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Regional drivers of on-farm energy production in Bavaria

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HIGHLIGHTS

- Energy transition is largely carried by farmers' adoption of renewable energy (RE).
- Adoption of RE generally follows an s-shaped diffusion curve.
- Drivers are regions' transformation ability and professionalization of agriculture.
- Adoption of RE conflicts with organic farming.

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ABSTRACT

Bavaria's energy policy seeks to increase the share of power supply from renewable sources related to on-farm energy production (agricultural biogas, wind- and solar energy) from currently 15% to more than 30% in 2021. It is therefore of particular interest for policy-makers to identify regional drivers of and barriers to this concept.

The presented study addresses this issue and applies a spatial regression analysis to Bavaria's 71 rural counties. The findings indicate significant impacts of technological regional transformation ability, agricultural structure (degree of professionalization and consolidation of organic farming) and neighborhood effects. This is in contrast to most geographical factors, which seem to be of minor relevance.

1. Introduction

In 2015 leading industrial nations agreed at the G7 summit to cut greenhouse gas emissions by 40–70% of the 2010 level by 2050 and phase out of fossil fuels by the end of the century (G7, 2015). This is in line with the transition path implemented by Germany in response to the Kyoto protocol (UN, 1998) and goes in hand with Bavaria's aim to increase the share of power supply from renewable sources from currently slightly more than 30–50% by the year 2021 (Bayerische Staatsregierung, 2011). Instruments to achieve these targets are manifold and have not been specified in either of the documents. Instead, the choice of appropriate measures rests with the national authorities. In this context, Germany adopted the *Renewable Energy Sources Act* (EEG) that grants priority to electricity from renewable energy sources and further guarantees, for a term of 20 years, comparatively high feed-in tariffs (BGBl, 2000; BMJV, 2014). In so doing, the regulation substantially reduces the risk for private investors.

Since the act came into force in the year 2000 the share of electricity produced from renewable energy has increased from about 6% to more than 25% in the year 2014 (BDEW, 2015). This positive trend corresponds with a rapid diffusion of small-scale solar installations attached to the roofs of private houses in urban areas. It relies, however, even more on the diffusion of renewable energy in rural areas. For this reason, on-farm energy production, which in the following refers to the adoption of agricultural biogas, wind and solar energy for electricity supply on agricultural land, can be considered a core element of the German transition towards a low carbon industry.

On the one hand, the successful implementation of this concept clearly relates to farm and farmers' characteristics such as farm type and size, or farmers' age and level of education (e.g. Bailey et al., 2008; Reise et al., 2012; Tate et al., 2012). On the other hand,

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farmers' decision to invest in photovoltaic installations, biogas plants or wind turbines further depends on local and regional determinants, such as regional transformation ability, agricultural structure or neighborhood effects (e.g. Coenen et al., 2012; Dewald and Truffer, 2012). The presented study addresses this issue for Bavaria's 71 rural counties and applies a spatial regression analysis to identify regional determinants for the adoption of renewable energy related to on-farm energy production in Bavaria's rural counties. The results can be used for policy fine-tuning and therefore contribute to the ongoing success of the energy transition.

The analysis clearly benefits from a rich empirical base with regard to Bavaria's agricultural sector in general and on-farm energy production in particular. In consequence, main findings particularly relate to the Bavarian situation. However, having in mind that Bavaria accounts for about one fifth of Germany's total agricultural land and almost one third of farms, the findings indeed matter in a broader sense.

The paper is organized as follows: Section 2 briefly illustrates the diffusion of agricultural biogas, photovoltaics and wind energy in Bavaria. The chapter is followed by a discussion of related literature and the derivation of the main hypotheses in Section 3. Sections 4 and 5 continue with methodological remarks and the discussion of the results. Finally, the paper concludes with the main findings and policy implications in Section 6.

2. Recent trends

Bavaria's installed capacity for electricity supply from renewable energy has been extended from 2800 MW in the year 2000 to about 15,600 MW in 2014. In consequence, electricity supply from renewable energy more than doubled from 15,300 GWh to 33,200 GWh. This corresponds to an increase in the share of total electricity supply from about 19% to more than 34% (StMWi, 2015).

With regard to the regions' role in adopting renewable energy, urban regions' capacity is rather small and limited to small-scale photovoltaic systems, some river hydropower plants and few wind turbines in industrial areas.

In contrast, Bavaria's rural regions dispose of substantial agricultural area, which allows for the large-scale adoption of land-consuming renewable energy. For this reason the transition of the energy system is largely carried by rural counties, where installed capacity from renewables increased from about 2500 MW in the year 2000 to more than 14,600 MW in 2014. This corresponds to shares of 90% and 94% respectively in Bavaria's overall capacity from renewables (DGS, 2014; StMWi, 2014).

On-farm energy production continuously gained in importance in this period. When the EEG came into force in the year 2000, related capacity in rural areas just added to 84 MW – a share of no more than 3% in Bavaria's overall installed capacity from renewables by this time. In 2014, related capacity amounted to about 9100 MW, which corresponds to a share of almost 60%.

Fig. 1 illustrates the diffusion of the renewables related to on-farm energy production in Bavaria over time. More than half of the installed capacity can be assigned to photovoltaic systems, which can further be subdivided into installations generally attached to the roofs of the farm buildings (16–30 kWp) and open space units (> 30 kWp).[1]

The diffusion of photovoltaics and agricultural biogas basically follows an s-shaped curve. This trend is characterized by low

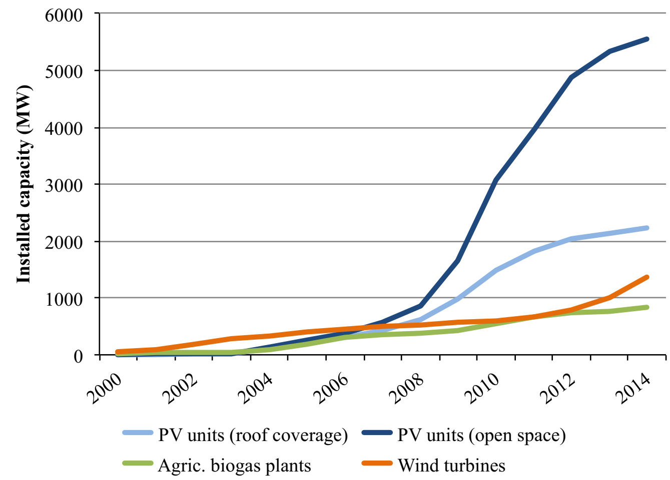

Fig. 1. Diffusion of renewables related to on-farm energy production in Bavaria (installed capacity in MW). Source: own illustration based on DGS (2014), LfL (2014), StMWi (2014), StMWi (2015).

adoption rates of renewables in the early stages of the diffusion process, rapid increases after the takeoff and a saturation (or at least first signs of a saturation) at the end of the considered period. The trend for wind energy seems to follow the same curve, but has not reached saturation level yet.

The diffusion at county level basically follows the curves observed for Bavaria as a whole. However, regions adopt renewables at different times and at different rates. This is exemplarily shown for photovoltaic installations attached to the roofs of farm buildings (16–30 kWp) by Fig. 2, but also holds for the other sources. The selected regions illustrate the broad range of diffusion at county level. Deggendorf, for example, is among the seven regions with an aggregated capacity from PV units attached to the roofs of farm buildings of more than 100 kWp/sqkm. This is in contrast to the county of Garmisch-Partenkirchen, one out of six regions with an installed capacity smaller than 30 kWp/sqkm.

As monetary incentives set by the EEG are basically the same for any region and against the background of rather homogeneous production conditions for on-farm energy production (e.g. similar solar radiation, soil quality, access to technology, etc.) the paper seeks to identify major regional determinants of the rather heterogeneous adoption of renewable energy.

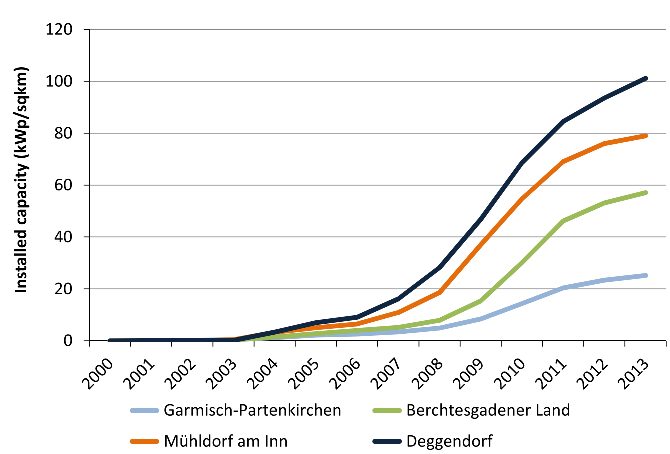

Fig. 2. Diffusion of PV units attached to the roofs of farm buildings (16–30 kWp) (kWp/sq km). Source: own illustration based on DGS (2014), StMWi (2014), StMWi (2015).

[1] Small-scale installations (< 16 kWp) remain unconsidered in this context. This is since installations of this size are not typical for on-farm energy production, but are mostly attached to roofs of private houses (Lödl et al., 2010).