MEASURING AND EXPLAINING PRODUCTIVITY GROWTH OF RENEWABLE ENERGY PLANTS: A CASE STUDY OF AUSTRIAN BIOGAS PLANTS

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Overview

Reducing greenhouse gas emissions, improving energy efficiency and promoting renewable energy sources are the main pillars of the EU climate policy. Indicative targets on the share of renewable electricity for each Member State for 2010 were introduced by the Renewable Electricity Directive (directive no. 2001/77/EC). According to the Renewable Energy Directive (directive no. 2009/28/EC) the share of renewable energy sources in total EU energy consumption should be increased to 20 per cent in 2020. In October 2014 the European Council agreed on the new target of 27 per cent for 2030. Within this framework, all EU Member States have implemented policy support for electricity generation from renewable energy sources (RES-E). As documented by Kitzing et al. (2012) RES-E support schemes vary across EU Member states, including feed-in-tariffs (FITs), feed-in-premiums, tender schemes, quota obligations, investment grants, tax incentives and loans. All of these schemes subsidize RES-E generation in one way or another.

Among others, electricity generated from biogas is one of the technologies promoted by the Austrian green electricity law (BGBl. I Nr. 149/2002; BGBl. I Nr. 75/2011). Biogas plants convert feedstock, e.g. maize silage, grass silage, manure or organic waste, by anaerobic digestion into biogas. Whereby, maize is the primarily feedstock component for biogas generation in Austria. Biogas is used in a cogeneration unit (CHP) to produce combined heat and power. The green electricity law implies a purchase guarantee for RES-E and technological specific fixed electricity prices (FITs) for at least 13 years. Production subsidies for heat are not available. Commonly, heat prices are negotiated bilaterally between the biogas plant operator and the buyer (e.g. district heating grid providers). Investment grants are provided, where eligibility and extend varies by Austrian federal states.

Productivity is an essential determinant of a firm's i) output given a fixed amount of inputs, ii) units costs and iii) profit. Reducing costs and increasing profits of renewable electricity generation i) fosters the deployment of RES-E technologies, ii) enables to reduce the financial burden faced by electricity consumers, and hence iii) could further raise the public acceptance of renewable energy technologies. Therefore, it is crucial to measure and understand productivity growth of RES-E. Only few studies analyze the productivity growth of renewable energy plants, except for hydroelectric power facilities. Our study aims to fill this gap in the literature. As far as we know, we are the first evaluating productivity change of biogas plants based on a broad sample and an extensive set of inputs and outputs.

Methods

This article explores productivity growth for a group of 65 biogas plants from 2006 to 2014 using a non-parametric approach that is data envelopment analysis. The sample covers about 25 % of the installed electric capacity of Austrian biogas plants. We measure productivity growth using the Malmquist productivity index, employing a decomposition under variable returns to scale proposed by Ray and Desli (1997). This decomposition isolates the contributions of technical change (i.e., shift of the technology frontier), technical efficiency change (i.e., movements towards the technology frontier) and scale change (i.e., exploitation of returns to scale) to productivity growth. Moreover, we complement the non-parametric analysis with pooled ordinary least squares regressions to explain differences in productivity change of biogas plants in terms of a number of variables, including capacity/size, output diversification, capital subsidies, capacity utilization, capital intensity, feedstock prices and regional location.

Results

We find that average annual productivity growth between 2006 and 2014 is 1.1 %. While average annual productivity growth was 1.7 % between 2006 and 2012, productivity change slowed down in 2013 and 2014. The decomposition of the Malmquist index shows that the annual scale change, technical change, and efficiency change for the average plant is 0.6 %, 0.3 % and 0.3 %, respectively. Those results indicate that the exploitation of returns to scale is an important driver of productivity growth in the Austrian biogas sector. However, the meaning of this average values is weakened by the huge heterogeneity of productivity growth found in this study. A majority of 41 plants experienced productivity gains between 2006 and 2014; 24 biogas plants show a productivity decline.

A second-stage pooled-OLS regression confirms that biogas plants, which expand their electric capacity, have on average higher productivity growth. Especially small plants (< 160 kW_{el}) increasing their capacity reap productivity gains via increasing returns to scale. Increasing returns to scale are a less important source of productivity growth for larger plants. Feedstock prices show a positive relationship with productivity and efficiency change. This may indicates that biogas plant operators react to fuel price increases with efficiency improvements. Further, the second-stage pooled OLS regressions reveal that biogas plants diversifying their outputs and increasing their capacity utilization as well as their capital intensity have higher productivity growth.

Conclusions

If the rather low productivity growth of the last years continues, and input price changes are absent, only minor unit cost reductions in biogas production can be expected. Technical change is low, which might reflects that technical innovations where hardly implemented in Austrian biogas plants. The exploitation of returns to scale seems to be the most important driver of productivity growth in the period 2006-2014. However, if technical progress is missing (outward shift of the production possibility curve) productivity growth will be exhausted over time. For plant operators the results indicate that increasing the size, more full-load hours or shorter operational interruptions (e.g. through regular maintenance) and diversification (e.g. increased heat utilization) may contribute to an improvement of productivity.

Output-mix diversification seems to be an important determinant of productivity growth. Though, complete specialization in electricity generation declined substantially between 2006 and 2014, most of the CHPs are still partially specialized in electricity production. That means electricity output exceeds heat output. The focus of biogas plant operators on electricity generation is largely driven by regulatory measures. Absent or weak locational signals led to placement of generation at sites, where heat demand is low and expenditures for district heat connections are high. Policy makers should be aware that CHPs are characterized by positive synergies among power and heat generation, which are primarily based on cost reductions through fuel savings (cf. Kwon and Yun, 2003). Policies that incentivize biogas plant operators to diversify can generate substantial productivity gains.

The results of this article are in line with anecdotal evidence and previous analysis suggesting increasing returns to scale in biogas production; see e.g. Skovsgaard and Klinge Jacobsen (2017). Policy makers and regulators should be aware that larger plants might generate biogas at lower unit costs due to increasing returns to scale. Incentivising the cooperation of farmers in one region to run a collaborative biogas plant is one possibility to exploit returns to scale. Another option is to set a uniform feed-in tariff for all biogas plants, which does not cover the costs of small-scaled plants.

The fact that harvesting and transportation of feedstock as well as the handling of digestate are not considered in our study might be seen as a limitation. Skovsgaard and Klinge Jacobsen (2017) show in a Danish case study that per unit transport costs for biogas plants increase with scale, which partly offsets the economies of scale found for capital and operational expenditures. Hence, one possible avenue for future research could reconsider scale effects based on an investigation of cost functions including costs for i) feedstock transportation and ii) digestate handling. Last but not least similar analyses of technical and cost efficiency as well as productivity and profitability change should be carried out for other renewable energy technologies such as wind power plants, solar power plants, biomass power plants, etc. Those technologies play a major role in the energy transition towards a low carbon economy.

References

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