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The impact of the German feed-in tariff scheme on innovation: Evidence based on patent filings in renewable energy technologies

Christoph Böhringer [a], Alexander Cuntz [b], Dietmar Harhoff [c], Emmanuel Asane-Otoo [a,*]

[a] Department of Economics, University of Oldenburg, Ammerländer Heerstrasse 114-118, D-26129 Oldenburg, Germany
[b] Expert Commission for Research and Innovation, Pariser Platz 6, D-10117 Berlin, Germany
[c] Max Planck Institute for Innovation and Competition, Marstallplatz 1, D-80539 Munich, Germany

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ABSTRACT

Over the last two decades, feed-in tariffs have pushed the massive expansion of electricity from renewable energy sources in Germany. Between 1991 and 1999, feed-in tariffs were prescribed through the Electricity Feed-in Law – the so-called Stromeinspeisungsgesetz (SEG) – at relatively moderate rates. From 2000 onwards, the SEG was replaced by the Renewable Energy Sources Act – the so-called Erneuerbare-Energien-Gesetz (EEG) – with much higher subsidy rates. The rise in subsidies to renewable power generation under the EEG came along with a substantial increase in electricity prices provoking an intense public debate on the benefits of renewable energy promotion. In our regression analysis, we assess one popular justification for feed-in tariffs: the demand-side effect of induced innovation. We find that the innovation impact of the German feed-in tariff scheme over the last two decades supports the positive innovation hypothesis. However, the inducement effect of the feed-in tariff scheme under the EEG is not significantly different from that of the SEG. Given the drastic cost of the EEG, we caution against the appraisal of the EEG feed-in tariff scheme solely on the grounds of its impact on technological innovation.

1. Introduction

Subsidies for electricity production from renewable energy sources have been on the agenda of German energy policies since the early 1990s. A central justification for renewable energy promotion policy is climate protection, i.e., the reduction of anthropogenic greenhouse gas emissions emerging to a large extent from the combustion of fossil fuels. Germany aims at curbing greenhouse gas emissions compared to 1990 levels by 40% by the year 2020, and by 80% to 90% by 2050. A major contribution to emission reduction should thereby stem from the "greening" of the power sector, with a target share of renewable electricity production in total electricity consumption of 35% by 2020 and 80% by 2050.

The primary policy instrument for pushing power generation from renewable energy sources in Germany is a feed-in tariff scheme that guarantees purchases of green power at fixed prices. Feed-in tariffs (FITs) are differentiated by technology to outweigh technology-specific cost disadvantages compared to conventional power generation based on fossil or nuclear fuels. Between 1991 and 1999, feed-in tariffs were prescribed through the Electricity Feed-in Law, the so-called Stromeinspeisungsgesetz (SEG). The SEG obligated grid operators to purchase green power at a minimum price calculated as a share of the average consumer price for electricity in past years (SEG, 1990).

Since 2000, the SEG has been replaced by the Renewable Energy Sources Act, the so-called Erneuerbare-Energien-Gesetz (EEG). Compared to the preceding SEG, the EEG increased feed-in-tariffs (in particular for solar photovoltaic) and included additional technologies such as geothermal energy into the promotion scheme. The EEG guarantees investors above-market price for renewable energy for 20 years from the point of installation. An EEG surcharge – equal to the difference between feed-in tariffs paid by utilities for renewable energy and the revenue from electricity fed into the grid – is added to the bills of electricity consumers.[1]

The subsidies granted under the SEG and EEG triggered a massive growth in renewable electricity production. The share of renewable energy in gross electricity consumption increased from 3.4% in 1990 to 6.2% in 2000 and to 31.7% in 2016 (AGEE-Stat, 2017). Within the various renewable energy technologies, electricity generation from wind power currently commands the highest share (41.1%) followed by bioenergy (27.4%), photovoltaic (20.3%), and hydropower (11.2%). The increase

* Corresponding author.
E-mail addresses: boehringer@uni-oldenburg.de (C. Böhringer), alexander.cuntz@e-fi.de (A. Cuntz), dietmar.harhoff@ip.mpg.de (D. Harhoff), asane.otoo@uni-oldenburg.de (E. Asane-Otoo).

[1] Energy-intensive companies pay a reduced EEG surcharge in order to remain competitive.

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in non-competitive renewable power generation, particularly under the EEG, went hand in hand with a substantial rise in electricity prices.[2] Between 2000 and 2016, the effective subsidies under the EEG increased from less than a billion Euro to roughly 26 billion Euro in 2016. As a consequence, the EEG surcharge on households' electric bills reached 6.35 Eurocent/kWh in 2016 (BMWi, 2016). The EEG surcharge thus accounts roughly for one-fourth of the average household electricity price in Germany.

Given its high-cost burden to consumers, the EEG has been particularly criticized due to its ineffectiveness with respect to greenhouse gas emission abatement. Greenhouse gas emissions from energy-intensive industries (including the power sector) in Germany are already regulated under the European Union emissions trading scheme (EU ETS), rendering the EEG redundant with respect to climate protection. Subsidies to renewable power production exert a downward pressure on the price of emission allowances and simply reallocate emissions across energy-intensive industries and regions covered by the cap-and-trade system. The overall cost of the emission cap increases due to excessive abatement from the expansion of renewable energies and too little abatement from other mitigation opportunities such as fuel switching (Böhringer et al., 2009; Böhringer, 2014; Frondel et al., 2010; Böhringer and Behrens, 2015).

As the argument of climate protection fails, protagonists of renewable energy promotion strive after additional reasons (e.g., increasing innovation activities) to justify green subsidies. One prominent justification roots in a market failure caused by knowledge externalities. This may result in substantial underinvestment in technological innovation by firms relative to the social optimum (Mohr, 2002; Fischer et al., 2012). The proposition that the production and deployment of renewable energy technologies could trigger learning-by-doing and R&D spillovers which are external to the individual firm provides the theoretical efficiency rationale for corrective measures such as green subsidies. In this vein, feed-in tariffs with medium- to long-run take-and-pay provisions are envisaged to stimulate demand and increase investment security in renewable power plants. Consequently, R&D activities might increase and spur technological innovation.

While the presence of learning and R&D spillovers in principle provide a case for subsidies, the specific design of subsidy policies may have adverse effects on learning and innovation (Söderholm and Klaassen, 2007). For example, a (too) generous production subsidy such as the EEG fosters the deployment of high-cost and inefficient technologies. It can create lock-in effects in pre-existing technologies thereby hindering the diffusion of other technologies that may be more efficient in the mid-run (Frondel et al., 2010).

High tariffs – with relatively modest yearly reduction or "degression" rates – also enhance short- to medium-term exploitative behavior rather than intensive explorative investment in R&D by technology producers.[3] From the perspective of the innovator, the revenue from an (ex-post) cost-effective new technology might be less or just the same as the revenue generated through the increased production of pre-existing technologies. High demand and production of existing inefficient technologies could also increase the cost of scarce inputs making R&D activities and the cost of producing alternative technologies that employ the same inputs more expensive (Koseoglu et al., 2013). Expensive R&D activities coupled with generous tariffs that reward high-cost and inefficient production thus lower incentives to improve the efficiency of existing technologies as well as further technological innovation.

In this paper, we scrutinize the innovation argument for renewable energy promotion in Germany by applying fixed effect negative binomial and Poisson panel data regression models. Our analysis investigates the impact of the feed-in-tariff scheme under both the SEG and EEG regimes on technological innovation measured by patent counts in renewable energy technologies (RETs). Our results support the positive innovation hypothesis of feed-in tariffs over the last two decades. However, we also find that the EEG does not incentivize more innovation than the SEG regulation. The findings thus cast doubts on the additional positive innovation impacts of the generous feed-in tariff scheme under the EEG. This can be attributed to the design of the EEG tariff scheme which provides limited incentives for developing more high-valued technological innovations.

The remainder of this paper is organized as follows. In Section 2, we provide a brief review of the relevant literature. We lay out data sources and describe the econometric model settings underlying our estimations in Section 3. In Section 4, we discuss results and draw policy conclusions in Section 5.

2. Related literature

Over the past decades, much of the policy-induced innovation literature has been devoted to assessing the "weak" version of the so-called "Porter hypothesis" which postulates that well designed environmental policies spur innovation (see e.g., Jaffe and Palmer, 1997; Lanjouw and Mody, 1996; Brunnermeier and Cohen, 2003; Popp, 2006; Lanoie et al., 2011; Lee et al., 2011). Broadly, these studies show the existence of a positive correlation between environmental policies and innovation. In the context of renewable energy technologies, the various policies aimed at stimulating technological innovation can be classified as either demand-pull (e.g., FITs) or technology-push (e.g., R&D subsidies). The channels through which RETs promotion policies trigger technological innovation are as follows.

Firstly, policies that create demand or expand the market size for renewable energy are envisaged to encourage learning-by-doing and increase the cost-competitiveness of renewable energy technologies. The growing market size also increases the return on R&D investment (Popp, 2006; Scherer and Harhoff, 2000) and further draws more investment to RETs. Secondly, the outcome of all phases of technological development in RETs is associated with a high degree of uncertainty. This impedes investment decisions by innovators or manufacturers, particularly if the economic significance of R&D investment, for example, is uncertain. Thus, policies (e.g., R&D subsidies, green quota) that mitigate the inherent riskiness of investment would most likely stimulate R&D investment and drive innovation. Lastly, due to knowledge externalities, renewable energy promotion policies that correct this market failure are also expected to stimulate technological innovation.

Against this background, a growing number of empirical studies have provided evidence regarding the innovation impacts of promotion policies for renewable energy (see e.g., Bergek et al., 2014; Kemp and Pontoglio, 2011 for a review of the extant literature). Johnstone et al. (2010a) for example, examine the effects of environmental policies on technological innovations in renewable energy using a panel dataset of 25 countries and across several sources of renewable energy. They provide evidence that the effectiveness of alternative policy measures depends on the specific energy source. Price-based instruments such as feed-in tariffs are most effective in encouraging innovation in solar while quantity-based policy instruments such as tradable certificates turn out to be most effective in spurring innovation in wind and geothermal technologies. The authors further conclude that broader market-based regulations such as tradable green certificates are more likely to induce innovation in renewable technologies that are close to competitive, whereas technology-specific measures tend to induce innovation in more costly energy technologies such as solar power.

[2] Note that recent amendments to the EEG legislation in 2014 and 2017 have introduced the so-called "deployment corridors" and an auction system to respectively, control deployment and ensure market-based support system for some technologies.

[3] Generous tariffs could primarily lead to a "gold rush" for subsidies (in terms of increased demand and production of existing technologies) instead of increased investment efforts to perfect new and efficient technologies. The incentives towards exploitative market expansion can create a risk of reduced competitiveness if firms reduce or no longer pursue vigorous R&D investments (as may be evidenced along the example of the German solar industry over the last years).