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Effects of the German Renewable Energy Act on structural change in agriculture – The case of biogas

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ABSTRACT

The strong political support for biogas production in Germany over the past decade has greatly affected agricultural production, farms and land markets. This paper analyzes the effects of Germany's biogas policies on agricultural development by using the agent-based simulation model AgriPoliS. Particular focus is placed on the effects of the previous German Renewable Energy Act (REA, German "EEG") of 2012, as well as the latest amendments, which were added in 2014. Our results show that under the previous REA and its predecessors, biogas production provided an attractive investment opportunity, especially for large farms, which led to a boost in biogas production. However, this policy also caused distortions within the agricultural sector, including increasing land rental prices. These effects particularly threatened farms that were not able to invest in biogas, as well as smaller biogas farms. On average, biogas farms could not increase their profitability. The main reason for this effect can be seen in the fact that a significant share of the value added is transferred via increased rental prices to land owners. The amendment of the REA in 2014, which reduced support levels substantially, partly attenuates some of these effects, though the previous policy will cast a long shadow.

1. Introduction and background

Biogas production can be considered one of the most influential innovations in German agriculture in recent decades. Farms' adoption of biogas production jumped after the Renewable Energy Sources Act (REA)[1] was introduced in 2004. Guaranteed feed-in tariffs (which mean a guaranteed price for the delivered electricity) for a period of 20 years and priority access to the electricity grid provided strong incentives for farmers to invest in biogas plants (AEE, 2012). Prior to 2004, biogas played only a minor role in German agriculture, but after the REA was established, both the number of biogas plants and the average plant capacity increased. Particularly between 2006 and 2011, the total number of plants doubled and the total capacity increased by more than 150%. In 2013, more than 7850 biogas plants with a total capacity of 3543 MW produced renewable energy in Germany (Fachverband Biogas, 2014); this has implications on the structure of German agriculture. About 85% of these plants are operated by farmers, and most feedstuff used in biogas plants is based on agricultural produce (Fachverband Biogas, 2015).

In general, agricultural structural change involves multiple and interlinked drivers that affect farm sizes, production patterns and farm capacities, as well as the economic and social situation of farms (cf. Goddard et al., 1993; Balmann et al., 2006). The renewable energy policies on the national level in Germany, i.e. the guaranteed feed-in tariffs for biogas production, also have strong implications for farms and farm structures. Several empirical studies found that the higher the biogas production in a region, the stronger was the increase in land purchase and rental prices (Braun et al., 2007; Kilian et al., 2008; Habermann and Breustedt, 2011; Hüttel et al., 2012). This is because biogas producers need substrates to feed their biogas plants; key feed stuffs are silage from maize, other cereals and grasses. To produce the necessary amount of biomass, an appropriate amount of land is required either by the farms or by farms in the region that provide the feedstuff. Although biogas plants are usually planned and built according to the available feedstock, the lifetime of the plants exceeds the duration of rental contracts. Therefore, farms with biogas plants have to ensure access to land rental contracts via high bids. In addition to the effects on the land market, biogas production also affects the composition of regional production. Fodder production for livestock and food

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[1] REA: Renewable Energy Act; in German: Erneuerbare-Energien-Gesetz (EEG).

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production is argued to be increasingly displaced by renewable energy crops such as maize and ley (cf. Agrarheute, 2013; KLU, 2013). On the other hand, livestock production on biogas farms partly benefits from biogas investments because since 2009 the use of manure as a complementary co-substrate has been highly subsidized (REA, 2008).

Concerns regarding their future development perspectives exist on the side of farms that are either not willing or not able to invest in biogas production. These farms fear for their (future) competiveness, particularly on the land market (cf. Deutschlandfunk, 2013; Spiegel, 2010). On the other hand, biogas farmers are concerned about the stability of political decisions (cf. Hemmerling, 2013; taz 2015). Furthermore, electricity prices for private households and smaller firms increased significantly (cf. Editorial, this issue). The Renewable Energy Act was amended several times since 2000 (see Editorial, same issue). The latest change introduced in 2014, resulted in a substantial reduction of the guaranteed feed-in tariffs.

While the impacts of biogas production on land markets and land prices have been analyzed in the past, other aspects of structural change such as impacts on farm performance and cultivation patterns have hardly been analyzed. The present paper seeks to fill this gap by studying the long-term impacts of renewable energy policy and subsequently biogas production on two German regions, namely the Altmark in Eastern Germany and the Ostallgäu (East Allgäu) in Southern Germany, which have very different farm structures. Nevertheless, both regions have an agricultural sector with a high proportion of specialized dairy farms and grassland, and therefore have sources of biomass from several sectors, including manure.

As we focus on the farm level as well as on the regional level, we concentrate on the following aspects: the investment behavior of farms regarding biogas production; the effects of biogas production on structural change; regional cultivation patterns; the land market; and on the overall performance of farms. Contrary to previous studies focusing on empirical land market data, we use an agent-based simulation model, namely AgriPoliS. This spatially explicit and dynamic agent-based model enables ex post and ex ante analyses of agricultural structural change, particularly regarding the impact of alternative policies and assumptions on agriculture by comparing actual policies with counterfactual assumptions. Policy impacts that can be analyzed include shares of different crops, profits of biogas and non-biogas farms, rental prices for arable and grazing land, as well as farm size developments. As far as possible, simulation results are validated by comparing them with empirical observations. As the majority of biogas plants are operated by farmers (Fachverband Biogas, 2015), biogas production of non-agricultural investors is not considered in the model simulations, though these investments also affect agricultural production and land markets.

The paper proceeds as follows. The next section introduces the agent-based model AgriPoliS, together with the case study regions Altmark and East Allgäu. In section 3, simulation results for a time period of 12 years are analyzed, while section 4 provides discussion and conclusions.

2. Methodological approach and case study region

To analyze 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's features and the study regions.

2.1. The agent-based model AgriPoliS

AgriPoliS is an agent-based spatial model that enables one to simulate the development of regional agricultural structures over time in response to alternative scenarios such as specific policies (see Happe, 2004; Happe et al., 2008; Sahrbacher et al., 2012a; Balmann, 1997). A detailed documentation of the current version can be found in Kellermann et al. (2008). A protocol following the ODD standard (Overview, Design concepts and Details) is available in Sahrbacher et al. (2012b).

In AgriPoliS, a number of individual agents represent farms that interact in a synthetic landscape that maps agriculturally related regional and structural characteristics. AgriPolis is adapted to selected regions by specifying farm types that are typical for that region and which are weighted to match regional characteristics. Apart from the farms' initial factor endowment and size, the different farm types are differentiated in a stratification process during the initialization of a model run. According to the weight of the farm types, a proportional number of farm agents are randomly distributed in the spatial grid of land plots and initialized with individual management skills (i.e. different variable production costs) and ages of the farmer and farm assets.

The farms are assumed to maximize profits or household income by use of a mixed-integer programming model that is linked to the selected farm agents' data on factor endowments (facilities, labor, capital, land, management quality, etc.), as well as the various production and investment alternatives from which the farms can choose to maximize their profit. The provided investment and production activities can be considered as typical for the region and are calibrated such that in the beginning of each simulation, the derived farm agents choose the same or similar production activities as the real farms they represent.

Besides deciding on products and investments, farms can also extend their capacities by renting additional agricultural land and employing workers. Furthermore, capital can be borrowed on a short- and long-term basis. In contrast, capacities can be reduced, e.g., land rental contracts can expire, quotas can be rented out, hired labor can be dismissed and family workers can be employed outside of the farm. Furthermore, liquid assets may be invested outside the farm. In case of renting land, farms compete for available land (i.e. land that is currently not rented) via a repeated auction. Within the auction, every farmer first selects the available plot that is most valuable to the farm and then calculates a bid for this plot. Every farm's bid equals a specific proportion (e.g. 80%) of the marginal gross margin of this additional plot. The bid considers transportation costs that are assumed to be proportional to the distance between plot and farm. The farm with the highest bid receives the plot and is able to use it for a specific contract length (cf. Kellermann et al., 2008, p. 28 ff.). Afterwards, all farms can again submit bids that are compared again. This procedure continues as long as land is available. Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

2.2. Case study regions

The first case study region is the Altmark, which is located in the north of the German Federal State of Saxony-Anhalt, approx. 50–150 km west of Berlin, and comprises the two districts Stendal and Altmarkkreis Salzwedel. Being characterized by large arable farms, as well as large mixed farms with livestock, the Altmark captures important features of East German agriculture (see Table 1). The relative importance of livestock production is emphasized by the fact that as of 2007, some 40% of the dairy cows and 53% of the specialized dairy farms in Saxony-Anhalt were located in the Altmark, though the region covers only 23% of the

Table 1
Characteristic indicators of the study regions.

	Altmark	East Allgäu
Number of farms	957	1057
Average farm size in ha UAA/farm[a]	278	26
Number of dairy cows/dairy farm	178	30
Share of grassland in %	27	>90

[a] UAA: utilizable agricultural area.
Source: StaLa (2008, 2014), Bayrisches Landesamt für Statistik und Datenverarbeitung (2011).

state's utilizable agricultural area (UAA) (StaLa, 2008 and StaLa, 2014). Farms are predominantly organized as legal entities, full- and part-time family farms, as well as partnerships. Although legal entities that are usually either limited liabilities or production co-operatives only account for some 10% of the farms, they use almost 45% of the UAA.

The other study region is located in the district of Ostallgäu (East Allgäu) in the south of Bavaria. The landscape structure of mainly pre-Alpine terrain is bounded on the south by the Allgäu Alps. This region is also relatively homogeneous in terms of geographic and climatic conditions. With a high share of grassland (almost no arable land), this region is particularly suitable for dairy production. The East Allgäu is predominated by small and more homogeneous family farms with less than 30 ha. Overall in 2007, the 27,117 ha UAA in the selected municipalities were maintained by 1057 farms; 844 of them hold a total of 25,499 dairy cows (Bayrisches Landesamt für Statistik und Datenverarbeitung, 2011). Beef cattle and suckler cows are less common, and there is hardly any other livestock in the study area.

Both study regions are suitable for biogas production. Since 2009, the Altmark has been assigned as one of 25 so-called bio-energy regions (BMELV, 2012) in Germany because it offers a huge potential of biomass from several sectors. In the long run, one aim of the bioenergy regions initiative is to generate regional value added by extending bioenergy production to support the sustainable development of rural areas (Regionale Planungsgemeinschaft Altmark, 2012). With a high proportion of specialized dairy farms and grass land, agriculture provides biomass for energy production, e.g. biogas. Many farms have invested in biogas production in recent years: in 2012, a total of 107 biogas plants produced 364 GWh electrical energy (Landtag von Sachsen-Anhalt, 2014).

As a region focused on grassland and livestock, East Allgäu is also suitable for biogas production. The distribution of biogas plants in Bavaria (LFL, 2006) shows a significant investment concentration in the cattle-growing regions of Swabia and Allgäu, Bavaria Central Franconia and the Southeast. Currently, 74 biogas plants are operating in East Allgäu (LFL, 2014).

2.3. Modelling the regions in AgriPoliS[2]

To adapt AgriPoliS to the regional agricultural structure of the Altmark and East Allgäu, 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 of data availability and calibration purposes, the model was initialized for 2006 and simulations start in 2006. The adaptation procedure resulted in 33 typical farms for the Altmark, which are stratified according to their weights to 968 model farms. For the East Allgäu, 16 typical farms represent 962 model farms.

The model farms are able to produce cash crops and fodder from arable land (only in the Altmark), and feedstuff from grass and livestock. The assumptions for the different production processes are derived from publicly available data bases for crops (LLFG, 2009), as well as feed and livestock (MLUV, 2008; LFL, 2006 and 2014). For the initialization, i.e. the starting year of 2006, no model farm is assumed to be invested in biogas production. The reason is that statistical data about existing biogas plants for both regions in 2006 were not available. With regard to biogas production, starting in 2006, the model farms can invest in biogas plants of different sizes. For biogas production they can choose between different substrate mixtures. Table 2 shows the assumptions on the biogas plants regarding their revenues from feed-in tariffs, the investment and calculated substrate costs, as well as the working time required to operate the plant. The guaranteed feed-in remuneration, consisting of a basic payment and bonuses, are derived from the REA 2009 and 2012 (BMJ, 2008, 2010 and 2011). Overall, three plant sizes for each region (150, 450, 800 kW for Altmark and 70, 125, 200 kW for East Allgäu), and three mixtures with different shares of maize and grass silage, liquid cattle manure, and rye grain are offered. The plant sizes between which the farms can choose are adapted to the regional characteristics and are derived from data provided from KTBL (2010) and Grundmann et al. (2006). The investment costs per kW are assumed to decrease with increasing plant size, but are also regionally adjusted and calibrated in relation to other costs in the region so that the simulation results are assessed as realistic by stakeholders (Ostermeyer, 2015). Model farms can neither choose intermediate plant sizes, e.g. between 150 and 450 kW, nor cooperate and share facilities. In the East Allgäu region, farms have no access to arable land. The farms are, however, allowed to buy maize silage from outside the region. We assume fixed exogenous prices for maize silage, which probably underestimates that these substrate costs also rise because of substantial biogas investments. In the Altmark region, model farms do not have the opportunity to buy substrates from other farms. Local experts and farmers reported during stakeholder workshops in the Altmark that in general only non-agricultural investors buy their substrates from other farmers The biogas-producing farmers in the Altmark are assumed to have either sufficient arable land or can rent additional land to produce the required substrates by themselves (see Ostermeyer, 2015). As the activities of non-agricultural biogas producers are not considered, our analysis underestimates the indirect land market effects of biogas support.

According to the REA 2012 and its previous forms, the basic guaranteed feed-in tariff for new bioenergy plants declines over time. For simplification, we did not consider this dynamic degression of feed-in tariffs. This is to some extent balanced by ignoring the likely decrease in investment and production costs over time because of technological progress (cf. Prognos, 2010). Therefore, we assume constant remunerations (Table 2) during the 2013 to 2025 period according to the REA. Furthermore, we have not implemented the requirement that biogas operations require a minimum use of heat because there is no data available regarding the extent to which these could be used in the respective regions.

The REA has been reformed several times. These reforms are considered in a simplified way. For 2006 to 2011, the regulations of the REA 2009 (BMJ, 2010) are assumed to be valid. Starting in 2012, assumptions shown in Tables 1 and 2 are considered. The main difference between the REA 2012 and the REA 2009 affects the allowed shares of different substrate types. In 2012 a maximum limit of 60% of maize silage, corncob mix and grain kernel was introduced in the REA. This limitation is also used in the model (Table 3). Accordingly, from 2012 on, farms can choose between three mixtures to produce biogas. With Mix 3 it is possible to operate a biogas plant without cattle manure. More common in

[2] This section is based on Ostermeyer (2015) which contains a more detailed description of the implementation of the two model regions.

Table 2
Assumptions on biogas production from 2013 to 2025.

	Altmark			East Allgäu		
	150 kW	450 kW	800 kW	70 kW	125 kW	200 kW
Feed-in tariff in 1000 Euro/year (dep. on mix)	208–213	544–579	935–992	93–118	168–173	295–303
Feed-in tariff in 1000 Euro/year (REA 2014)	129[a]	401[a]	720[a]	55–111[a]	99[a]	161[a]
Investment costs in 1000 Euro	850	1825	2650	420	625	800
Investment costs in Euro/kW	5667	4056	3313	6000	5000	4000
Calculated substrate costs in 1000 Euro/year (w/o costs for manure)	66–99	198–277	351–476	35–50	59–85	93–131
Working hours (dep. on mix)	894–1064	1344–1581	1839–2227	623–642	709–738	819–862

[a] From 2014 in the REA 2014 scenario.
Source: Own assumptions according to BMJ (2011), KTBL (2010).

Table 3
Assumptions on substrate mixtures from 2013 to 2025.

	Altmark			East Allgäu		
	Mix 1	Mix 2	Mix 3	Mix 1	Mix 2	Mix 3
Cattle manure	60%	30%	–	80%	50%	45%
Maize silage	20%	60%	20%	10%	50%	20%
Grass silage	20%	10%	20%	10%	–	35%
Whole-crop-silage	–	–	40%	–	–	–
Rye grain	–	–	20%	–	–	–

Source: Ostermeyer (2015).

reality is the use of manure and maize silage (see Mix 1 and Mix 2). For validation of both model regions, as well as for the simulation of biogas production we used a participatory approach that included stakeholders (for more details see Ostermeyer, 2015, p 96 ff).

In our study, we compare two biogas scenarios with a reference scenario (REF). In the REF scenario, farms cannot invest in biogas plants at any time. This counterfactual scenario enables us to analyze how the model regions would have developed without the influence of the REA and biogas production; it thus serves as a benchmark to analyze the effects of biogas production. Biogas production is implemented in two scenarios, where model farmers can choose biogas production as an activity. In the REA 2014 scenario, the feed-in tariffs and conditions follow the REA 2012 from 2006 until 2013 for new investments. From 2014 onwards, the conditions of REA 2014 apply according to the latest amendment of the renewable energy act in 2014 (cf. Table 4). Other regulations such as the capping of the guaranteed payments for plants larger than 100 kW were not considered. The REA 2012 scenario contains a hypothetical continuation of the REA 2012 after 2014. Apart from these differences regarding biogas production, farms have the same conditions in all three scenarios.

3. Results

The analysis of biogas policy impacts focuses on the following aspects: Investments in biogas plants, structural change, changes in cultivation patterns, effects on land markets, and farm performance. To minimize random effects resulting from the initialization of AgriPoliS, each scenario is simulated 100 times. Simulations start for calendar year 2006, and our analyses consider the period 2013 as the last year before the reform of 2025.

For the analysis, we differentiate between “biogas farms” and “non-biogas farms”. Those farms that invest in biogas plants in the REA 2012 scenario are labeled “biogas farms” irrespective of their behavior in the other scenarios. Farms that do not invest in biogas plants in the REA 2012 scenario are labeled as “non-biogas farms”. These labels are applied for the same farms in the REF and REA 2014 scenario, irrespective of whether the farms invest in a biogas plant in these scenarios. In doing so we are able to analyze how biogas producers in the scenario REA 2012 would have developed without

Table 4
Comparison of scenarios and basis payments[a]) in ct/kWh.

			REF	REA 2012	REA 2014
	Possibility to invest in biogas plants		no	yes	Yes
		plant size			
2013 - 2014	Basis Payment in ct/kWh	75 kW		25.00*	25.00*
		150 kW		14.30	14.30
		500 kW		12.30	12.30
		5 MW		11.00	11.00
		20 MW		6.00	6.00
2014 - 2025	Basis Payment in ct/kWh	75 kW		25.00*	23.73*
		150 kW		14.30	13.66
		500 kW		12.30	11.78
		5 MW		11.00	10.55
		20 MW		6.00	5.85

* Minimum share of manure in the substrate mixture is 80% (manure bonus)
[a)] Bonus payments e.g. for Feedstock class I and II, and manure were not considered in the Simulation

Source: Juris (2014).

the opportunity to invest in biogas or under another political setting.

3.1. Investment in biogas

Only a fraction of the farms is able and willing to invest in a biogas plant. A certain farm size and sufficient financial resources are prerequisites for investments. Table 5 shows that biogas farms are on average substantially larger than non-biogas farms. In terms of European size units (ESU), biogas farms are nearly 1.8 times as large as other farms in the Altmark region. In the East Allgäu region they are even 2.5 times larger. In terms of farm size in ha, they are around 4 times (6 times in East Allgäu) larger, have a higher share of rented land, keep many more dairy cows, and have a higher equity capital.

In the “REA 2012” scenario, in 2013, 89 of the 709 model farms (i.e. 12.6%) in the Altmark region own a total of 184 biogas plants, with a total capacity of around 36 MW. Accordingly, biogas-producing farms have, on average, an installed capacity of around 405 kW. In the East Allgäu region there are far fewer biogas farms. Only 5 of the 917 model farms (0.5%) invest until 2013 in biogas plants, with a total capacity of 744 kW. The lower level of biogas production in the East Allgäu region is mainly due to the fact that the farms have only grassland and no arable land, and thus can neither cultivate maize as feed for their cattle, nor use it as a substrate for their biogas plants; they have to purchase maize silage.

Compared to reality, model farms invest in more but smaller biogas plants. This is because 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 (except for maize silage in the East Allgäu region). Therefore, most model farms are too small to invest in biogas plants. In 2013, the smallest farm that invests in a biogas plant in the Altmark manages 315 ha and 240 dairy cows, and in the East Allgäu 103 ha and 135 dairy cows. As a consequence, the simulation results underestimate the real investments systematically. For example in 2012, the installed capacity of the Altmark region was around 48 MW (Landtag von Sachsen-Anhalt, 2014), while in the model, in 2013 the plants have a total installed capacity of 36 MW.

For the period since the latest amendment of the renewable energy act in 2014, simulation results support expectations that biogas production would continue to increase if there would be no policy reform. A continuation of bioenergy support according to the REA 2012 would have offered substantial potentials for biogas farms to invest in more and even larger plants: in the Altmark, the number of some 90 biogas-producing farms remains stable, while the installed capacity increases. This indicates rising plant sizes. From 2013 with an average installed capacity of 405 kW, biogas farms increase their capacities to 892 kW per farm in 2025. In the East Allgäu region, the average installed capacity increases from 161 kW to 174 kW per farm, and the number of biogas-producing farms increases by almost a factor of 6 between 2013 and 2025 (Fig. 1). This means that farms need to reach a critical size first before they are able to invest in biogas.

According to our simulations, the REA 2014 stops the rapid expansion of biogas production in both study regions (cf. Fig. 1). In the Altmark, the number of biogas plants even declines slightly as some biogas farms exit in the REA 2014 scenario and no new investments in biogas plants are realized after 2013. The installed capacity for the whole region remains constant for several years due to the operational lifetime of the existing biogas plants. In the East Allgäu, the capacity increases after the reform slightly further due to a few additional investments. The reason is that in the East Allgäu there are still some investments in small plants that benefit from a specific manure bonus (cf. Table 4). Until 2025, the installed capacity only reaches 1.4 MW in the East Allgäu and even declines to 26.9 MW in the Altmark.

3.2. Structural change

Tables 5 and 6 show that in the Altmark, especially farms with more than 1000 ha invest in biogas production. Also in the East Allgäu, only larger farms have resources to invest in biogas plants. Once invested, biogas farms have the potential to grow faster than other farms because some of them generate additional profits with biogas production and offer higher rental prices on the land market.

The model results (Table 6) show that in the Altmark, farms with biogas production would grow in the REA 2012 scenario between 2013 and 2025 by some 38%, to 1636 ha, on average, while their number would increase by some 21% during the period 2013 taz, 2015. In contrast, non-biogas farms decline faster in total number as well as in average size compared to the REF scenario.

In the East Allgäu region, the biogas farms are also larger with an average farm size of about 170 ha in the REA scenarios, compared to non-biogas farms with 28 ha on average. Until 2025, the number of biogas farms would increase by 540%, while the average acreage of these biogas farms increases by only 14% to an average farm size of 194 ha in the REA 2012 scenario. Despite this growth in numbers and size, the overall share of biogas farms is much lower than in the Altmark. Accordingly, competition between the non-biogas farms is not as heavy as in the Altmark. In the REA 2012 scenario, 40% of the farms in the East Allgäu quit farming until 2025. In the REF scenario, the number of exits is slightly lower. Thus, in both regions, structural change is fostered by the biogas subsidies.

In both regions, the REA 2014 amendments affect structural change in terms of farm sizes and farm exits. While some farms that invested in biogas production before the introduction of the REA 2014 would grow less fast in the future, others may even grow faster (cf. Fig. 2). These farms benefit from the fact that after 2013, hardly any farm invests in biogas production, while they still receive the guaranteed high feed-in tariffs. In the East Allgäu

Table 5
Characteristics of biogas and non-biogas farms in the REA 2012 scenario 2013 (model results).

Characteristics	Altmark		East Allgäu	
	Biogas farms	Non-biogas farms	Biogas farms	Non-biogas farms
Number of farms	89	620	5	925
Average farm size in ha	1182	282	170	28
Average farm size in ESU[a]	655	76	355	31
Share of rented land (%)	93	82	76	29
Number of dairy cows	1048	48	488	92
Equity capital in EUR	1,268,139	272,679	1,097,237	361,940
Equity capital in EUR/ha	1073	967	6454	12,926

[a] ESU means European size units; one ESU equals 1200 Euro standard gross margins (SGM).

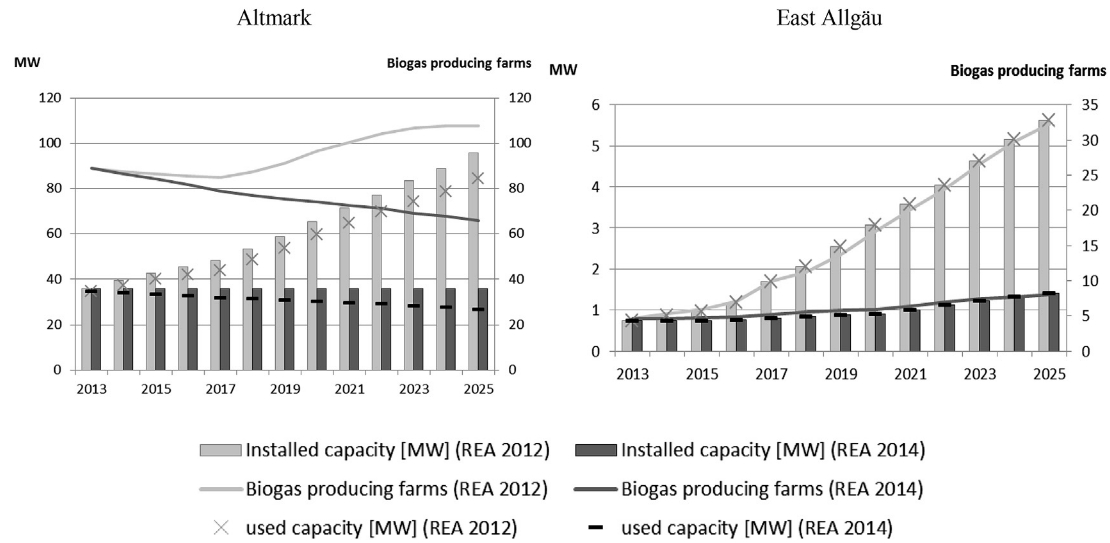

Fig. 1. Number of biogas-producing farms and their installed and used capacity in megawatts in the REA 2012 and REA 2014 scenarios, 2013–2025 (model results).

Table 6
Number of farms and farm sizes in the model regions, REF, REA 2012 and REA 2014 scenario (model results).

		Altmark				East Allgäu			
		Non-bio. farms		Biogas farms		Non-bio. farms		Biogas farms	
		Farms	Farm size[a]	Farms	Farm size[a]	Farms	Farm size[a]	Farms	Farm size[a]
2013	REF	627	273	87	1252	913	28	5	99
	REA 2012	620	282	89	1182	912	28	5	170
	REA 2014	620	282	89	1182	912	28	5	170
2025	REF	452	274	101	1545	543	43	32	84
	REA 2012	424	245	108	1636	519	38	32	194
	REA 2014	428	249	107	1624	533	41	32	140

Note: Biogas farms are those farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario); Non-Bio. Farms are those farms that do not invest in biogas plants in the REA 2012 scenario.
[a] Farm size in hectare UAA.

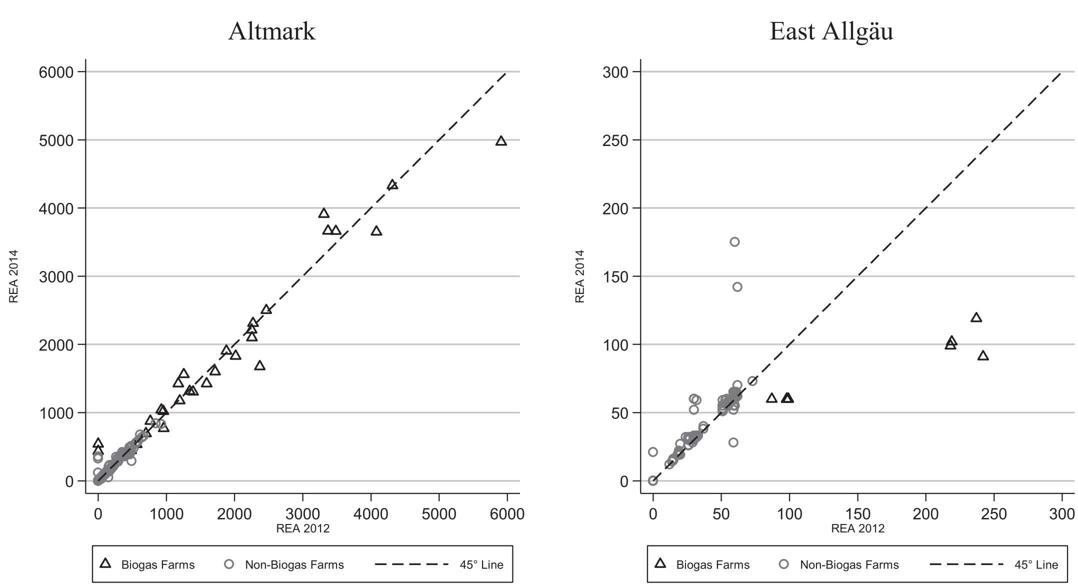

Fig. 2. Farm size of biogas and non-biogas farms in 2025, in the REA 2012 and REA 2014 scenarios (model results). Note: Farm size in hectares of single farms in 2025. Farms that are on the 45° degree line are equally sized in both scenarios. Farms underneath the 45° line are larger in the REA 2012 scenario, while farms above the 45° line farm more hectares in the REA 2014 scenario. Biogas farms are farms that produce biogas in the REA 2012 scenario.

region, a few larger biogas farms that would grow substantially in the REA 2012 scenario would not do so in the REA 2014. Vice versa, a few non-biogas farms may benefit in the REA 2014 because of higher relative competitiveness.

3.3. Cultivation

Due to biogas production, the farms' overall production structure changes. The amount of fallow land decreases and the cultivation of maize and other energy crops increases (cf. Fig. 3). Furthermore, the use of grassland is intensified as the usage changes from meadows to grass silage. Due to the lack of arable land in the East Allgäu region, there is only a minor intensification in the use of grassland, while the purchase of maize silage increases substantially. In 2013 this rate is doubled compared to the REF scenario. In total, the amount of purchased maize silage is rather small; its production requires arable land in an amount of only 0.4% of total UAA in the East Allgäu. Therefore, a significant impact of this demand for maize silage should not to be expected on the regional market and thus also not on the price.

Livestock production in the Altmark is positively affected in the REA 2012 scenario. Due to synergy effects of liquid manure for bioenergy production, more cows and cattle are kept in the biogas scenario. This means that the REA policy indirectly supports livestock production. Accordingly, the demand for grass and maize as feed for cattle increases in parallel. In East Allgäu there is no significant effect on regional production, neither in crop nor livestock production, until 2013. This is mainly due to the low level of biogas production in that region (only 0.5% of the farms in 2013).

The cultivation patterns are also affected by the REA reform in 2014 (Fig. 4). However, there is no straight adjustment towards the results of the REF situation. In the Altmark, the biogas investments before 2014 have a long-lasting effect because the assumed operational lifetime of biogas plants is 20 years and feed-in tariffs are fixed. Nevertheless, there are some adjustments. Fig. 4 shows that in the REA 2014 scenario, farms produce more cash crops while the area for maize, grass silage and other energy crops decreases. More land becomes fallow, and the stock of cattle declines. This is different for the East Allgäu because investments in biogas plants continue even under the REA 2014 conditions. The production structure in the REA 2014 very strongly resembles the REF situation. The only observable difference in the land use is a slight drop in meadows in favor of grass silage production. Accordingly, the 2014 amendments of the REA cause a partial re-adjustment towards the situation without the previous strong support of the REA 2012, though there remains a long-term effect.

3.4. Land market

AgriPoliS allows one to keep track of the rents paid by single farms or specific groups of farms. Table 7 shows that in general, biogas support causes higher and increasing rental prices. There are only a few exceptions for 2013 that may be seen as outliers. Moreover, Table 7 shows that biogas farms pay substantially higher land rental prices than non-biogas farms. Obviously, biogas farms are also more competitive if they cannot invest in biogas. The reasons for this can be seen in economies of size, as well as in a superior management coefficient, i.e. producing at lower variable costs than the average. Vice versa, the relatively low level of rents paid by non-biogas farms is mainly because these farms are less competitive in the land auction and rarely get new rental contracts.

In the East Allgäu region, rental prices are substantially higher than in the Altmark. Several reasons are responsible: Farms in the East Allgäu often have overcapacities of family labor and a high equity capital compared to their farm size. Thus, the competition for land is very intensive in the East Allgäu, as land is the most scarce production factor. Moreover, the extremely high prices for newly rented land in 2013 were caused by the fact that in the beginning, only few farms invest in biogas. This can be seen as a specific outlier effect: These few farms are exceptionally profitable compared to the average farm and therefore have a very high marginal gross margin for additional land. The average rental price of biogas farms decrease as more and more other farms also invest in biogas production, because then also more farms with lower profitability belongs to the group of biogas farmers In the Altmark, competition for land is much lower. Compared to the profitability level, the relatively large farms in Eastern Germany pay relatively low rental prices (Balmann, 2015). Eventually, they benefit from a certain market power.

The rental price effects of biogas production decline after the introduction of the REA 2014 (Table 7). Due to the reduced guaranteed feed-in tariffs, biogas farms no longer invest and rent additional land for biogas production. Nevertheless, in both regions the rental price for biogas farms remains substantially higher than in the reference scenario, and may even continue to increase, particularly in the Altmark. The main reason is the fact that in the Altmark, rental prices are still low compared to the profitability of farming, irrespective of biogas support. In the East Allgäu region, the rental prices in the REA 2014 scenario start to decrease after the reform.

3.5. Farm performance

Rental prices for land affect the farms' profits. The higher the share of the value-added that is transferred to the land owners as a result of increased rental prices, the less remains as farm income. Fig. 5 shows for the Altmark that some biogas-producing farms have higher profits in the scenario REA 2012 compared to the REF scenario. The variance of profits is, however, also larger under conditions of the REA 2012. The average profit of biogas farms is even slightly lower in the REA 2012 scenario. Comparing 2025 and

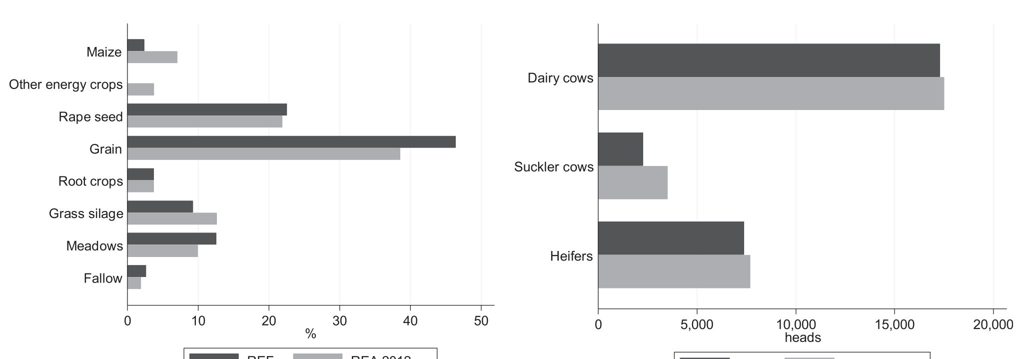

Fig. 3. Shares of different crop types; and number of cows and heifers in the Altmark in the REF and REA 2012 scenario, 2013 (model results).

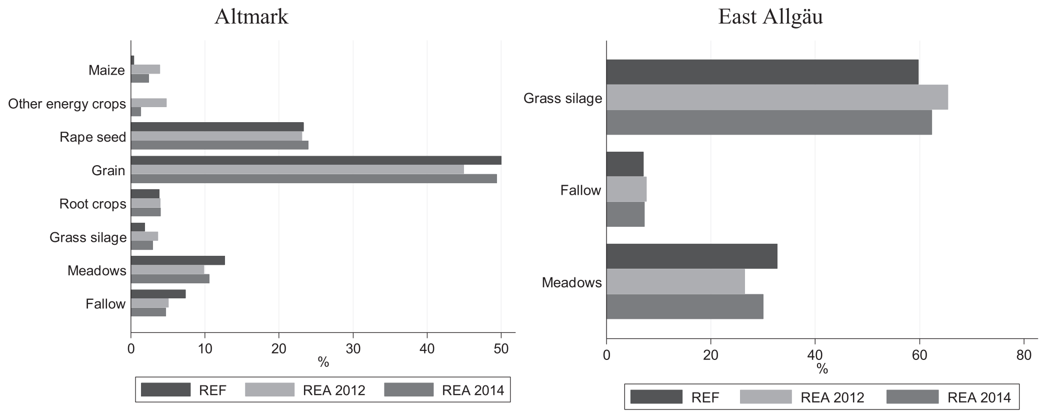

Fig. 4. Shares of different crop types in the model regions Altmark and East Allgäu in the REA 2012 and REA 2014 scenario, 2025 (model results).

Table 7
Average rental prices for new rented land in 2013 and 2025in Euro per hectare of biogas and non-biogas farms in the model regions, REF, REA 2012 and REA 2014 scenario (model results).

		Altmark				East Allgäu	
		Non-bio. Farms (87%)[a]		Biogas farms (13%)[a]		Non-bio. farms (99%)[a]	Biogas farms (1%)[a]
		Arable land	Grassland	Arable land	Grassland	Grassland	Grassland
2013	REF	112.06	26.99	206.21	109.35	130.57	351.81
	REA 2012	117.03	24.62	191.95	112.87	129.09	590.16
	REA 2014	117.03	24.62	191.95	112.87	129.09	590.16
2025	REF	176.18	33.78	299.59	120.59	108.71	187.11
	REA 2012	177.77	43.94	332.87	158.33	154.64	237.67
	REA 2014	181.91	42.19	316.76	150.08	127.92	220.78

Note: Biogas farms are farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario); Non-biogas farms are farms that do not invest in biogas plants in the REA 2012 scenario.
[a] Share of farms in 2013.

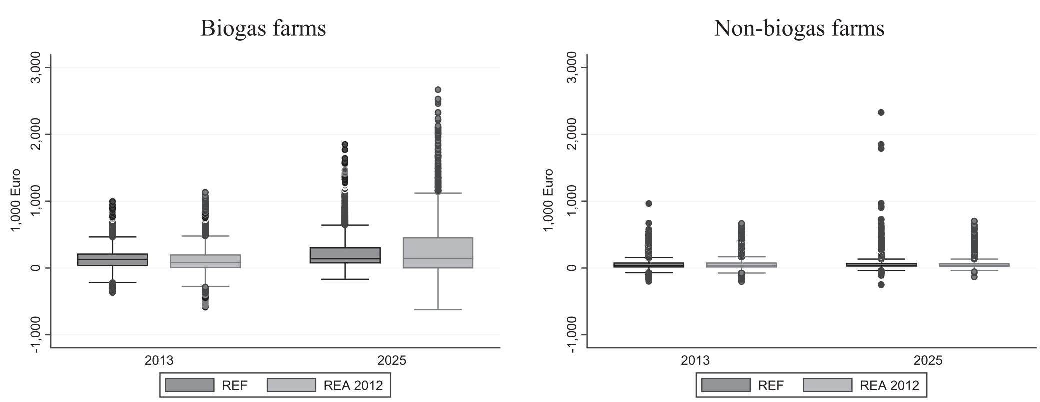

Fig. 5. Distribution of profits per biogas and non-biogas farms in 1000 Euro in 2013 and 2025 in the Altmark, REF and REA 2012 scenario (model results). Note: Biogas farms are those farms that invest in biogas plants in the REA 2012 scenario (they do not produce biogas in the REF scenario). Non-biogas farms are those farms that do not invest in biogas plants in the REA 2012 scenario.

2013 shows that the variance in profits increases over time for both scenarios, but particularly under conditions of the REA 2012. While some biogas farms can increase their profits substantially until 2025, other biogas farms even achieve high losses. After investing in a biogas plant, biogas farms are highly dependent on land to produce substrates for their biogas plant. Even if they are not profitable, they need to rent land if rental contracts expire. Then these farms are competing with profitable biogas farms that may even bid high rental prices for further growth. Because of the increasing competition for land, several biogas farms lose their initial advantage from biogas production. The beneficiaries are land owners who receive higher prices for their land. Only those farms with a real competitive advantage in biogas production benefit in the longer run; others even lose. The benefiting farms are larger and have a better management coefficient. In the long run, these effects accumulate. While some biogas farms benefit even more, others lose even more. On average, the non-biogas farms do not lose a lot. However, some non-biogas producers are not able to grow under the conditions of the REA 2012, while they would prosper in the REF scenario. For the East Allgäu region, these effects play a minor role, as there are only a few farms investing in biogas and these are rather large and have higher managerial skills.

Furthermore, for plant sizes less than 75 kW, these farms have the opportunity to receive an extra manure bonus. Therefore, biogas production is slightly more profitable in the East Allgäu, at least for those farms that have the required size to run a biogas plant.

The amendments of the REA 2014 cause several biogas farms that are very successful under conditions of the REA 2012 to lose (Fig. 6). On the other hand, a few biogas farms, and particularly a number of non-biogas farms in the East Allgäu benefit from the reduced competition on the land market. These farms benefit from higher profit per ha (Fig. 6).

4. Discussion and conclusions

Our analyses show that only farms with a sufficient farm size and sufficient financial resources are able to invest in biogas plants and thus benefit from the related subsidies. The reason is that a minimum size is needed to be able to feed a large biogas plant. If there is specific and sufficiently high support for smaller biogas plants like in the REA, such smaller plants can be attractive for farms that have less land. In any case, biogas production requires substantial amounts of substrate. According to Brendel (2011), some 200 ha of arable land are needed to operate a plant with a capacity of 500 kW – depending on the substrate sources and annual operating hours. Furthermore, the cultivation of energy maize comes at the expense of grassland as well as fallow and abandoned land (cf. Lupp et al., 2014); the simulation results support this finding.

Because of the complementarity between biogas production and cattle production in the case of attractive opportunities for using manure as a substrate, biogas support offers indirect subsidies for cattle production while at the same time other production activities are substituted. Due to the fact that land is scarce and biogas plants as well as cattle have to be fed constantly with maize and/or grass silage, biogas farmers have to reorient their production to the crops that deliver more biomass per ha to avoid feedstock bottlenecks. Lupp et al. (2014) also mention this connection: because maize is an attractive feedstuff for livestock and biogas, the share of maize production increases. Furthermore, Grundmann and Klauss (2014) conclude that "Increasing the production of energy from agricultural biomass tends to exert pressure on food production, especially when the comparative advantage of food production is low." As our analyses do not account for biogas investments of non-farmers, the effects are supposed to be even stronger in reality (cf. Thünen-Atlas, 2015). On the other hand, we have not implemented the requirement of a minimum use of heat which probably could overestimate the investments of farmers in biogas production.

Because the total amount of land within a region is limited, biogas increases competition for land between farms. Thus, land prices tend to rise. This linkage between biogas and land can affect the whole farm structure of agricultural regions. As a consequence of biogas support, smaller and less competitive farms quit at a higher pace. Brendel (2011) also argues that the high remunerations may cause traditional farmers to lose rented land after rental contracts expire.

However, these effects are overlapped with other more general tendencies of structural change. Irrespective of biogas support, structural change continues and more competitive farms pay higher land prices while less competitive farms stagnate, shrink or exit. Moreover, our simulations show that at least for the Altmark, rental prices for newly rented land plots are at a very similar level for biogas farms in the scenarios with and without biogas production. The same applies for the non-biogas farms, though at a substantially lower level. Accordingly, it is not only the biogas investments that drive up land prices, but rather the fact that in general, those farms that tend to invest in biogas are in any scenario very competitive on the land market. Rental prices are determined by the most efficient (biogas) farms. The more such potentially investing farms exist in a region, the higher are land prices, even if the farms would not be allowed to invest in biogas.

Because biogas support nevertheless leads to higher and increasing land prices, not all biogas farms gain in the long-run. As some farms may overenthusiastically invest in biogas, the increasing land prices may hit back and may even lead to losses for underperforming biogas farms compared to a situation without biogas support. In the end, only those farms gain from biogas support that are producing biogas most efficiently. We find that on average, the group of biogas farms has even a lower profitability

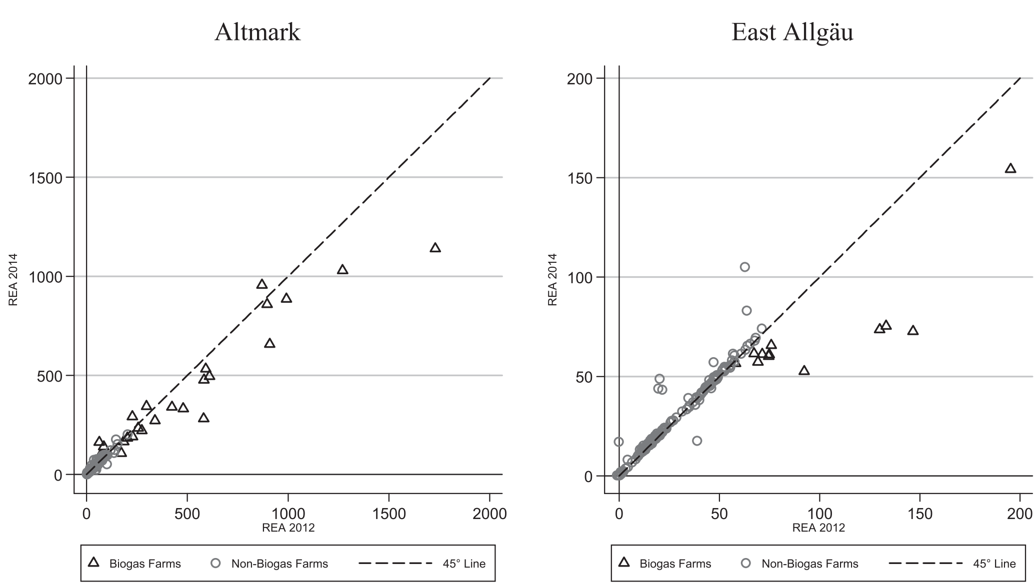

Fig. 6. Profit per farm of surviving farms in 2025 in the REA 2012 and REA 2014 scenario (model results). Note: The scatterplot shows profits per farm of single biogas and non-biogas farms. Farms that are on the 45° line perform equally well in both scenarios. Farms underneath the 45° line benefit in the REA 2012 scenario, while farms above the 45° line benefit in the REA 2014 scenario.

than without the support of biogas.

According to our results, the reform of the REA in 2014 only partly attenuates some of the above mentioned effects. Key structural implications of the previous REA regulations can only be reduced slowly, while others are persistent. The 2014 reform has created both winners and losers. Even some biogas farms that previously invested in biogas plants benefit in the future from less competition on the land market because other farms will no longer heavily invest in further biogas plants.

To sum up, our results show that biogas policies influence individual farms as well as the development of agricultural regions. Because different direct and indirect effects overlap, the impacts are of a complex nature. The complementarity of biogas and livestock production causes an additional intensification of land use and more investments in livestock production. Furthermore, the higher competition on the land market leads to increasing land prices. Those facts add up to changes in the agricultural structure of the analyzed regions. On average, biogas farms may not even achieve higher profitability because a significant share of the value added is transferred via increased rental prices to the land owners. In the end, every support for a specific type of investment has to be seen as a tax for competing production alternatives. Moreover, every subsidy for a specific type of farm creates disadvantages for competing farms. These indirect effects do not only affect farms investing in biogas, but rather the whole sector. Further reforms of the REA should therefore better consider the implications of limited land resources in agriculture.

Even though the last amendments of the REA in 2014 more or less stopped investments, the previously high level of support has long-term implications. This is mainly due to the long, useful duration of the bioenergy plants, as well as the guaranteed feed-in tariffs for 20 years. Therefore, the formerly high support level granted by the pre-2014 REA rules casts a long shadow of the past.

Most of the results of the simulations can be assumed to be true for other regions. Key drivers of the results such as differing farm sizes within each region and different management capabilities of farmers can be found everywhere. These heterogeneities are responsible for specific effects such as the differing ability of farms to invest in biogas plants and the differing profitability of farming in general, and biogas production in particular.

In principle, the heterogeneous ability of farms to invest in biogas plants could be partly addressed by policies that ease investments for smaller and less competitive farms by providing additional subsidies for smaller plants. It is, however, questionable why such investments should be more beneficial than support measures for biogas in general. Smaller investments would require guaranteed support at an even higher level per unit of bioenergy, which in the end has to be paid by someone. Moreover, such support would also cause side effects like higher land prices, and as a consequence unprofitable investments by farmers who are less competitive.

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