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Does localized imitation drive technology adoption? A case study on rooftop photovoltaic systems in Germany

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ABSTRACT

The purpose of this paper is to illuminate the spatio-temporal diffusion of rooftop household photovoltaic installations in Germany and to test whether localized imitation drives their adoption. Our study is based on a unique data set of some 576,000 household photovoltaic systems installed in Germany through 2009. We employ an epidemic diffusion model which includes a spatial dimension, and control for temporal and spatial heterogeneity. According to our results, imitative adoption behavior is highly localized and an important factor for the diffusion of household photovoltaic systems.

Introduction

The finiteness of fossil fuels and their effect on climate change has encouraged the search for sustainable energy technologies.[1] One of these technologies is photovoltaics (PV), i.e., solar cell systems for producing electric power. Although, in the past, PV electricity could not compete in price with conventionally produced electricity, since the year 2000 a system of financial subsidies has provided significant incentives for installing photovoltaic systems in Germany. In consequence, the photovoltaic capacity installed per capita was by far the highest worldwide in 2009 (REN21, 2010), even though the global solar radiation is low when compared to other countries in the south.

Fig. 1, in which each gray dot marks a photovoltaic system, shows that the spatial distribution of photovoltaic systems is inhomogeneous in Germany. Our objective is to analyze this observed distribution and in particular to understand whether localized imitation drives PV adoption.

Our analysis may contribute to the understanding of policy-induced diffusion and could therefore be helpful for fostering the diffusion of other distributed energy technologies or subsidized products in general.[2] In order to do so, we base our

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[1] An early version of this paper was part of Johannes Rode's (2014) doctoral thesis.

[2] When referring to a technology, we refer to the artifact, thus, in our case, the photovoltaic system as such. In contrast, there are studies which define technology differently, e.g. according to Comin and Hobijn (2010, p. 2032) a technology "*is a group of production methods that is used to produce an intermediate good or service*." Furthermore, adoption – in our sense – describes the first purchase by an individual whereas diffusion refers to the rate at which something spreads within a group of individuals.

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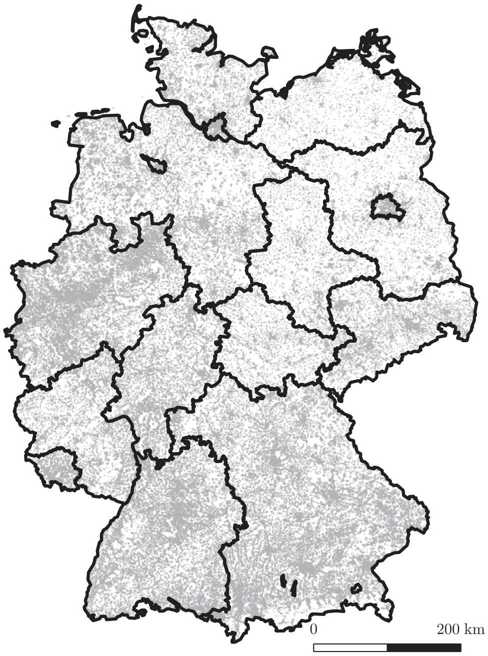

Fig. 1. Distribution of photovoltaic systems within Germany through 2009; each gray dot represents a photovoltaic system. *Map in Gauss–Krüger zone 3 projection.*

analysis on a data set covering the photovoltaic installations in Germany through 2009, focusing on rooftop household installations. We analyze the data in an epidemic diffusion model which includes a spatial dimension and allows us to account for the common S-shaped diffusion path of technologies. The model is discrete in time and space, but its level of geographical aggregation is adjustable in arbitrarily small steps.

In their overview of analytical tools for environmental economists studying technological change Jaffe et al. (2002) suggest the epidemic model of technology diffusion when – as in our case – no specific data on the respective decision makers is available. The model builds on the idea that diffusion is primarily driven by the spread of information.[3] Focusing on this aspect seems reasonable as rooftop PV installations are easily visible.

The analysis of PV adoption is different to the general case of purely market driven diffusion since use of the innovation is highly subsidized (Jaffe et al., 2002; Rosendahl, 2004; Davies and Diaz-Rainey, 2011), partly with yearly changes in the subsidy system. Therefore, we complement the epidemic diffusion model. As we have data on the installation year for all of the photovoltaic systems, we can include temporal fixed effects (FE) to cover – e.g. – changes in the subsidy system. Further, we account for spatial heterogeneity by employing spatial fixed effects, allow a time-varying number of potential adopters in line with Mahajan and Peterson (1985) and follow Peres et al. (2010) when including space in the epidemic diffusion model. The epidemic diffusion model requires information on the number of potential adopters in order to capture saturation. As most of the photovoltaic installations in Germany ($>80\%$) are rooftop installations (BSW-Solar, 2011), we take the number of buildings as a proxy for the number of potential users.

According to Janssen and Jager (2002), the decision to install solar power can be characterized by a high relevance of social compatibility: "[*c*]*onsumers frequently feel satisfied when consuming the same as their neighbors* (*social needs*) *and often engage in social comparison and imitation when deciding what to consume*" (Ibid., p. 288). Bollinger and Gillingham (2012), Noll et al. (2014), Rai and Robinson (2013) and Graziano and Gillingham (2015) point in the same direction. They find peer effects in the adoption of photovoltaics in regions in the United States (U.S.). In their analysis of individual-level data on the adoption of solar thermal equipment, Welsch and Kühling (2009) confirm that the behavior of reference groups is important for installing solar thermal equipment in Germany.[4]

In contrast to previous studies on PV adoption, we know the exact location and the year of installation for all 576,056 German (PV) household PV adopters through the end of 2009. We use this comprehensive panel to estimate the extent of spatial imitation at both a very low level of spatial aggregation and for a whole country. Thus, we overcome the modifiable areal unit problem (Openshaw, 1984) by not relying on pre-defined regional units. This is in contrast to other studies which also observe imitative

[3] The information may come from a central entity or adopters nearby. The latter covers both, just seeing the technology or product at work and being convinced through being informed by peers.

[4] Solar thermal systems generate heat whereas PV systems generate electricity. Still, solar thermal systems are also rooftop installations and have a similar appearance as PV systems.