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Effects of biogas production on inter- and in-farm competition

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Annotation: Biogas production is one of the influential innovations of recent decades in German agriculture. Due to high guaranteed energy prices biogas production led to distortions in agricultural and land markets. This paper provides insights in effects of biogas production on farms, farm structures and rural areas for the region Altmark, Germany, for the period 2012-2026 by using the agent-based simulation model AgriPoliS. AgriPoliS enables to simulate agricultural structural change and impacts of policies based on a linear programming approach. To maximize the household-income, farm agents can invest, produce and compete against each other on the land rental market. To analyse effects of biogas production, biogas plants, possible substrate mixtures and feed-in remunerations are introduced in the model. In our analyses, we focus on 1) the choice of production of farms, 2) the competition between farms, and 3) impacts on rural areas including environmental issues and labour market. Our simulation results show that biogas production provides especially for farmers with high management capabilities and large farms a profitable income opportunity. On average, biogas farms cannot increase their profitability. As result of an increased value added through biogas production and high competition among farms, rental prices increase and thus a high share of the value added is transferred to the land owners. Biogas production leads to an intensification of land use, especially to increases in cultivation of grass and maize silage instead of meadows and other crops, and in livestock production. This may cause negative environmental effects. On the other hand both, the intensification and the biogas production have positive effects on the labour market as biogas farms have an additional workforce demand.

Key words: biogas production, agricultural production, agent-based model AgriPoliS, land rental prices.

1 Introduction and Background

Biogas production is one of the most influential innovations of recent decades in German agriculture. Supported by guaranteed feed-in tariffs and priority connection to the electricity grid regulated by the Renewable Energy Sources Act (in German: Erneuerbare-Energien-Gesetz, EEG) (AEE, 2012a) farms were able to rapidly adapt to the new opportunities. Between 2006 and 2011 the total number of plants doubled while the capacity even increased to more than two-and-a-half times. In 2011, more than 7,000 biogas plants with an average plant capacity of 402 kW produced renewable energy in Germany (AEE, 2012).

Because of the guaranteed feed-in tariffs for 20 years, investments in biogas plants promise to be secure and very profitable for farmers, particularly if manure is available. On the other hand, the high profitability leads to new dynamics on land markets. Several studies show that the higher the biogas production in a region the stronger is the increase in land purchase and rental prices. For example, Braun, Lorleberg and Wacup (2007) found that biogas producers in North Rhine-Westfalia (West Germany) have a much higher willingness to pay for arable land and especially grazing land than food producing farmers. Kilian et al. (2008) find that high shares of biogas production led to higher rental prices in Bavaria. Habermann and Breustedt (2011) detect differences of impacts of biogas production between West and East Germany. They examine in their spatial econometric analysis that “agricultural biogas production, measured as the share of acreage cultivated with energy crops, increases the rental rates in Western Germany significantly” (Habermann and Breustedt, 2011), but that does not hold for Eastern Germany. Habermann and Breustedt explain the insignificance in East Germany by referring to the average larger size of East German farms, which causes less

pressure to rent land for growing biogas substrates. In a more recent study, Hüttel et al. (2012) demonstrate that biogas production measured in kW per sub-district has a significant positive impact on sales prices of auctioned land in Saxony-Anhalt, East Germany. As an interim summary, effects of biogas production on land rental markets may vary for different regions and farm sizes. Nevertheless, increases in rental prices might be at least partly driven by biogas producers as they need feed for their biogas plants and are able to bid high prices for land because of the high guaranteed feed-in tariffs. Finally, biogas production may also lead to a different production structure of farms. Feed and food production are increasingly displaced by renewable energy crops such as maize and ley. Furthermore manure is a cheap co-substrate, but it needs cattle and therefore also feed.

Besides many effects on agricultural structures and developments, also rural areas are affected by the new dynamics. On the one hand, biogas producing farms can serve as an employer in rural areas and, furthermore, the newly created biogas branch generates jobs for selling, building and maintaining biogas plants (O'Sullivan et al., 2012). On the other hand, monocultures, ploughing-up of grassland to grow maize, and increasing traffic (transport of substrates and digestates) might affect the environment and the living conditions of rural inhabitants.

While impacts of biogas production on land markets and, thus, farm competition with regard to rental prices have been analysed in the past, impacts on farm competition and cultivation with focus on East German agriculture are underrepresented. The present paper seeks to fill this gap by studying impacts of biogas production in the East German region Altmark. The Altmark region is one of 25 selected German bioenergy regions ('Bioenergieregionen', BMELV, 2012a) because it offers a huge potential of biomass from several sectors. Among them is the agricultural sector with a high proportion of specialized dairy farms and grassland.

The present paper analyses in the first place impacts of biogas production on agriculture. The focus is on three aspects: Firstly, on the competitiveness of production activities within a farm (we call this in-farm competition), secondly on the competitiveness of farms within a region (we call this inter-farm competition) and thirdly on the impact of biogas production on rural areas, including environmental issues and labour markets. Different to other studies we use in our analysis an agent-based simulation model, namely AgriPoliS, which enables simulation of agricultural structural change and the impact of policies on agriculture. The simulation results enable to examine in-farm competition by comparing revenue shares of production branches, as well as cultivation sizes and livestock keeping. Besides, we analyse profits of biogas and non-biogas farms, rental prices for arable and grazing land as well as farm size developments which represent the inter-farm competition. The cultivation size of different crops, number of animals and the annual working units employed on farms provide information about the impact of biogas production on rural development, environment and labour market.

The paper proceeds as follows. The next section introduces the agent-based model AgriPoliS together with the case study region Altmark. In section 3 simulation results for a time period of 15 years are analysed and discussed. The paper ends with conclusions in section 4.

2 Methodological approach and case study region

To analyse the impact of biogas production we use the agent-based model AgriPoliS (Agricultural Policy Simulator, e.g. Happe et al., 2006). In this chapter we describe the model features and the study region Altmark in East Germany.

2.1 The agent-based model AgriPoliS

AgriPoliS is an agent-based model which enables to simulate regional agricultural structures and their developments over time in response to different policies (see Happe, 2004; Happe et

al. 2008, Sahrbacher et al. 2012). A detailed documentation of the current version can be found in Kellermann et al. (2008), and a protocol following the ODD standard (Overview, Design concepts and Details) is available in Sahrbacher et al. (2012a).

In AgriPoliS a number of individual agents acts and also interacts in an environment which maps agriculturally related regional and structural characteristics. First, the region has to be initialised by adapting the model to the real region. This happens on two levels. On the one hand, statistical data about regional agriculture and data of individual farms (usually data from the farm accountancy data network (FADN)) are used to map the regional characteristics of agriculture regarding number of farms, farm types and farm orientations, amount of arable and grazing land, number of livestock in the region, size classes in hectares and number of livestock per farm. In a programming approach based on the method of Balmann, Lotze and Noleppa (1998) and further developed by Sahrbacher (2003), typical farms are identified from a large number of individual farms. By minimizing the deviation between the sum of the weighted characteristics of individual farm types and the overall characteristics of the region, it is determined how often the different farm types should be weighted to map this region as accurately as possible. Apart from a farm's factor endowment and size, farms differ in the management skills, which influence the variable costs of production processes, and in the age of machinery, buildings. The management skills and the ages are varied randomly to ensure heterogeneity among agents.

On the other hand, the organization, i.e. possible production processes and investments, of the selected typical farms is projected by adapting model farms to the selected real farms. Therefore, a linear programming model is built, in which the selected typical farms' data on factor endowments (quota, facilities, labour, capital, land, etc.) is incorporated. Furthermore, various production and investment alternatives are entered, from which the farms can choose to optimally utilize their factor endowments. All options must be typical for the region and are calibrated such that in the beginning of each simulation, the derived model farms choose nearly the same production processes as the real farms they represent. For the different types of production, each farm can choose between a number of investment alternatives of different size to capture size effects due to decreasing investment costs and labour requirements per unit.

Besides deciding on products and investments, farms can also extend their capacities by renting agricultural land, buying production quotas, and employing workers. Furthermore, capital can be borrowed on a short- and long-term basis. In contrast, capacities can be set free, e.g., land rental contracts can expire, quotas can be rented out, hired labour can be dismissed or family workers can be employed outside the farm. Furthermore, liquid assets may be invested outside the farm. All decisions on production, investment and redundancy of capacities are based on a one period mixed-integer programming. In case of renting land farms compete for free land via an auction on the land rental market. Generally, it is assumed that each farm operates independently to maximize its individual household income or profit in case of legal persons. The resulting decision behaviour of the agents is rational, but myopic. Strategic decisions considering future changes in the technical and economical conditions are currently not included in the model. Farms are assumed to expect constant environmental conditions for future periods and adjust their price expectations adaptively from period to period. Policy changes are anticipated one period in advance and included in the decision.

Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

2.2 Case study region

The case study region is the Altmark region with its two districts Stendal and Altmarkkreis Salzwedel. The Altmark is located in the German Federal State of Saxony-Anhalt, approx. 50-150 km west of Berlin. In this structurally weak region, agriculture is of high importance for the rural development. By offering jobs to 6 % of employed people, farms are considerable employers, especially because income opportunities outside the farms are scarce and the unemployment rate is above 10 %. Bioenergy production could save existing and create new jobs. Altmark is, not only therefore, a predestined region to study effects of biogas production on farms and rural areas. Being characterized by large arable farms as well as large mixed farms with livestock, Altmark is a good representative of East German agricultural regions. The importance of livestock production is emphasized by the fact that around 40 % of the dairy cows and 53 % of the specialised dairy farms in Saxony-Anhalt were located in Altmark in 2007. The proportion of grassland is comparatively high (nearly 27 %).

Since 2009 the Altmark is one of 25 so-called bioenergy regions (BMELV, 2012a) in Germany because it offers a huge potential of biomass from several sectors. In the long run, one aim of this initiative is to generate regional value added by the extension of bioenergy production to support sustainable developments of rural areas (Regionale Planungsgemeinschaft Altmark, 2012). With a high proportion of specialized dairy farms and grass land, agriculture provides many possible usages of biomass for energy production, e.g. biogas. Many farms already invested in biogas production in recent years: in 2010 a total number of 65 biogas plants produced energy, whereof 26 were owned by regional investors, mainly farmers or agricultural cooperatives. Besides many positive synergy effects of biogas production regarding, e.g., energy recovery in local households there are also critical voices in society concerning the building of biogas plants. In a SWOT analysis of the “bioenergy-region Altmark“, Regionalverein Altmark e.V. (2008) mentioned acceptance problems in the public as well as conflicts, fears or resistance on local level which may prevent the implementation of bioenergy projects. However, there is less potential for conflicts in the field of biogas compared to other areas of renewable energies such as wind power plants. Despite all prejudices and reservations against bioenergy, there have not been any serious conflicts in the Altmark so far. Problems with existing biogas plants have only concerned individual cases. But from the perspective of nature and environmental protection, there are more and more critical arguments against further extension of bioenergy, such as negative effects due to ploughing up of grassland, cultivation of agricultural monocultures and increasing pressure on the use of sensitive areas (cf. Regionalverein Altmark e.V., 2008).

2.3 Modelling Altmark region in AgriPoliS

To capture the regional agricultural structure as good as possible, typical farms for the representation and their weights have to be identified as described in section 2.1. Therefore, most recent available statistics on regional agricultural characteristics (e.g. number of farms, livestock, farm size classes etc.) and FADN data of regional farms are used (cf. Balmann et al., 2010). Because agricultural statistics were last available for 2007, we also used FADN data for 2006/07 and start simulations in 2006. The up-scaling procedure resulted in 33 typical farms which represent with their weights 968 model farms. The 968 farms differ in their type of farm, available capacities, management capabilities, which influence their variable costs, and in the age of machinery and buildings.

Model farms are able to produce crops and livestock. The assumptions for those different production processes come from data bases of contribution margins of crops (LLFG, 2009) as well as feed and livestock (MLUV, 2008). The reference year to which the region is calibrated is the financial year 2006/07.

Focus of this paper is biogas production. Thus, biogas production is introduced in the model. Farms can choose between different options of plant sizes and substrate mixtures. Overall, three plant capacities (150, 450, 800 kW), and three mixtures with different shares of maize and grass silage, liquid cattle manure, and rye grain are offered. Table 1 shows the assumptions on the biogas plants with their revenues from feed-in tariffs, the investment and calculated substrate costs as well as the needed working time to operate the plant. The investments costs per kW are assumed to decrease with increasing plant size. Investment and production data for biogas production were taken from KTBL (2010); the guaranteed feed-in remuneration, consisting of a basic payment and bonuses, is based on the EEG 2009 and 2012 (BMJ, 2008, 2010 and 2011).

Table 1. Assumptions on biogas production from 2012 to 2026

	150 kW	450 kW	800 kW
Feed-in tariff in 1,000 Euro/year (dep. on mix)	208-213	544-579	935-992
Investment costs in Euro	850.000	1.825.000	2.650.000
Investment costs in Euro/kW	5.667	4.056	3.313
Calculated substrate costs in 1,000 Euro/kW (w/o costs for manure)	74 -92	202-256	341-431
working hours (dep. on mix)	894-1.064	1.344-1.581	1.839-2.227

Source: Own assumptions according to BMJ (2011), KTBL (2010).

In reality the basic remuneration is oriented towards the time of building of the biogas plant. Accordingly, a plant built later receives lower basic feed-in tariffs. For simplification we did not consider such a dynamic depression of feed-in tariffs. Background is that in reality not only remuneration would decrease but it can also be assumed that investment costs decrease because of efficiencies, e.g., by up to 5 % according to Prognos AG (2010). Therefore, we assume constant remunerations during the period 2012 to 2026 according the EEG 2012. Both, the decreasing investment costs and degressive remuneration would in reality more or less neutralize each other. Furthermore, we have not implemented a minimum use of lost heat so far.

Table 2. Assumptions on substrate mixtures from 2012 to 2026

	Mix 1	Mix 2	Mix 3
Maize silage	20 %	60 %	20 %
Grass silage	20 %	10 %	20 %
Whole-crop-silage	-	-	40 %
Cattle manure	60 %	30 %	-
Rye grain	-	-	20 %

Source: Own assumptions according to Grundmann et al. (2006), KTBL (2010).

In reality the Renewable Energy Sources Act changed in 2012. This is considered in the model as well. From 2006 to 2012 the former EEG 2009 is applied, from 2012 assumptions shown in Tables 1 and 2 are considered. The main difference of the EEG 2012 to the EEG 2009 lies in the allowed shares of substrates. In 2012 a maximum limit of 60 % of maize silage, corncob mix and grain kernel was introduced. This limitation is also used in the model

as can be seen in Table 2. From 2012 on, farms can choose between three mixtures to produce biogas. With Mix 3 it is even possible to operate a biogas plant without cattle manure. More common in reality is the use of manure and maize silage (see Mix 1 and Mix 2).

To illustrate the effects of biogas production, we compare a biogas scenario with a reference scenario. In the reference scenario farms cannot invest in biogas plants while in the biogas scenario biogas production is available. In both scenarios, farms have the same conditions apart from the availability to invest in biogas plants in the biogas scenario. No model farm has been given a biogas plant as capacity in the beginning of simulations, i.e. in 2006, because the most substantial growth began first in 2005/06 after the EEG was revised and statistical data about existing biogas plants in the Altmark region in 2006 were not available.

3 Results and Discussion

As illustrated above, biogas production offers both threats and opportunities for farms and has impacts on land markets as well as on the cultural landscape. We analyse impacts of biogas production on farms and the rural area in the Altmark region while focusing on three aspects: 1) the choice of production of farms, 2) the competition for land between farms, and 3) impacts on environment and labour market. With the agent-based model AgriPoliS we simulate two scenarios: the biogas scenario and the reference scenario. Simulations start in calendar year 2006. Our analyses were made for the period 2012 to 2026.

3.1 In-farm competition

Before we present results regarding the choice of production of farms, we introduce characteristics of biogas and non-biogas model farms in 2012 (Table 3).

In general, not every farmer is able to invest in a biogas plant. Size, management capability and resources such as capital and labour are prerequisites to invest and succeed. Because biogas production is a knowledge-intensive and demanding business, farmers need high management capabilities to be successful in this production branch. Thus, only model farms with a high management capability invest in biogas plants. On average, model farms which invest in biogas have due to higher management skills ca. 1.8 % less variable costs in all production processes, i.e. also in biogas production, while all other farms only save ca. 0.8 % on average in 2012.¹ Biogas farms are on average also larger than non-biogas farms. In terms of European size units (ESU) biogas farms are nearly ten times as large as other farms. The farm size in ha is 3.7 times higher, they keep much more cattle, and have because of their size more equity capital.

In the biogas scenario in 2012, 108 of the 741 model farms (i.e. 14.6 %) own 282 biogas plants with a total capacity of 45 MW. That means every biogas producing farm owns on average 2.6 biogas plants in the model with an average installed capacity of 160 kW per plant or 416 kW per farm. Compared to reality, model farms invest in more but smaller biogas plants. This is due to the fact that model farms can neither choose intermediate sizes, e.g., between 150 and 450 kW nor cooperate and share facilities. Furthermore, model farms do not have the opportunity to buy substrates from other farms yet. Therefore, model farms' sizes are mostly too small to invest in larger plants. The smallest farm which invests in a biogas plant manages 290 ha and 240 dairy cows plus offspring.

¹ The reduced variable costs result from a farm specific management factor. During the initialization of a simulation, every farm is assigned a randomly chosen management factor between 0.8 and 1.2. According to this management factors the variable costs of every production activity are proportionally increased or decreased. The fact that on average the management factor in 2012 is less than 1.0 is based on the endogenous structural change between the initialization of the model for 2006 and 2012. I.e., that in general farms with poor management factors (>1) exit earlier than those with high management skills (<1).

Nevertheless, the results fit to real observations regarding the total installed capacity per farm and for the whole region. For example in 2011 farms produce 40.95 MW in the model while real production resulted in 41 MW in the Altmark region (2011 is the latest available data; LLFG, 2011). Average plant capacity per model farm in 2011 amounted 369 kW; in Germany it reached at the same time 402 kW on average.

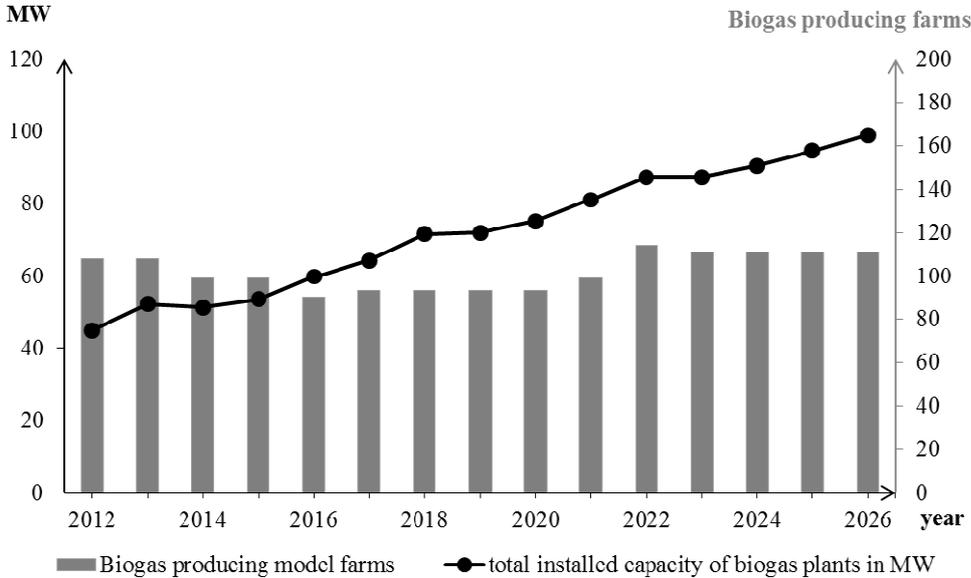
Table 3. Characteristics of biogas and non-biogas farms in the biogas scenario 2012

Characteristics	Biogas Farms	Non-biogas Farms
Number of farms	108	633
Average farm size in ha	996	272
Average farm size in ESU*	661	69
Variable cost saving due to management capability	1.78 %	0.84 %
Number of cattle	500	29
Equity capital in EUR	1,133,071	235,320

* ESU means European size units, one ESU equals to 1,200 Euro standard gross margins.

Source: Own simulation results from AgriPoliS.

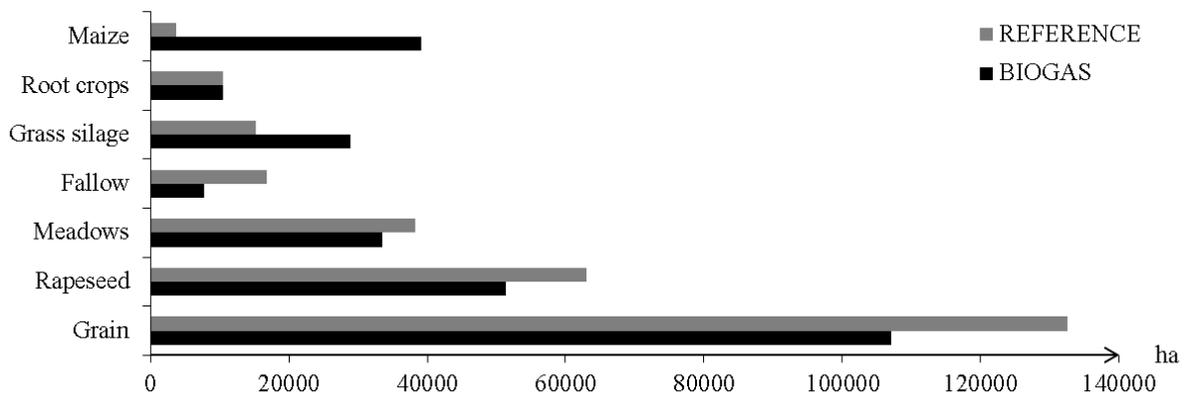
Figure 1 shows the further development of plants and their total installed capacity between 2012 and 2026 in the model. Accordingly, model results support expectations that biogas production will increase further, in particular due to a rise in the installed capacity per farm. During the simulations, farms grow because others quit farming. This offers potentials to invest in larger plants (450 to 800 kW) as well. The almost stable number of plants, while at the same time increasing installed capacity, indicates rising plant sizes. Starting in 2012 with an average installed capacity of 416 kW, biogas farms increase their capacities to 943 kW per farm in 2026.



Source: Own simulation results from AgriPoliS.

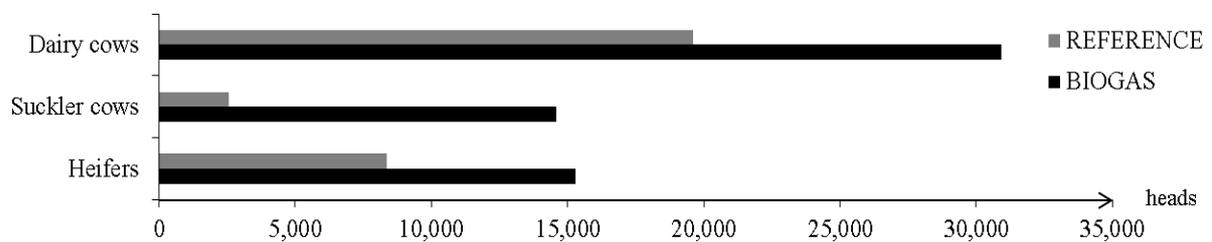
Fig. 1. Number of biogas producing farms and their installed capacity in megawatt in the biogas scenario, 2012-2026 (model results)

Due to these developments the structure of the farms' production changed. According to Brendel (2011) one megawatt electrical power requires about 550 ha of energy crops. Furthermore, the cultivation of energy maize needs much grassland as well as fallow and abandoned land (Brendel, 2011). The simulation results support this. The amount of fallow land decreases and cultivation of maize increases (see Fig. 2). Furthermore, the use of grassland is intensified as the usage changes from meadows to grass silage. Only the increase in suckler cows hinders a stronger decrease of meadows and even higher intensification. But grass and maize silage are not only cultivated for direct use in the biogas plants. To use liquid manure for bioenergy production, more cows are kept in the biogas scenario (see Fig. 3) and demand grass and maize for feed as well. Also Ehrenstein et al. (2012) see this connection: Because maize is predominantly cultivated as feed, livestock may contribute significantly to the maize production.



Source: Own simulation results from AgriPoliS.

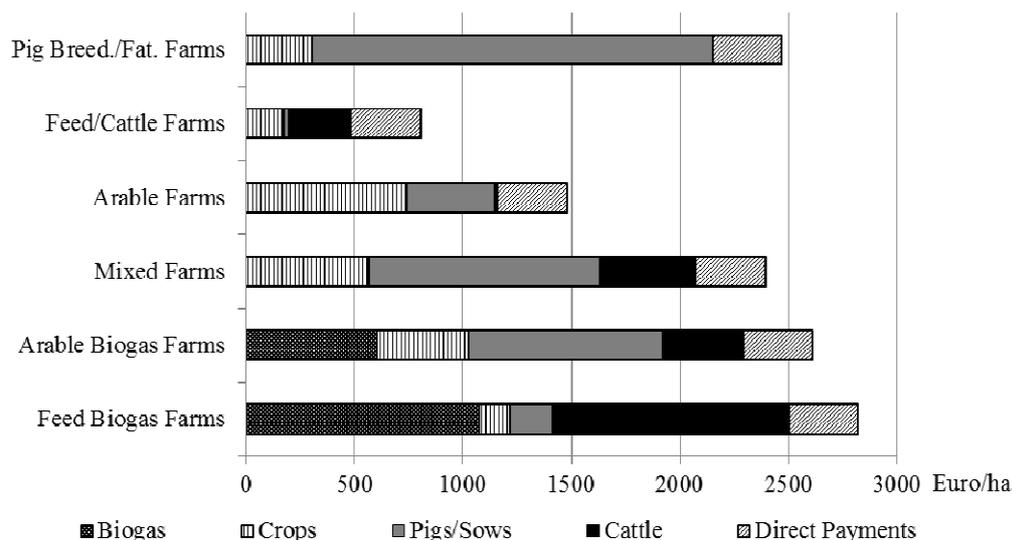
Fig. 2. Cultivation size of different crop types in the reference and biogas scenario, 2020 (model results)



Source: Own simulation results from AgriPoliS.

Fig. 3. Number of cows and heifers in the reference and biogas scenario, 2020 (model results)

Biogas producing farms do not only change their production because of the demand of the biogas plant but also increase their dependency from biogas revenues. Fig. 4 shows the composition of average revenue per ha of various farm types in the biogas scenario. At first it can be shown that revenue per ha differs highly between farm types: feed/cattle farms have with 809 Euro/ha on average the lowest, feed farms with biogas production (feed biogas farms) with an average 2,821 Euro/ha the highest revenue. Interesting is, furthermore, the contribution of the farm branches to the revenue. While pig breeding/fattening farms and arable farms receive their main revenues from their special fields, feed/cattle farms are highly dependent on direct payments. Compared to feed farms without biogas production, feed biogas farms have high revenues in cattle production and additionally the revenues from biogas production. They are far less dependent on direct payments. All other biogas farms (arable biogas farms) have on average absolute higher revenues than non-biogas producers. Furthermore, the dependency on revenues from crop and pig production of arable biogas farms is reduced while biogas production contributes 28 % to total revenues of those farms.



Source: Own simulation results from AgriPoliS.

Note: Feed biogas farms are feed farms with biogas production, arable biogas farms are mixed, arable or pig breeding/fattening farms with biogas production. As can be seen the other farm types do not produce biogas.

Fig. 4. Composition of revenue of different farm types in Euro per hectare in the biogas scenario, averages 2012-2026 (model results)

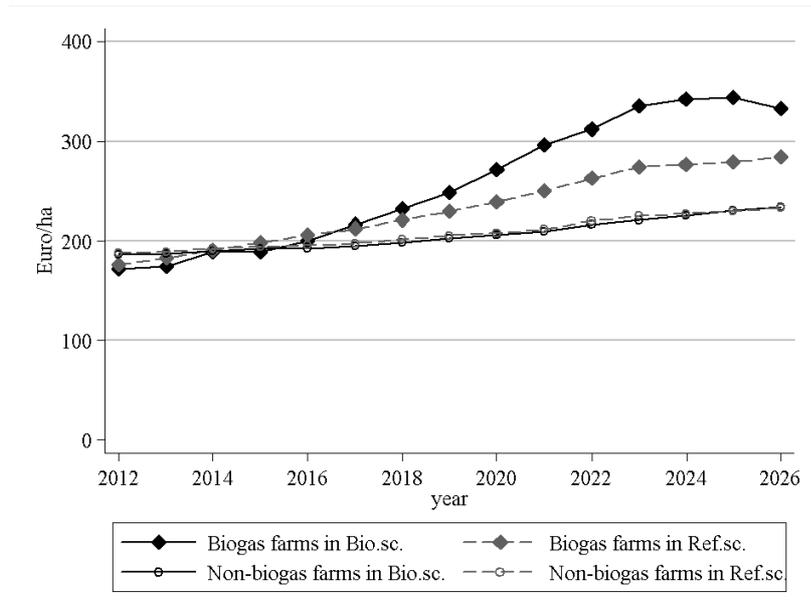
Summing up, farms with biogas production gain a main part of revenues from this new branch. Not only revenues absolutely increase in biogas producing farms, also the composition of total revenue changes on average compared to similar farm types such that biogas production takes over a big part of revenue contribution.

Overall, biogas affects the in-farm competition of the different branches significantly. Because of the complementarity, biogas production offers synergies for cattle production, but at the same time there are competitive effects for other production activities which are substituted. Due to the fact that land is scarce and the biogas plant has to be fed constantly with maize and/or grass silage, a biogas farmer has to reorient his production to the crops which deliver more biomass per ha to avoid feed bottlenecks. That results in both, reality and model to intensification: fallow land and extensive use of grassland decrease while maize cropping and production of grass silage increase.

3.2 Inter-farm competition

Biogas plants have to be fed with energy crops (maize and grass silage) and manure from livestock which also needs feed. Thus, biogas farms need land. At the same time, the total amount of land is limited and can only in rare cases be expanded in Germany. Thus, biogas increases competition for land and land (rental) prices might rise. Furthermore, biogas farms are not only heavily dependent on land, they may also have above average management capabilities (i.e. lower variable production costs) and receive high remuneration payments for delivered energy. Hüttl (2012) stated that because of the high feed-in remuneration for electricity from biogas, in some places the food production oriented agriculture is already displaced by the new energy producers. According to Brendel (2011) these high remunerations cause that traditional farmers may lose rental contracts after expiring to biomass plant operators because the latter can offer higher prices per hectare.

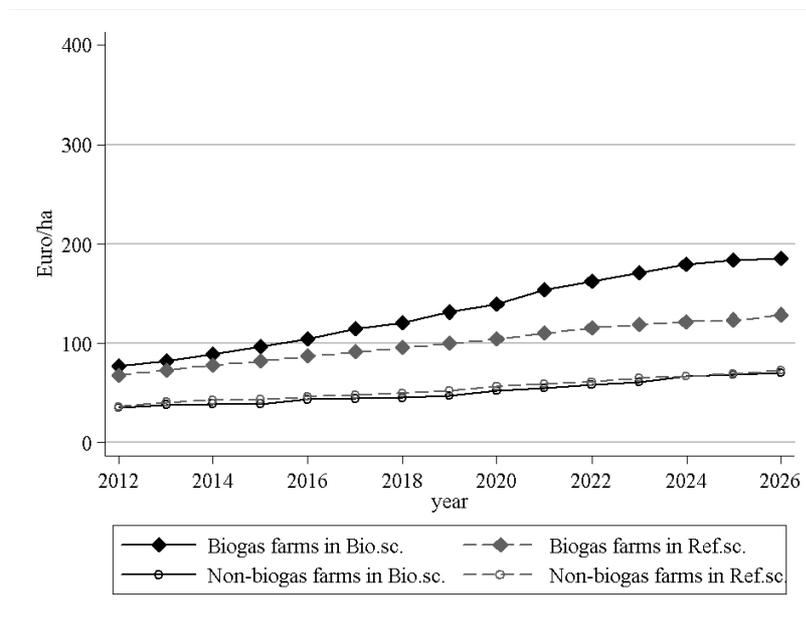
Our simulation results confirm the advantage of biogas producers: the average rental prices for rented arable and grazing land of those farms which produce biogas in the biogas scenario are higher in the biogas scenario than in the reference scenario (Fig. 5 and 6). At the same time non-biogas farms have to pay in both scenarios nearly the same (see Fig. 6).



Note: Biogas farms in Bio. sc.: average rental price for rented arable land of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented arable land of farms in the reference scenario which invest in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenarios.

Source: Own simulation results from AgriPoliS.

Fig. 5. Average rental prices for rented arable land in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, reference and biogas scenario (model results)



Note: Biogas farms in Bio. sc.: average rental price for rented grassland of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented grassland of farms in the reference scenario which invest in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenarios

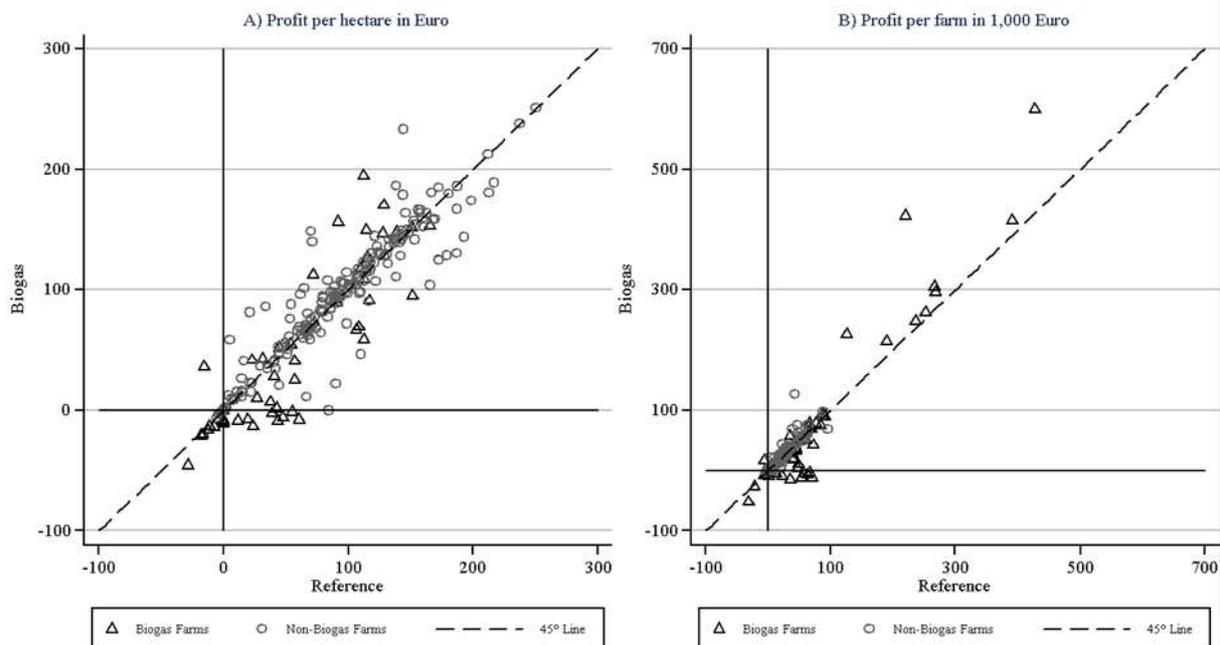
Source: Own simulation results from AgriPoliS.

Fig. 6. Average rental prices for rented grassland in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, reference and biogas scenario (model results)

Furthermore, Fig. 5 particularly shows that prices for rented arable land of biogas farms are also higher in the reference scenario. I.e., farms which invest in biogas production have in

both scenarios a higher ability to pay more for land – and these farms also have higher management capabilities (cp. Table 3). Therefore, part of the increase in the rental prices must be independent from the development of biogas production. The management capabilities to save variable costs play a role as well. During simulations less successful farms exit and more and more farms with better management capabilities remain in the sector and grow. The ability of good managers as well as of farms which exploit economies of size allows paying higher prices for land and leads in both scenarios to increased rental prices of their farms.

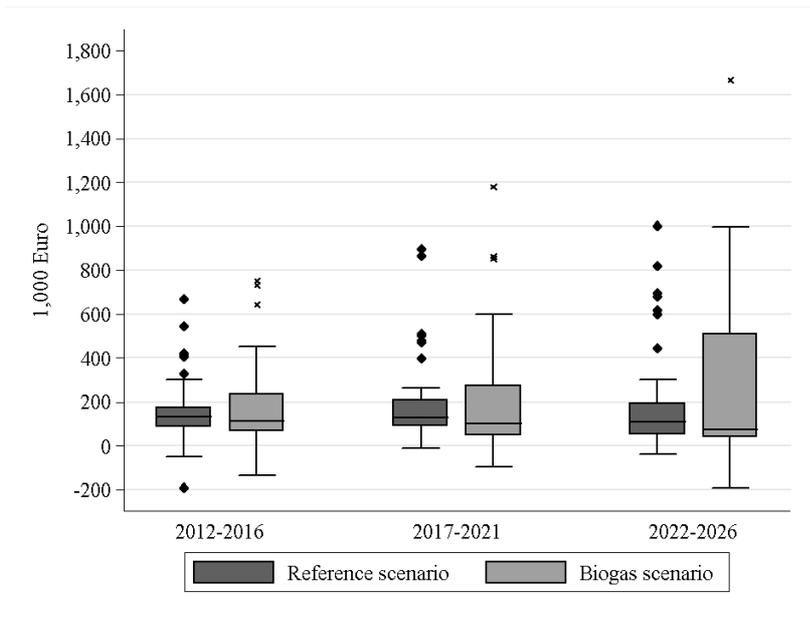
In general, rental prices for land have an impact on the resulting profits of a farm. The more money is forwarded to the land owners, the less money remains for the farmer. Indeed, our simulation results show that some biogas producing farms can increase their average profits between 2012 and 2026 compared to the reference scenario (see Fig. 7). Those benefitting biogas farmers have generally better management capabilities and are larger in hectare size than less successful biogas producers. However, Figure 7 shows as well, that not all biogas farms benefit. Quite some biogas farms lose profits. In comparison to biogas farmers who gain in the biogas scenario, the losing biogas farmers have on average lower management capabilities and are smaller. After investing in a biogas plant they are highly dependent on land to produce substrates for feeding the biogas plant. Because of the high competition for land and the resulting increases in rental prices, these biogas farms lose their initial advantage from biogas. This finding is also supported by Figure 8. Accordingly, the variance of the biogas farms' profits increases significantly compared to the same farms' profits in the reference scenario. This means that competition diminishes the potential profits of biogas very quickly. Only those farms with a real comparative advantage benefit while other investors even lose.



Note: A) The first scatterplot shows average profits per hectare of single biogas and non-biogas farms between 2012 and 2026. Farms which are on the 45° line perform equally well in both scenarios. Farms underneath the 45° line benefit in the reference scenario, farms above the 45° line benefit in the biogas scenario. B) The second scatterplot shows the average profit per farm of single biogas and non-biogas farms between 2012 and 2026 in 1,000 Euro.

Source: Own simulation results from AgriPoliS.

Fig. 7. Average profit A) per hectare and B) per farm of surviving farms between 2012 and 2026 in the reference and biogas scenario (model results)

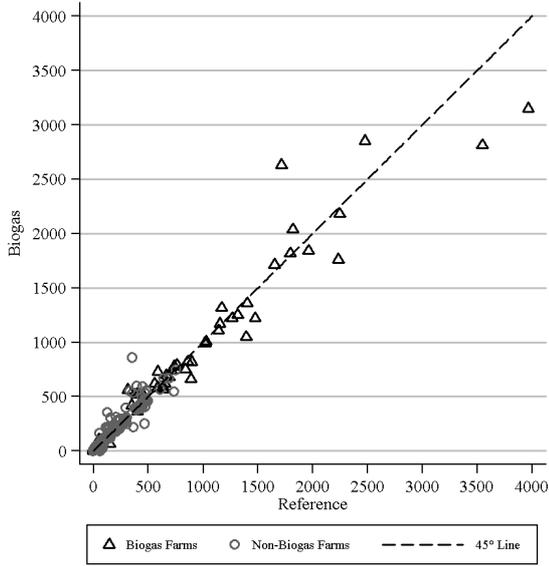


Note: Only biogas farms are considered, i.e. farms which invest in farms in the biogas scenario in biogas plants (they do not produce biogas in the reference scenario).

Source: Own simulation results from AgriPoliS.

Fig. 8. Distribution of average total profits per biogas farm in 1,000 Euro in the time periods 2012-2016, 2017-2021 and 2022-2026, reference and biogas scenario (model results)

Interestingly, Figure 7 shows for the non-biogas farms in contrast no clear disadvantage in the biogas scenario. Some of them even increase their profits per ha as well as on the farm level. However, in general, total profits of surviving biogas farms are much higher (between two and six hundred thousand Euros per farm). This applies also to farm size. Biogas farms have more land than non-biogas farms (cp. Fig. 9).



Note: Average farm size in hectare of single farms between 2012 and 2026. Farms which are on the 45° degree line have equal size in both scenarios. Farms underneath the 45° line are larger in the reference scenario, farms above the 45° line farm more hectares in the biogas scenario.

Source: Own simulation results from AgriPoliS.

Fig. 9. Average farm size of surviving biogas and non-biogas farms between 2012 and 2026 in the reference and biogas scenario (model results)

Fig. 9 also shows that all farms with more than 1,000 ha produce biogas. One explanation for that is that a minimum size is needed to be able to feed a biogas plant with enough substrates. Only large farms have enough capital and resources to build and feed biogas plants. Another important aspect is the better management skills of the biogas farms which allow them to have lower variable costs also in biogas production compared to non-biogas farms. Once invested, biogas farms have the potential to grow faster than other farms because they generate additional money with biogas production and bid higher rents on the land market. The model results show that indeed farms with biogas production grow in the biogas scenario by ca. 77.5 % to 1,484 ha between 2006 and 2026 while non-biogas farms can increase their size on average by ca. 46 % up to ca. 275 ha on average. However, in both scenarios the speed of growth of both farm types is rather similar. In the reference scenario farms which invested in biogas production in the biogas scenario grow by ca. 77 % up to 1,479 ha on average and the other farms by ca. 38.5 % up to 261 ha on average. Obviously, biogas farms do not only compete with non-biogas farms but rather with other biogas-farms. This finding may be specific for Eastern German conditions, where about 45 % of the land is farmed by farms larger than 1,000 ha and some further 23 % by farms with more than 500 ha (BMELV 2012).

In the following, we analyse the stability of farms using the equity ratio to compare the risk of insolvency of biogas and non-biogas farms. A high share of equity can help to cover losses and survive in low price periods. On the other side it should be considered that a reduction of the equity ratio and a simultaneous increase of profits lead to a rise in return of equity (leverage effect). In general, the farms which invest in biogas plants during simulations have a lower equity ratio than other farms in both scenarios. That means biogas farms are less stable than other farms. Biogas farms even worsen their stability when investing in a biogas plant: they have an even lower equity ratio in the biogas scenario than in the reference scenario (cp. Table 4), where the same farms are not able to invest in a biogas plant. That comes as no surprise, given the fact that the investment costs are very high and require a large amount of loan capital. Although biogas farms have a lower stability, farm exits of biogas producers are up to 2024 less often in the biogas scenario than in the reference scenario².

Table 4. Equity share and return of equity of biogas farms in the reference and biogas scenario (model results)

	Scenario	2012	2016	2020	2024
Equity ratio in %	Biogas	35.0	37.9	38.6	39.5
	Reference	49.1	53.7	58.8	61.4
Return of equity in %	Biogas	12.3	14.1	11.1	5.3
	Reference	14.5	14.3	13.3	9.5

Note: Biogas farms in the reference scenario are those farms which invest in biogas plants in the biogas scenario (they do not produce biogas in the reference scenario).

Source: Own simulation results from AgriPoliS.

As mentioned before, borrowing capital offers possibilities to increase the return of equity when a farmer can increase profits as well. In contrast, the simulation results show that biogas farms are on average not able to increase their profitability in the biogas scenario compared to the reference scenario. This holds also regarding the return of equity (Table 4).

Summing up, biogas farms are highly dependent on how successful they manage their biogas plants. The potential benefits of high feed-in tariffs result in strong competition among farms. As a result, biogas producing farms pay on average higher rents, they increase the amount of

² In the years 2024 and 2025 three more biogas farms each and in 2026 six more biogas farms exit the sector in the biogas scenario compared to the reference scenario. Exit reasons of those farms are illiquidity in 2024 and 2026, and opportunity costs in 2025.

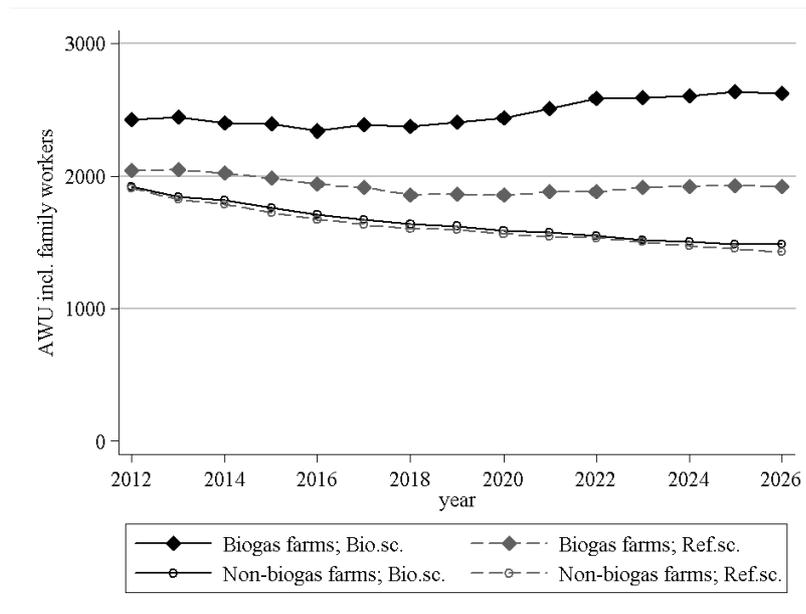
debt capital and have to pay interest for these debts. Thus, instability of biogas farms in the biogas scenario is higher. Nevertheless, biogas production is not the only driver for increasing rental prices and changes in farm size. In the end, the management capabilities of a farm play a major role. Only good managers can operate a biogas plant successfully, i.e. only they succeed to generate higher profits on average than in the reference scenario. Moreover, the comparative advantage of biogas within the farms' production opportunities has a strong impact regarding the question whether a farm benefits from biogas compared to a scenario without this opportunity.

3.3 Impacts on rural area, environment and labour market

Until now, we discussed the impact of biogas production on farm level and inter farm relations. But there is also a lively public discussion on how biogas production affects rural areas and the environment. Some argue that biogas leads to a critical rise of the share of maize within the crop rotation: Succow (2011) even calls this a serious maldevelopment in biomass utilization. 'Maize encourages erosion, destroys the soil fertility and humus, requires a lot of pesticides and artificial fertilizer, in addition it provides habitat only for few organisms' (Succow, 2011). The increase of maize cropping is also supported by our simulation results (cf. Fig. 2). While in reference scenario farms produce mainly rapeseed and grain and feed their livestock with meadow grass farms intensify their cultivation in the biogas scenario while producing more maize and grass silage. Another effect of biogas production is that idle land is partly brought into production. To sum up, biogas production leads regionally to an intensification of production from meadows and grain to maize and grass silage. Besides the maize cultivation also livestock is growing, because biogas provides an additional income for feed farms as the by-products can be utilized. Fig. 3 shows the increase in livestock. A vicious circle seems to establish: On the one hand, the proportion of maize increases because silage is used as substrate for the biogas plant. On the other hand, biogas production provides additional incentives for livestock production because of the synergies (i.e. manure use). This rise in livestock again drives the demand for maize silage. However, Karpenstein-Machan and Weber (2010) state that a narrowing crop rotation is not a new, bioenergy specific problem: 'Due to specialization and intensification of agriculture since 1980 and the focusing on only a few economically interesting and marketable products, the appreciation of healthy crop rotation and the observance of principles of crop rotation has apparently become less important' (Karpenstein-Machan and Weber, 2010: 312-313).

Not only crop rotation is affected. As already mentioned, more fallow land is used. By reducing fallow land, large scale habitats are harmed and connecting habitat structures for wildlife and plants are lost (Brendel, 2011). But there are also arguments for a positive environmental effect of biogas production: Biogas production has advantages for the use of manure. It not only enables a carbon cycle management because after fermentation the digestate can be used as fertilizer, moreover, the digestate has higher nitrogen availability and a lower aggressiveness than raw manure (Fulton et al., 2011).

Another fact is that biogas production influences the rural development. In Saxony-Anhalt, 1.5 % of employees already work in the field of renewable energy production, whereof the bioenergy sector became the third largest employer after wind and solar energy (Ulrich et al., 2012). Therefore, biogas production can ensure regional incomes as well as employment and promotes the development of rural areas (Fulton et al., 2011). The increase of agricultural employees is also shown in our simulation results (cp. Fig. 10). Accordingly, the biogas scenario leads to an increased employment of 10 to 22 %, partly because of more cattle-based and intensified production. Especially biogas farms employ on average up to 37 % more annual working units (AWU) in the biogas scenario than in the reference scenario.



Note: Biogas farms in Bio. sc.: average rental price for rented grassland of biogas farms in the biogas scenario, Biogas farms in Ref. sc.: average rental price for rented grassland of farms in the reference scenario which invest in the biogas scenario in biogas (they do not produce biogas in the reference scenario); same for non-biogas farms in biogas and reference scenario.

Source: Own simulation results from AgriPoliS.

Fig. 10. Total number of annual working units (AWU) in biogas and non-biogas farms including family workers between 2012 and 2026 (model results)

With regard to the effect on the employment in the whole rural area (besides agriculture), Berenz et al. (2007) mention an important aspect. In their model calculations it is shown that dairy farming has a much higher area-based effect on employment than biogas production. Extending the observation to the downstream areas these differences in labor input are even growing. ‘The biogas plant produces electricity, a salable product, which requires hardly any jobs in the downstream area. By contrast, dairy products and animals for slaughter have still to be processed much further to become finally a salable good’ (Berenz et al., 2007: 10). Conclusions on environmental aspects cannot be drawn directly. But it can be said that employment of workers in agriculture, number of livestock and the number of land under usage increase. Therefore biogas production can contribute to the development of rural areas as it provides income opportunities for farmers as well as job opportunities. On the other hand, it may imply environmental risks due to an intensified agriculture.

4 Conclusions

We analysed impacts of biogas production regarding the production choice of farms, the competition between farms, and impacts on rural areas including environmental and employment effects. The analysis is based on the agent-based model AgriPoliS which enables to simulate regional agricultural structures and their developments over time. Our case study region is the Altmark region in East Germany because this region is characterized by significant biomass potentials and a high degree of rurality. Agriculture has a considerable share in employment and, thus, agricultural developments may strongly affect the regional development. For the analysis two scenarios are compared: In a biogas scenario it is assumed that farms can invest in a highly subsidized biogas production, while in the reference scenario biogas investments are not possible.

Our analyses showed that on the farm level biogas production provides especially for large farms and with high management skills a profitable income opportunity. Biogas farms gain a

main part of revenues from this new branch. Not only revenues absolutely increase, also the composition of total revenue changes such that biogas production takes over a significant part of revenue contribution. It implies an increasing dependency of the whole farm on their biogas plant(s). Furthermore, the whole production structure of a farm changes. Our simulation results have shown that biogas production leads to an intensification of land use, especially to an increase in cultivation of grass silage instead of meadows, maize instead of other crops and to an increase in livestock production. The proportion of maize increases because silage is used as substrate for the biogas plant and as feed in cattle keeping. In general, biogas production provides additional incentives for livestock production because of the synergies (i.e. manure use). As result of an increased value added through biogas production and high competition among farms, rental prices increase. This may be a threat particularly for biogas farms which are smaller and have less management capabilities. On average, biogas farms do not increase their profitability, while the variance of the biogas farms' profits is significantly higher. The main reason for these effects can be seen in the fact that a significant share of the value added is transferred via increased rental prices to the land owners. These rental prices are driven by the marginal land rents of the most efficient biogas farms.

Looking at the impacts of biogas production outside agriculture we find that the implementation of biogas plants can offer new employment potentials in biogas production as well as livestock keeping. Therefore biogas production can contribute to the development of rural areas as it provides income opportunities for farmers as well as job opportunities. But biogas production also causes public concerns regarding the impact on the environment. The detected intensification in the agricultural production may imply environmental risks.

Summing up, we conclude that biogas production provides opportunities especially for larger farms with high management capabilities and for employment in rural areas. It can be a profitable option in times of increasing uncertainty and volatility of agricultural prices due to globalization of the EU agricultural markets.

The development in the bioenergy market is policy driven. Therefore, the market conditions and developments are distorted as the demand for biogas is raised artificially through the guaranteed feed-in tariffs. Long-term effects are difficult to be estimated exactly. As we have shown in our simulation, biogas farms gain a main part of revenues from this new branch which means that also the dependency of farms on the biogas production, specifically on the guaranteed feed-in tariffs and therefore on political decisions is growing. Therefore, reservations and discussions exist on the side of the non-biogas farmers who fear for their (future) competitiveness particularly on the land market, as well as on the side of the biogas farmers who are concerned about the stability of political decisions. This is embedded in a public discussion on impacts of biogas production on environment and quality of life in rural areas.

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