Can the growing demand for non-food biomass benefit smaller farms in Germany?

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Introduction

The success of an industrial bioeconomy requires not only continuing advances in technologies, but also a sufficient and reliable supply of renewable biomass (EC 2018). This challenges the main producers of biomass, including the agricultural sector (HERTEL et al. 2013). Especially in industrial countries with limited arable land, such as Germany, large-scale production of agricultural non-food biomass can accelerate the pace of structural change. Between 2005 and 2019, the number of farms in Germany decreased by 32 per cent, while the average farm size grew at almost the same rate (EUROSTAT 2020). However, the pace of the farm number decline has been slowing down (LANDATLAS 2018). This is mainly due to diseconomies of scale in large agricultural enterprises in eastern Germany, which prompted the emergence of spin-off companies, leading to a statistical increase in the number of smaller farms (JOCHEN 2016).

Diseconomies of scale in large farms indicate the limited cost reduction potential in competitive industrial agriculture, suggesting that reducing transaction costs will become increasingly relevant for optimising production decisions. Smaller farms can better economise on certain transaction costs, benefitting from their higher flexibility and lower supervision costs, local infrastructural advantages, or better access to some factor markets (VILLORIA 2017). They also can potentially benefit from a growing demand for non-fossil resources and vertical integration


Whereas maize silage is grown partly for generating energy in biogas plants…

…industrial sugar and glucose syrup from sugar beet, straw or bagasse are used as the raw materials for the production of bio-isobutene.

in the bioeconomy (SCARLAT et al. 2016). In fact, some German regions, in which (bio)economic activities tend to cluster around the chemical industry, hold potential to become large demanders of plant-based biomass for material and energy applications. This might support biotech start-ups and create new jobs in the agricultural sector and processing industries (BUDZINSKI et al. 2017). Nonetheless, the capacity of the agricultural and other sectors to create room for new and smaller agricultural producers remains debatable. Besides, imperfect factor markets or other conditions may offset the advantages of the lower supervision costs of smaller farms.

Against this background, this study developed a stylised model with two scenarios to anticipate the optimal farm size and the resulting prospects for smaller producers in Germany from 2017 to 2030. **The first scenario** was the adoption of neutral-to-scale technologies and the second one was the growing demand for plant-based biomass. **The second scenario** was further divided into two subcases to address the total and farm type specific implications of non-food biomass production. Methodologically, the study focused on the combined effect of transaction costs and economies of scale on optimal production decisions. From this novel perspective, the study sought to contribute to the debate on agricultural structural change and transaction costs.

Data and methodological approach

The analysis used secondary data from 2005 to 2016 which were collected from the European Statistical Office (Eurostat), statistics from the Federal Ministry of Food and Agriculture, and the Land Market Report (ACCESS TO LAND 2013). Based on these data, the average per hectare

Table 1: Overview of scenarios and their basic assumptions

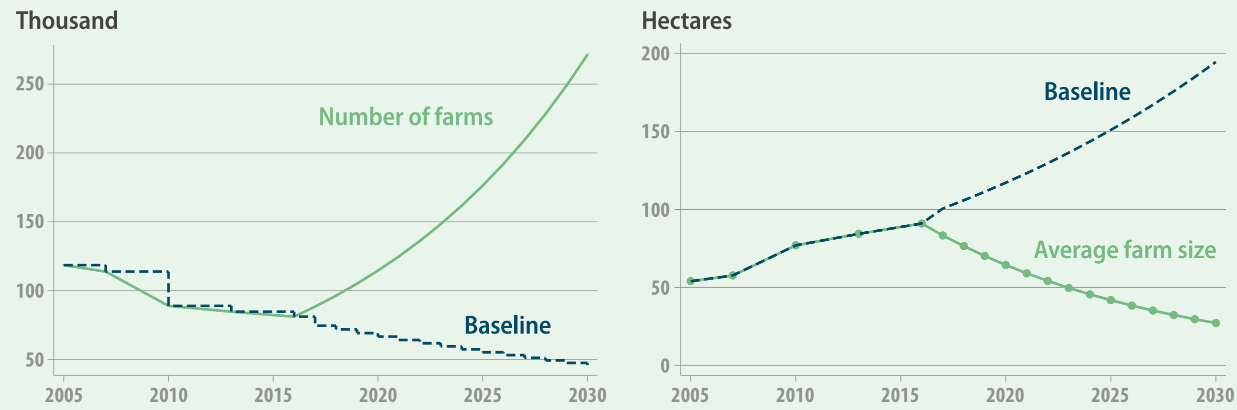
Scenarios and assumptions	Estimated production functions	Adjusted production functions
Scenario 1: Neutral-to-scale technologies • Annual increase in factor productivity by 1% • Constant profit rate and output price • Hicks-neutral technology	$Y=-2.77L^{0.50}S^{0.56}$	$Y=-2.45L^{0.67}S^{0.49}$
Scenario 2: Higher demand for non-food biomass • Annual increase in demand by 2% • Constant profit rate and product price • Constant factor productivity/technology		
2a: Average sectoral effects	$Y=-2.77L^{0.50}S^{0.56}$	$Y=-2.45L^{0.67}S^{0.49}$
2b: Effects for farm size groups		
Group 1: <10 ha	$Y=-3.47L^{0.53}S^{0.54}$	$Y=-8.41L^{1.35}$
Group 2: 10 ha–50 ha	$Y=4.54L^{-0.99}S^{2.13}$	$Y=21.49L^{-4.36}S^{5.36}$
Group 3: 50 ha–100 ha	$Y=2.98L^{-0.89}S^{2.12}$	$Y=S^{1.49}$
Group 4: 100 ha–200 ha	$Y=L^{-0.35}S^{1.7}$	$Y=L^{-0.33}S^{1.64}$
Group 5: >200 ha	$Y=S^{1.07}$	$Y=S^{0.81}$

Note: Z-stats for *α(ln_labour)* in scenario 2(b) are 1.05, 2.17^{**}, −1.11, −0.61, 2.27^{**}; Z-stats für *β(ln_land)* in 2(b) are 0.29, 3.12^{***}, 2.07^{**}, 2.15^{**}, -1.88^{*}; Z-stats for *constant* in 2(b) are 0.96, 0.3, −0.31, 0.58, 3.23^{***}.

farmland price was set at €8,000 (with an annual increase by 9.1%) and the average industrial agriculture wage at €3,000 per person per month. Land and labour reflected the amount of arable land and labour units involved in non-food biomass production. The output was measured in its monetary value. Using the panel data for 13 federal states (that is, excluding three city states) for five years (2005, 2007, 2010, 2013, and 2016), the production function was estimated for each scenario (see **Table 1**).

Data Envelopment Analysis (DEA) was used to estimate the efficiency of economic performance (ϵ) and transaction costs as inefficiency ($1-\epsilon$). The transaction costs of biomass production were given by the distance of the equilibrium state to the best-practice frontier, where the benchmark output under variable returns to scale was interpolated from annual output levels of German farms. The evaluation index system included input indexes (land size, farm number, and labour of non-food biomass pro-

Figure 1: The number of farms and average farm size, 2005–2030 (Scenario 1)



duction) and output index (the revenue of non-food biomass production). Thus, the adjusted production functions accounted for the constrains on minimum transaction costs in the input-oriented DEA model.

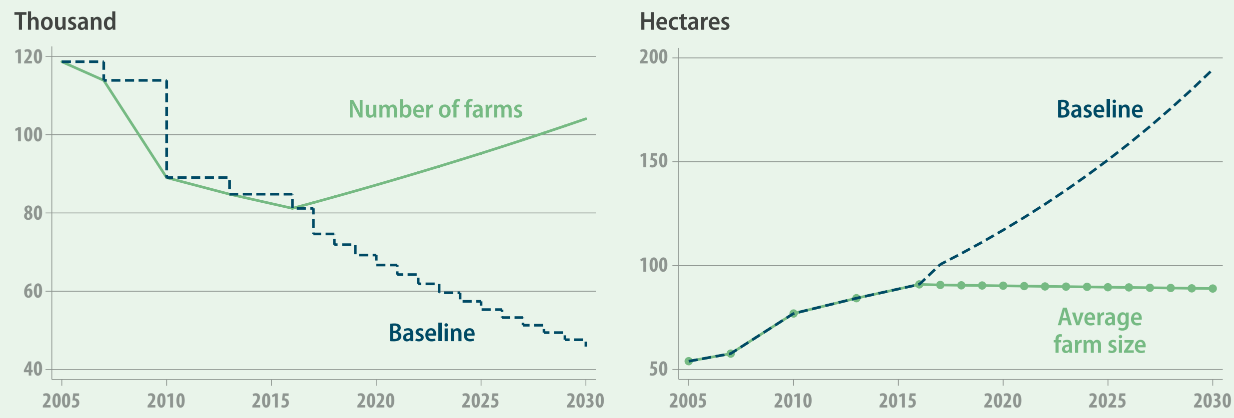
Main results

Scenario 1: Neutral-to-scale technologies

Figure 1 shows that in the projected period of 2017–2030, a technology-induced annual increase in efficiency by 1% (cf. KLÄRLE 2018) leads to an increase in the number of farms and a decline in the average farm size by 9.1%. This indicates that, under the given assumptions, more farms will switch from food to non-food biomass production.

This dynamic is due to the fact that neutral-to-scale technologies reduce the part of investment costs that create competitive disadvantages for smaller producers. This implies that under such an optimistic scenario of significant technological breakthroughs, the bioeconomy could indeed support diseconomies of scale and encourage smaller and new agricultural businesses. The comparison with the baseline case, which is the extrapolated trend of farm size and number, illustrates a possible scale of this effect. Although the positive effect of new technologies on the farm number may seem trivial under the given assumptions, this reveals that a scale-induced decline in transaction costs (and hence, in inefficiency) observed for the real data (2005–2016), may, if supported by technological advances, continue even under diseconomies of scale.

Figure 2: Number of farms and average farm size, 2005–2030 (Scenario 2a)



Scenario 2: Increasing demand for non-food biomass

(a) Average sectoral effects

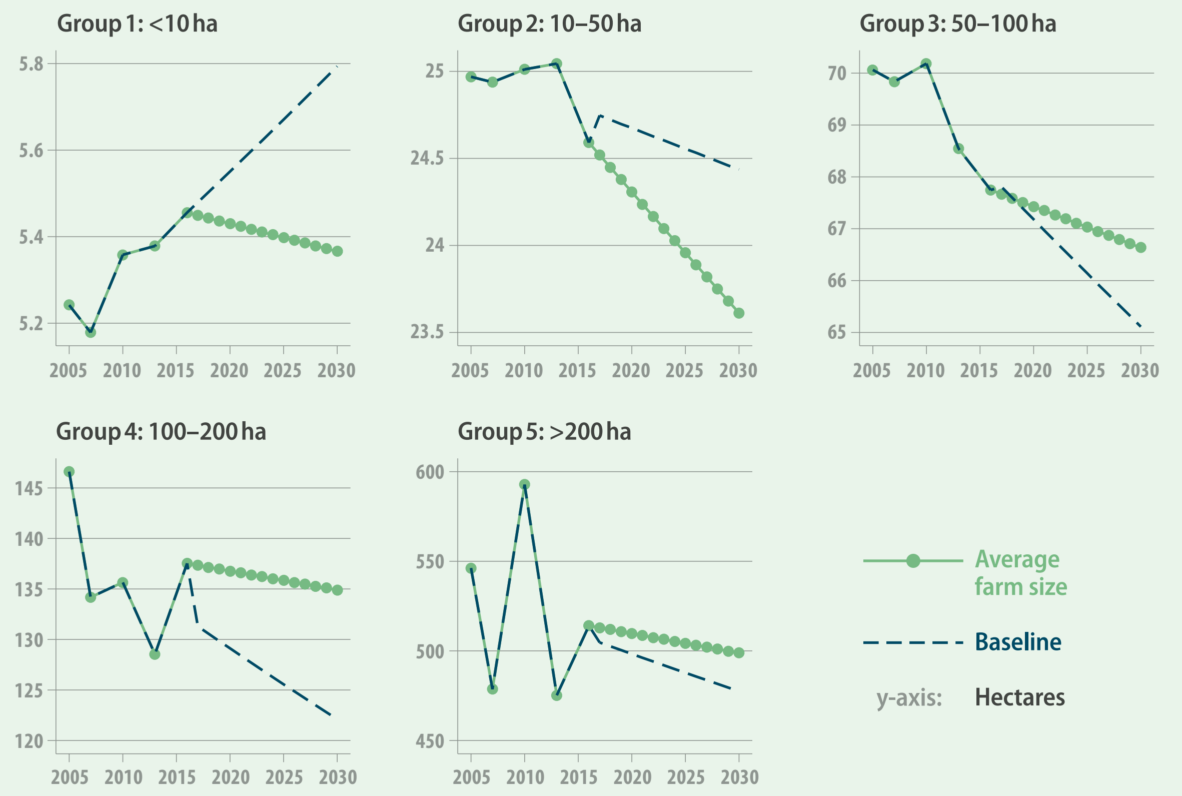
An annual increase in demand for agricultural non-food biomass by 2% (cf. PIOTROWSKI et al. 2016) starting in 2017 raises the number of farms (and labour force) by 1.79% annually (**Figure 2**). The average farm size, by contrast, remains almost constant, decreasing only slightly, namely from 90.80 ha in 2017 to 88.95 ha in 2030 (that is, by 0.15% annually).

Assuming that the technology level and the total agricultural area remain constant, enlarging the area under non-food biomass at the expense of food crop production is the only means to meet the increasing non-food biomass demand. Consequently, there should still be a clear decrease in the average farm size. An overall increase in average farm size is necessarily constrained by threshold costs of investments (BUCKLEY 1997). As the rate of increase in farm number (1.79%) is higher than that of land under non-food biomass (1.64%), the observed average decrease in farm size may therefore be due to the combined effects of the relative share of farm size groups, and regional heterogeneities in agricultural and ownership structures (DEININGER 2013).

(b) Effects for farm size groups

The optimal average farm size (**Figure 3**) declines in response to higher demand for non-food biomass in each group, namely by 0.12%, 0.30%, 0.12%, 0.14%, and 0.21%, respectively. The comparison with the baseline trend reveals that the effect of transaction cost economisation is particularly strong in groups 1, 2, and 4. The difference between the baseline and projected dynamics in group 1 and 2 can support the argument that transaction cost

Figure 3: Average farm size in different farm size groups, 2005–2030 (Scenario 2b)



savings in competitive industrial agriculture can help small farms realise their advantages of lower supervision costs and local infrastructure (VILLORIA 2017). In group 4, by contrast, this difference is mainly due to a lower growth rate of farm numbers in the projected trend. Given that the technological (and hence the productivity) level remains unchanged, producers respond to increasing biomass demand by readjusting their input-output combinations. For instance, the adjusted production function in group 5 (**Table 1**) changes from increasing to decreasing returns to scale. In this case, the largest farms adjust their optimal size less than other farm size groups, both in the projected and the baseline case.

Discussion and conclusion

This study draws the following four main conclusions: **First**, significant technological breakthroughs, which render the scale advantages less relevant, improve the production efficiency of smaller producers and potentially lower the entry barriers for new businesses. **Second**, a steadily growing demand for non-food biomass encourages more farms to switch from food to non-food biomass production and reduces the optimal average farm size. **Third**, the combined effect of economies of scale and transaction costs reveals that if farms cannot economise on transaction costs, investments in land and labour that are needed to adjust to higher biomass demand partly compromise returns to scale, so that the growth in farm size is slowed down. **Finally**, a higher degree of asset specificity, indicated by the greater sum of elasticities of farmland and labour, gives rise to transaction costs, which slows down the rate at which the farm size decreases.

These findings make important contributions to the debates on transaction costs and agricultural structural change by highlighting the combined effect of economies of scale and transaction costs on the optimisation of agricultural production decisions in different farm size groups. The observed greater effect of transaction costs savings for smaller farms indicates a potential competitive advantage of smaller producers in industrial agriculture (JOCHEN 2016). The slowdown in the growth rate of larger farms, caused by decreasing returns to scale, reveals the trade-off between the transaction cost effect and the economies of scale effect. This finding extends the relevant debate by showing that economies of scale mediate the impact of asset specificity on transaction costs (MCCANN 2009). Furthermore, given a productivity increase due to the application of technological innovations, transaction cost savings can lead to economies of scale. Since their combined effect is highly sensitive to the asset specificity of farms, it may unfold to different extents in eastern and western Germany, other than suggested by Buckley and Chapman (1997).

The study extends the application of the transaction cost approach to the sectoral level, suggesting that pivoting a highly competitive industrial agriculture towards a bioeconomy requires considering the associated transaction costs. The findings also inform bioeconomy strategies and action plans to account for the combined effect of transaction costs and economies of scale when assessing opportunities of smaller and larger producers in the bioeconomy.

The authors belong to the **junior research group 'Economics and Institutions of the Bioeconomy'**. This group was funded by the ScienceCampus Halle—Plant-based Bioeconomy (WCH) in the period 2017–2020. The project will continue until April 2023 with IAMO funding. The junior research group deals with selected economic and institutional challenges of the plant-based bioeconomy. The group seeks to illuminate some of the critical points in the transition towards more resource-efficient and sustainable economies by examining the role of innovation-driven advances and disruptions in this process. The work program includes conceptual and empirical analysis of current and emerging trends

in production and management practices of plant-based industries.

The geographical focus is on Central Germany; three transition countries (Russia, Ukraine, China) form the basis for comparative studies. Methodologically, it applies theoretical concepts and analysis tools from economics and sociology—such as comparative case studies, stakeholder interviews, scenario-based simulations of innovation adoption, Spatial Durbin Model and the Long-Cycles concept—to address possible disruptions in the established business models and societal norms and expectations.

The junior research group works closely with German and international research teams from Russia, China, the USA, and the Netherlands.

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2017 saw the first fermentative production of isobutene at Global Bioenergies' industrial demonstration plant. Until now this hydrocarbon has been derived from crude oil and is one of the most important primary petrochemical products. (Sources: Global Bioenergies and bioökonomie.de)

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