arbeit soll beitragen zu einem tieferen Verständnis der Dynamik des Strukturwandels. Die Arbeit basiert auf der Hypothese, dass die Agrarstruktur Hohenlohes eine Reihe von Ineffizienzen aufweist und strukturelle Anpassungsprozesse in der Vergangenheit durch agrarpolitische Maßnahmen, wie Preisstützungen und produktionsgebundene Direktzahlungen, behindert wurden. Ausgehend von dieser Hypothese wird untersucht, ob und inwieweit Politiken strukturelle Anpassungsprozesse in Richtung einer effizienteren und wettbewerbsfähigeren Agrarstruktur unterstützen können.

Im Mittelpunkt der Arbeit steht die Entwicklung und Anwendung des agentenbasierten, räumlich-dynamischen Modells regionaler Agrarstrukturen AgriPoliS (Agricultural Policy Simulator). AgriPoliS setzt an bei der Interpretation einer Agrarregion als agentenbasiertes System, d.h., einem System interagierender und heterogener Agenten. Das Modell erweitert frühere Arbeiten von Balmann (1995, 1997). AgriPoliS ist ein normatives räumlich-dynamisches Modell, das explizit die Aktionen und Interaktionen einer Vielzahl individuell agierender Betriebe abbildet. Betriebsagenten entwickeln sich in Abhängigkeit von ihrer

Umwelt. Jeder Betrieb kann mehreren Produktionsrichtungen nachgehen, für die Investitionsalternativen unterschiedlicher Ausrichtung und Größe zur Verfügung stehen.

Das allen Simulationen zu Grunde liegende Referenzjahr ist das Wirtschaftsjahr 2000/2001. Die Anpassung von AgriPoliS an die Region Hohenlohe verfolgt das Ziel, die Agrarstruktur Hohenlohes möglichst treffend abzubilden. Dazu werden Datenquellen wie Testbetriebsdaten, Regionalstatistik, Investitionsdaten, sowie technische Koeffizienten herangezogen. Die Umsetzung der Agenda 2000 am Ende des Jahres 2002 definiert das Referenzszenario.

In einem ersten Satz von Simulationsrechnungen wird zunächst das Verhalten von AgriPoliS in der Referenzsituation untersucht. Insbesondere werden die getroffenen Annahmen zum technischen Fortschritt, den Zinsen, der Regionsgröße sowie der Managementfähigkeiten der Betriebsagenten variiert. Es zeigt sich, dass hohe Zinsen in Verbindung mit heterogenen Managementfähigkeiten der Betriebsagenten und hohem technischen Fortschritt zu einem ausgeprägten Strukturwandel führen. Weiterhin zeigt es sich, dass AgriPoliS sich robust im Bezug auf Zufallsinitialisierungen verhält. Ein weiteres Ergebnis besteht darin, dass Betriebsaufgaben und Managementfähigkeiten negativ korreliert sind.

Bei der Simulation und Analyse von Politikvarianten wurde der Schwerpunkt auf Politiken gelegt, die potenziell geeignet sind, strukturelle Anpassungsprozesse in Richtung einer effizienteren und wettbewerbsfähigen Agrarstruktur zu unterstützen. Konkret sind dieses eine Abwanderungsprämie, eine schrittweise Rückführung gekoppelter Direktzahlungen sowie verschiedene Varianten entkoppelter Direktzahlungen (eine an den Betriebsleiter gebundene Betriebsprämie, einheitliche Flächenprämie, teilentkoppelte Prämien). Zentrale Ergebnisse sind die Folgenden:

- Strukturwirkungen: Es zeigt sich, dass die Einführung einer vollständig entkoppelten Betriebsprämie, kurzfristig zu starken Anpassungsreaktionen führt, bei der viele Betriebe ausscheiden. Insbesondere kommt es zu einem starken Verfall der Schattenpreise des Faktors Boden und damit der Pachtpreise. Betriebe haben somit stärkere Anreize, die komplementären Faktoren Arbeit und Kapital anderen Verwertungen zuzuführen, was den Strukturwandel verstärkt. Als problematisch stellt sich jedoch heraus, dass ein nicht unbeträchtlicher Teil des Bodens brach fällt. Eine geringe einheitliche Flächenprämie von 50 €/ha könnte diesem entgegenwirken. Auch eine Abwanderungsprämie von jährlich 10,000 € führt kurzfristig zu starken Anpassungsreaktionen. Allerdings kommt es, bedingt durch gekoppelte Direktzahlungen, zu keinem gravierenden Verfall der Schattenpreise der Produktionsfaktoren.

Während es bei den genannten Politiken zu einer sofortigen Strukturanpassung kommt, führt die schrittweise Rückführung gekoppelter Direktzahlungen über einen Zeitraum von 10 Perioden zu einem jährlich ansteigenden Anpassungsdruck, der sich in graduell fallenden Pachtpreisen ausdrückt. Die Einführung einer einheitlichen Flächenprämie führt zu keinen nennenswerten Strukturveränderungen im Vergleich zur Referenz.

- Einkommenswirkungen: Bei Einführung einer Betriebsprämie sowie einer Abwanderungsprämie profitieren sowohl Wachstumsbetriebe, als auch unprofitable Betriebe. Letztere profitieren, weil ihr Ausscheiden in beiden Politiken belohnt wird. Durch das Ausscheiden dieser Betriebe entspannt sich insbesondere die Lage auf dem Bodenmarkt, so dass Wachstumsbetriebe sowohl von niedrigeren Pachtpreisen als auch von der Realisierung von Größeneffekten profitieren können. Besonders im Vorteil sind dabei Betriebe mit einem hohen Anteil Pachtland. Auch bei einer schrittweisen Absenkung gekoppelter Direktzahlungen profitieren Wachstumsbetriebe, allerdings auf geringerem Niveau, da im Gegensatz zu den anderen Politiken nach Abschluss der Rückführung keinerlei Beihilfen gewährt werden. Die offensichtlichen Verlierer bei sinkenden Pachtpreisen sind die Bodeneigentümer.
- Effizienzaspekte: Mit Hilfe der Data Envelopment Analyse (DEA) wird die Effizienz der Betriebsagenten zu verschiedenen Zeitpunkten bestimmt. Aufbauend darauf wird mit der so genannten strukturellen Effizienz ein Maß für die Effizienz der Agrarstruktur bestimmt. Es zeigt sich, dass die Effizienz der Betriebe im Durchschnitt deutlich ansteigt, wenn Anreize für ineffiziente Betriebe geschaffen werden, aus der Produktion auszusteigen. Der Anstieg erklärt sich durch die Realisierung von Größeneffekten und effizienzsteigernder Investitionen. Besteht ein solcher Anreiz nicht (wie z.B. bei einer einheitlichen Flächenprämie) oder sind Direktzahlungen an die Produktion gekoppelt, so verbleiben ineffiziente Betriebe. Allerdings ist der Anteil ineffizienter Betriebe an der Gesamtproduktion gering, so dass es zu keiner gravierenden Änderung der mit dem Produktionsanteil gewichteten (strukturellen) Effizienz kommt. Zur Bewertung der Allokationseffizienz der eingesetzten Produktionsfaktoren wird die Grundrente als Indikator hinzugezogen. Trotz zum Teil fallender Pachtpreise, steigt die durchschnittliche Grundrente in der Region über die Zeit, bedingt durch Strukturwandel, technische Fortschritte und Größeneffekte. Wenn die Anlagenentwertung ausscheidender Betriebe zusätzlich berücksichtigt wird zeigt sich, dass im Durchschnitt der Simulationsperioden, eine vollständig entkoppelte Betriebsprämie mit den geringsten Anpassungskosten verbunden ist.

Zusammenfassend kann festgestellt werden, dass die Politikwirkungen auf den Agrarstrukturwandel vielfältig sind. Eine zentrale Schlussfolgerung der Arbeit ist, dass eine vollständige Entkopplung von Direktzahlungen unter den getroffenen Annahmen die Faktormobilität erhöht, und Produktionsentscheidungen sich stärker am Markt orientieren. Die Ergebnisse der Arbeit sind theoretisch plausibel und entsprechen weitestgehend empirisch gewonnenen Erkenntnissen. Dennoch kann das vorgestellte Modell nur einen Teilaspekt struktureller Anpassungsprozesse berücksichtigen. Die Ergebnisse weisen jedoch darauf hin, dass der jeweilige Anpassungsspielraum eines Betriebs in einer Agrarregion abhängig ist von den Gegebenheiten des einzelnen Betriebs sowie der Region.

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Appendix

A.1 Definition of livestock production activities

Table A-1: Production activity 'fattening pigs'

Performance		
Starting weight	kg	28
Final weight	kg	117
Carcass weight	kg	94
Fattening days	days	135
Revenue	**€/year**	**372**
Variable costs		
Piglets, equipment, vet, electricity, compound fodder etc.	€/year	314
Gross margin	**€/year**	**58**
	€/pig produced	21.5

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001), STMLF (2003).

Table A-2: Production activity 'sows'

Performance		
Piglets	Piglets/year	20
Useful lifetime of sow	Months	36
Piglet price	€/piglet	53.3
Revenue		
Piglets	€/year	1067
Old sows	€/year	83
Variable costs		
Replacement, equipment, vet, electricity, compound fodder etc.	€/year	683
Gross margin	**€/year**	**467**

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001), STMLF (2003).

Table A-3: Production activity 'turkeys'

Performance		
Final weight		
Hen	kg	9.5
Rooster	kg	19.4
Fattening days	Days	159
Revenue	**€/year**	**33.75**
Variable costs		
Replacement, equipment, vet, electricity, compound fodder etc.	€/year	26.6
Gross margin	**€/year**	**7.15**

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001).

Table A-4: Production activity 'suckler cows'

Revenue incl. old cow	**€/year**	**634**
Premium	€/year	317
Variable costs		
Replacement, equipment, vet, electricity, marketing costs, insurance etc.	€/year	266
Gross margin excluding basic ration and premium	**€/year**	**368**

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001), STMLF (2003).

Table A-5: Production activity 'beef cattle'

Performance		
Starting weight	kg	90
Final weight	kg	660
Daily weight gain	g	1,140
Fattening days	Days	500
Revenue	**€/year**	**864**
Premium	€/year	211
Variable costs		
Calves, equipment, vet, electricity, compound fodder, insurance etc.	€/year	600
Gross margin excluding basic ration and premium	**€/year**	**264**

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001), STMLF (2003), LEL (2003b).

Table A-6: Production activity 'dairy cows'

Performance		
Milk yield	kg	5,700
Milk price	€/kg	0.35
Revenue		
Milk	€/year	1,995
Old cow	€/year	150
Calves	€/year	155
Variable costs		
Replacement, equipment, vet, electricity, compound fodder, insemination etc.	€/year	920
Gross margin	**€/year**	**1,380**

Source: SAHRBACHER (2003) based on REGIERUNGSBEZIRK MITTELFRANKEN (2001), STMLF (2003), KTBL (2000).

A.2 AgriPoliS data output

Table A-7: Data output at farm and sector level (selection of key data)

Farm level	Unit	Sector level	Unit
Structure		**Production**	
Farm size	ha	Region totals	ha, LU
Economic size	ESU	**Inputs**	
Farm type		Total land input	ha
Main income source	Professional/ non-prof.	Total capital input	€
Owned land	ha	Total labour	h
Rented land	ha	**Investment**	
Production		Investment expenditure	€
Output in quantities	ha, LU		
Output in value	€	Sector totals of farm level data	various units
Costs			
Overheads	€		
Maintenance	€		
Depreciation	€	**Farm level**	**Unit**
Wages paid	€	**Financial situation**	
Rent paid	€	Profit	€
Interest paid	€	Equity capital	€
Annualised average costs of fixed capital	€	Change in equity	€
Variable costs	€/unit	Net investments	€
Subsidies		**Income and labour**	
Direct payments	€	Labour input	h
Land		Family labour	h
Economic land rent	€/ha	Farm net value added	€
Rent paid arable land	€/ha	Total household income	€
Rent paid grassland	€/ha	Off-farm income	€
Balance sheet			
Total assets	€		
Total fixed assets	€		
Total land assets	€		
Liquidity	€		
Borrowed capital	€		
Short-term borrowed capital	€		

A.3 Bootstrap procedure to derive confidence intervals on structural efficiency measures

The bootstrap procedure to derive confidence intervals on structural efficiency estimates proposed by SIMAR and ZELENYUK (2003) is based on the bootstrap (EFRON 1979, SIMAR and WILSON 2000). The following points briefly describe the proposed procedure:[1]

1. Assume the vector $x^k = (x_1^k, x_2^k, \ldots, x_N^k)' \in \Re_+^N$ to denote N inputs the farm k ($k = 1, \ldots, K$) uses to produce a vector M o outputs, denoted by $y^k = (y_1^k, y_2^k, \ldots, y_M^k)' \in \Re_+^M$.
2. For each observation (farm k) in the sample $\Xi_K = \{(x^k, y^k): k = 1, \ldots, K\}$ in period $t = 1, \ldots, T$ compute the DEA estimated technical efficiency $T\hat{E}(x, y)$. It is computed relative to an estimated best practice frontier $\hat{P}(x)$ as a solution of the linear programming problem $T\hat{E}(x, y) = \max\{\theta : \theta \cdot y \in \hat{P}(x)\}$. $T\hat{E}(x, y)$ is an estimate of the relative efficiency of farm k in the sample $\{T\hat{E}(x^k, y^k): k = 1, \ldots, K\}$.
3. Aggregate the estimates of individual efficiencies from step 2 into L sub-groups, whereby sub-group l represents a policy regime. Derive L sub-group estimated aggregate efficiency measure using output shares as weights.
4. Obtain the bootstrap sequence $\Xi_{s_l,b}^* = \{(x_b^{*k}, y_b^{*k}): k = 1, \ldots, s_l\}$ (b denote the bootstrap iteration $b = 1, \ldots, B$) by sub-sampling with replacement independently from data on each sub-group l of the original sample of farms, where $s_l = (K_l)^\kappa, \kappa < 1, l = 1, \ldots, L$, where s_l is a sub-sample of the original sample of sub-group l.
5. Compute the bootstrap estimates of $T\hat{E}(x, y)$ with $T\hat{E}(x, y) = \max\{\theta : \theta \cdot y \in \hat{P}(x)\}$ using the bootstrapped sample $\Xi_{s_l,b}^*$ obtained from step 4. Call the bootstrapped estimates of technical (in)efficiency $T\hat{E}_b^{*l,k}$ for $k = 1, \ldots, s_l < K_l$ farms in subgroup l ($l = 1, \ldots, L$.)
6. Compute the bootstrap estimates of the estimated structural efficiency scores using

---

[1] Procedure and notation are adapted from SIMAR and ZELENYUK (2003) without change.

$\overline{T\hat{E}_b^*} = \sum_{l=1}^{L} \overline{T\hat{E}_b^{*l}} \cdot S_b^{*l}$, for the aggregate efficiency scores between the sub-groups and

$\overline{T\hat{E}_b^{*l}} = \sum_{k=1}^{s_l} T\hat{E}_b^{*l,k} \cdot S_b^{*l,k}$ for the aggregate efficiency of all farms within one sub-group. The price-independent weights used for aggregation between sub-groups are defined as

$$S_b^{*l} = \frac{1}{M} \sum_{m=1}^{M} \frac{\sum_{k=1}^{s_l} y_{m,b}^{*l,k}}{\sum_{l=1}^{L} \sum_{k=1}^{s_l} y_{m,b}^{*l,k}}, \qquad l = 1, \ldots, L.$$

and the weights for aggregation within one sub-group are defined as

$$S_b^{*l,k} = \frac{1}{M} \sum_{m=1}^{M} \frac{y_m^{l,k}}{y_{m,b}^{*l.k} \cdot S_b^{*l}}, \quad k = 1, \ldots, s_l < K_l, l = 1, \ldots, L \qquad .$$

7. Repeat steps 4 through 6 B times.

This procedure will provide B bootstrap estimates of estimated structural efficiencies $\left\{\overline{T\hat{E}_b}\right\}$. These estimates can be used to obtain the bootstrap confidence intervals, bias corrected estimates, and the standard error of the estimates.[2]

[2] The bias-corrected estimates correct for the fact that estimated efficiency scores are always larger than the true efficiencies for output-oriented efficiency scores. See KNEIP et al. (1998) on the statistical properties of DEA estimators.

A.4 The test for equality of structural and mean efficiencies of two sub-groups

SIMAR and ZELENYUK (2003) furthermore propose a statistical test for the equality of structural and mean efficiencies of two subgroups. The test is based on confidence intervals derived in the bootstrapping procedure. The test involves a pair-wise comparison of the structural and mean efficiencies of two sub-groups. Assuming that there are two sub-groups A and B,

$$H_0\text{: } \overline{TE^A} = \overline{TE^B} \qquad \text{is tested against } H_1\text{: } \quad \overline{TE^A} \neq \overline{TE^B}$$

It is then of interest, in how far the ratio $RD_{A,B} = \overline{TE^A} / \overline{TE^B}$ is different from unity. To infer about RD, its DEA estimator $R\hat{D}_{A,B} = \overline{T\hat{E}^A} / \overline{T\hat{E}^B}$ can be used, whose behaviour is mimicked by its bootstrap analogue. Accordingly, the null hypothesis of the equality of structural efficiencies of two sub-groups is rejected if the bootstrap confidence interval does not include unity.

A.5 DEA-model inputs and output

Table A-8: Inputs and output

Inputs	**Unit**
Labour	(hours)
Land	(ha)
Var. prod. costs	(€)
Capital	(€)
including: • Average annual costs of fixed assets • Interest on floating capital • Costs of service by contractors • Value milk quota	
Output	**Unit**
Total revenue	(€)
including: • Crops (+) • Sugar beets (+) • Rape seeds (+) • Protein plants (+) • Silage maize (-) • Intensive grassland (-) • Extensive permanent pasture (-) • Sows for piglet production (+) • Fattening pigs (+) • Beef cattle (+) • Suckler cows (+) • Dairy cows (+) • Turkeys (+) • Set-aside land (+) • Dispose of manure (-) • Take in manure (+) • Fine on livestock density exceeding 2.5 LU/ha (-) • Minimum management of grassland (+)	

In detail, capital input consists of the following components:

1. <u>Average annual costs of fixed assets</u>

$$AC = \sum_{k=1}^{K} AC_k \text{, where } AC_k = A_k \cdot \left(v \cdot \frac{q_{EK}^N (q_{EK} - 1)}{q_{EK}^N - 1} + (1 - v) \cdot \frac{q_{FK}^N (q_{FK} - 1)}{q_{FK}^N - 1} \right)$$

with: v : equity-finance share
$i_{FK} = 5.5\%$
$i_{EK} = 4\%$

2. <u>Value of milk quota</u>

Number of dairy cows times average milk yield times price of quota in period

3. <u>Agricultural services:</u> Costs of 1 ha services

4. <u>Interest on current assets:</u>

$$FC = \left(\sum_{i=1}^{M} x_i \cdot (c_i \cdot a_i) \right) \cdot i_{FK}$$

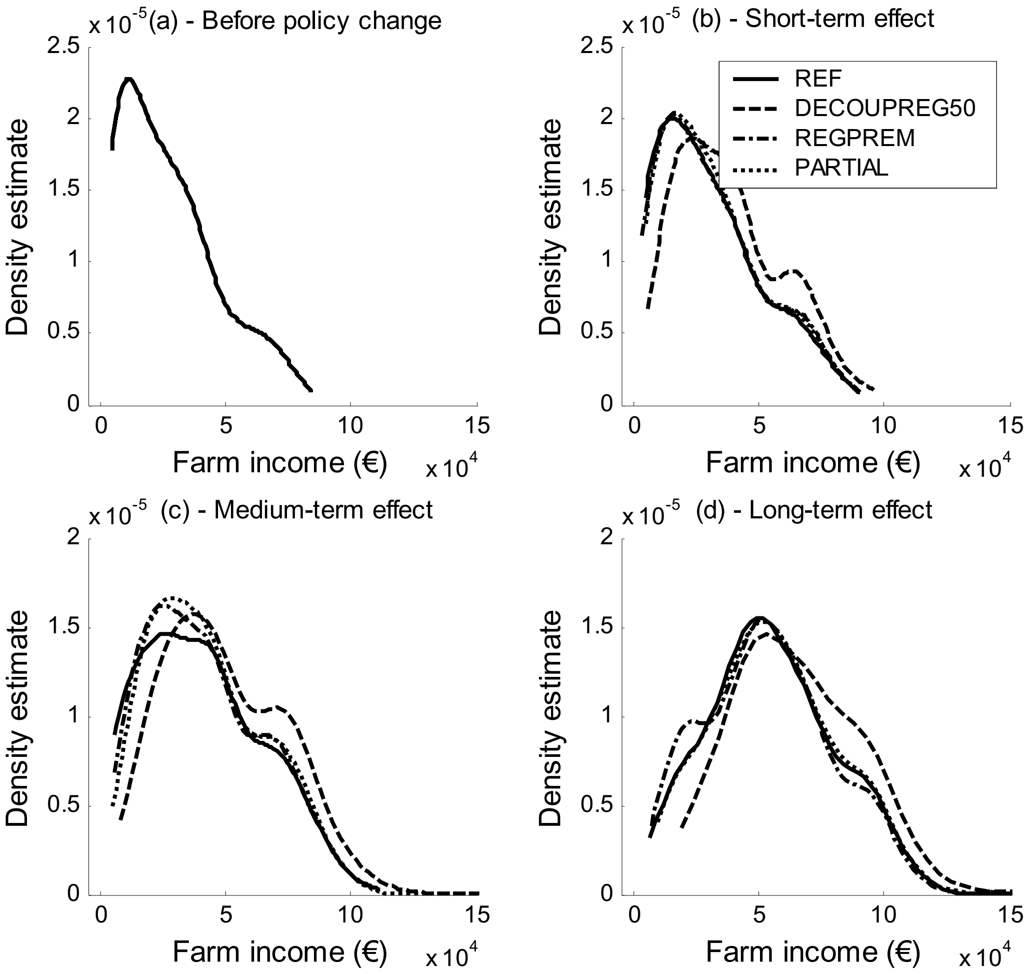
with: $i_{FK} = 5.5\%$
c_i : variable production costs of product i
a_i : bound capital of product i in time period t

A.6 Additional tables and figures of chapter 7 and chapter 8

Table A-9: Overview of farms leaving the sector between period 3 and period 24 differentiated by farm type and farm size in hectares

	REF	**RETPAY**	**PHASEOUT10**	**DECOUP**
Total number of farms leaving between t=3 and t=24…	**258**	**352**	**316**	**320**
…of which farms of type				
Spec. field crops	74	90	82	90
relative to total farms leaving	*28.7%*	*25.6%*	*25.9%*	*28.1%*
relative to all farms of type in t=3	*81.3%*	*98.9%*	*90.1%*	*98.9%*
Grazing livestock	38	63	41	49
relative to total farms leaving	*14.7%*	*17.9%*	*13.0%*	*15.3%*
relative to all farms of type in t=3	*55.9%*	*92.6%*	*60.3%*	*72.1%*
Spec. granivore	60	81	81	78
relative to total farms leaving	*23.3%*	*23.0%*	*25.6%*	*24.4%*
relative to all farms of type in t=3	*25.4%*	*34.3%*	*34.3%*	*33.1%*
Mixed farms	86	118	112	103
relative to total farms leaving	*33.3%*	*33.5%*	*35.4%*	*32.2%*
relative to all farms of type in t=3	*63.7%*	*87.4%*	*83.0%*	*76.3%*
…of which farms with size				
< 20 ha	175	204	195	205
relative	*67.83%*	*57.95%*	*61.71%*	*64.06%*
20-30 ha	36	46	45	41
relative	*13.95%*	*13.07%*	*14.24%*	*12.81%*
30-40 ha	28	55	37	38
relative	*10.85%*	*15.63%*	*11.71%*	*11.88%*
40-50 ha	16	35	30	29
relative	*6.20%*	*9.94%*	*9.49%*	*9.06%*
> 50 ha	3	12	9	7
relative	*1.16%*	*3.41%*	*2.85%*	*2.19%*

Figure A-1: Kernel density estimates of farm income for policy scenarios REF, DECOUPREG50, REGRPEM, and PARTIAL at four time periods

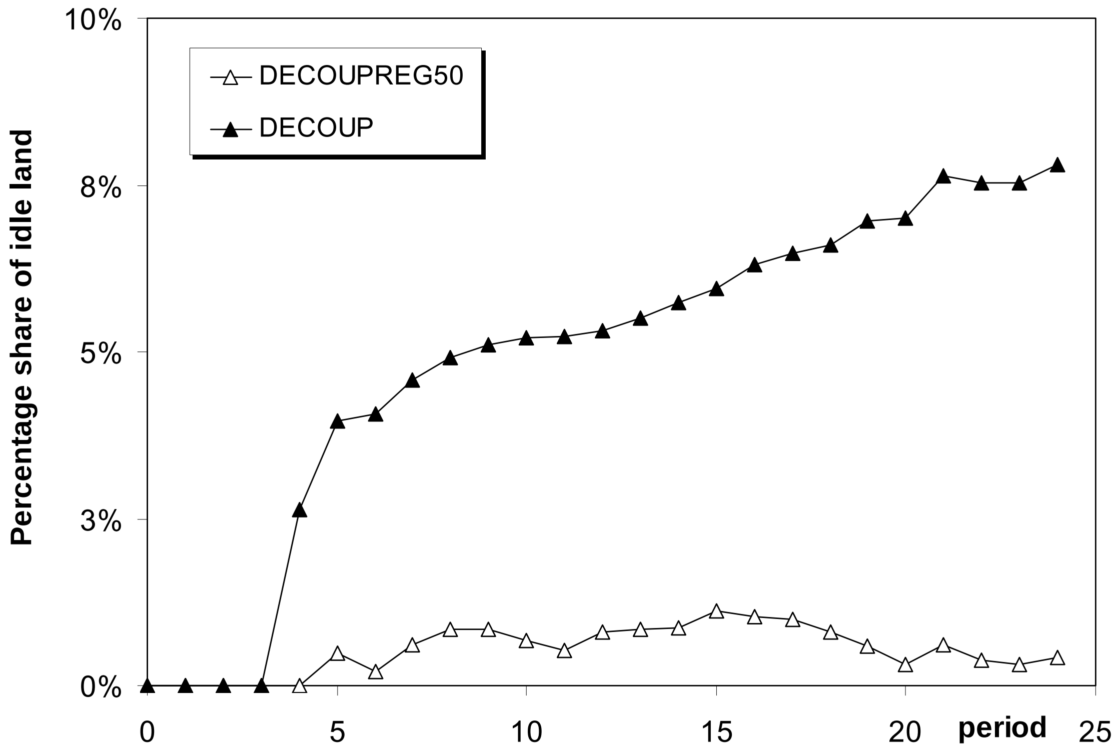


Source: Own calculations.

A.7 Ensuring the management of agricultural area

As Figure A-2 shows, a low regional per hectare payment leads to a significant decrease in idle land. A payment of 50 €/ha (scenario DECOUPREG50) ensured that almost all land in the region was farmed despite of the sharp decrease of cattle and dairy cow production that came about with decoupled direct payments (see chapter 7).

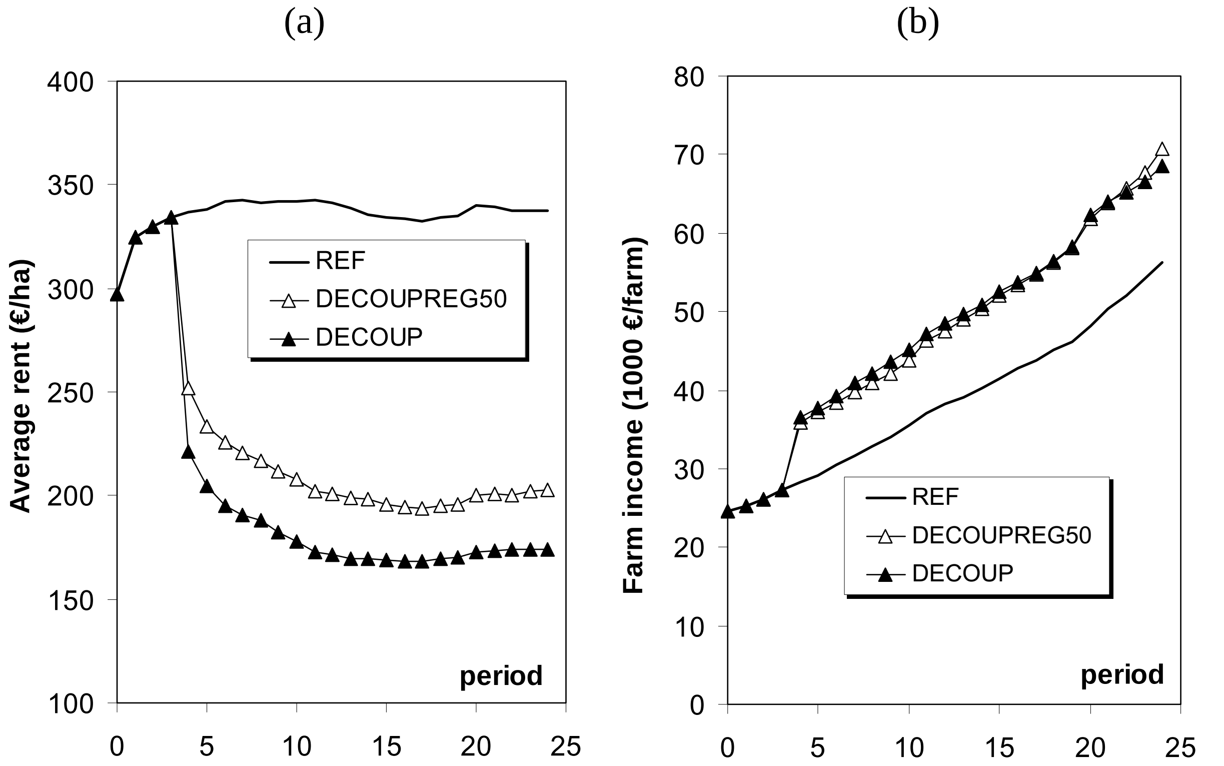
Figure A-2: Evolution of percentage share of idle farmland



Source: Own calculations.

Since the area payment is uniform across all plots in the region, i.e. it is paid for grassland and arable land alike, the payment transfers into higher shadow prices of land (Figure A-3 (b)) and therefore higher rental prices of land. Approximately, 60% (approximately 30 €) of the area payment was transferred into a higher rental price, as the difference between the two curves in Figure A-3 (b) shows. Nevertheless, on average higher rental prices do not lead to significant income losses (Figure A-3 (a)). It can be explained by a slightly increasing share of suckler cow production, which is less capital intensive compared to intensive livestock production.

Figure A-3: Evolution of (a) average rental prices for farmland and (b) average farm income.



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