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How do policies for efficient energy use in the household sector induce energy-efficiency innovation? An evaluation of European countries

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ABSTRACT

Research on innovation induced by climate-mitigation policy has been focused predominantly on the supply side of the energy system. Despite considerable climate-mitigation potential on the demand side, less attention is given to the innovation effect of policies addressing the household sector. Based on a comprehensive data set, including 550 policy measures over 30 years (1980–2009) and covering 21 European countries, we find—based on econometric estimations—that policies targeting efficient energy use in the household sector significantly increase the number of patented energy-efficiency inventions. A comparison of the different policy types reveals a particularly strong influence from financial subsidies and energy labels. The results indicate that policies supporting early market adoption of energy-efficient technologies are effective in fostering innovation.

1. Introduction

Efficient end-use technologies adopted by the household sector have significant potential to reduce carbon emissions and provide higher social returns on investment. However, public institutions, policies, and financial resources promoting technological innovation privilege the enterprise sector and energy-supply technologies (Wilson et al., 2012). Similarly, empirical economic literature mainly focuses on the effects of environmental policies targeting industry rather than households (Jaffe et al., 2002; Popp et al., 2010). There are some exceptions, however. Newell et al. (1999) looked at the energy-efficient product characteristics of consumer durables between 1958 and 1993 and found that higher energy prices, in combination with energy-efficiency labels, induced innovations that increased the energy efficiency of such products. Noailly (2011) focused on the building sector in seven OECD countries over the period 1989–2004 and investigated the influence of three policy types (energy standards, energy prices, and public energy R & D expenditures) on patent activities; she found a positive inducement effect for energy standards (insulation standards) and public R & D.

The study at hand investigates the relationship between energy-efficiency policies that address the household sector and innovations in energy-efficient technologies. More concretely, we investigate whether the intensity of such policy activities within a country increases patent activity in energy-efficient technologies in the field of building and lighting technologies. We also provide empirical evidence about which type of policy (e.g. subsidies, standards, labels, or taxes) is more likely to induce patented energy-efficiency inventions.

Our investigation contributes to the literature in several ways. First, we draw on a very comprehensive data set comprising 21 European countries and 22 industries, and spanning three decades (1980–2009). We use patent data from PATSTAT, industry-level data from the OECD STAN database, and information on 550 policies in the MURE database. This allows for the creation of a more comprehensive model, including control variables for different knowledge stocks, energy costs, industry size, and GDP (gross domestic product). Second, we integrate our measure for policies in the household sector into a more comprehensive model, controlling for the effect of alternative policies (i.e. technology-push and demand-pull policies in the enterprise sector). Furthermore, the full set of household-related policies is disaggregated into six different sub-categories comprising subsidies, standards, campaigns, labels, voluntary agreements, and taxes. Hence, we analyze the effect of a certain policy type while controlling for other types of policies, since neglecting other policy types could bias our results for the single policy. Accordingly, we expect our study to identify a "purer" innovation effect for policies compared to previous studies, which have focused on certain types of policies exclusively. The comprehensive vector of control variables, and the variables for the different types of policies, increase the robustness of our estimation.

The results show that policies promoting efficient energy use in the

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household sector are significantly and positively related with energy-efficient innovations in the fields of building and lighting. Moreover, we see that technology-push policies (RD & D spending) are also positively related to energy-efficient inventions, which means that policies focused on the household sector do not substitute technology-push policies in directly supporting the development of energy-efficient innovations; rather, they are complementary, inducing additional patenting activities. Concerning the different policy types, we see that subsidies (fiscal deductions or financial support) and energy-efficiency labels are significantly more important for the generation of energy-efficient inventions than other policy types (e.g. standards, campaigns, or voluntary agreements). These findings are in line with the theoretical suggestion by Gillingham et al. (2009) with respect to early market adoption. They find that labels and subsidies provide incentives for early adoption and thereby effectively address learning-by-doing spillovers (e.g. firms can free-ride on the costly market introductions and related product adjustments of other firms). The evaluation of the different policy types speaks to the importance of addressing the high up-front costs for new energy-efficiency technologies (Jaffe and Stavins, 1995). Subsidies reduce initial investment costs, while labels provide information on the savings resulting from the adoption of energy-efficient inventions.

In Section 2 we present the relevant literature and develop our research questions. We then describe the data used (Section 3) and the method applied to investigate the research questions (Section 4). Finally, we present the results, draw conclusions, and reflect on policy implications (Sections 5 and 6).

2. Literature and hypotheses

Energy-efficiency technologies, and environmentally friendly innovations in general, are afflicted by the double-externality problem (Jaffe et al., 2005; Nordhaus, 2011). First, because the greatest benefits from environmentally friendly products are likely to be public rather than private, customers' willingness to pay for these innovations is below the economic optimum. Second, due to the public-goods nature of knowledge, there are significant market failures, resulting in underinvestment in R & D activities (Arrow, 1962).

As a result of these two types of externalities, markets underinvest in the generation of energy-efficient technologies. Indeed, recent studies show that such activities are either unprofitable or, at best, less profitable than investing in the generation of traditional technologies (Marin, 2014; Soltmann et al., 2014). Governments redress this market failure with policy interventions, responding to each of the two types of externality with a different sort of policy. The rather general knowledge externality is addressed by general policies, e.g. IPR (Intellectual Property Rights) protection, while the environmental externality is addressed by policies supporting the adoption of "green" technologies by, e.g., the household sector. This study investigates the extent to which the latter type of policy also contributes to the generation of innovation.

The literature distinguishes between several different types of policies that are used to offer support for energy-efficiency technologies. As Fig. 1 shows, a first differentiation is based on the direction of the stimulus for innovation activities (i.e. whether innovation is "pushed," by supporting technological development, or "pulled" by an increase in demand (Nemet, 2009)). Technology-push policies reduce the private cost of producing innovation—for example, via targeted R & D support. Demand-pull policies increase the private payoff of successful innovation through intellectual property protection; tax credits and rebates for consumers of new technologies; government procurement; technology mandates; regulatory standards; and taxes on competing technologies (*ibid.*). A second differentiation can be made with respect to the target of the policy. While technology-push policies, by their very nature, can only focus on industry, demand-pull may seek to influence either industrial or household demand. In this paper, we try to identify the relationship between demand-pull policies in the household sector and the development of end-use technologies by industry—firstly based on an overall measure, and then separately for different types of policies. In this section, we set forth the relevant literature that guides our theoretical basis in order to formulate hypotheses that will be empirically tested.

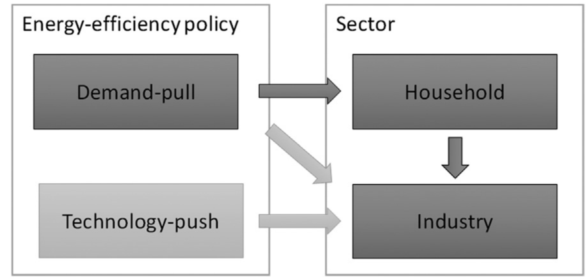

Fig. 1. Main energy-efficiency policy types and their impact on the household and industrial sectors. The effect of demand-pull policies on the development of end-use innovation in the industry (darker shaded areas) is the focus of this paper.

2.1. *Innovation impact of demand-pull policies in the household sector*

Policies focusing on the household sector should increase the demand for environmentally friendly products. As a consequence, such demand-pull policies should increase the incentives for firms to invest in the development of environmentally friendly technologies. This type of policy-induced effect was confirmed for energy prices, labels, and standards in a study by Newell et al. (1999), where innovations were measured using product modification. Moreover, Noailly (2011) identified the effect of "building codes," measured by the required thermal heat coefficient, on innovations (measured by patents). Based on these earlier findings, we expect to observe a positive effect on energy-efficiency innovations from demand-pull policies in the household sector, leading to the following hypothesis:

H1. Demand-pull policies for efficient energy use in the household sector increase energy-efficiency innovation.

To reach environmental goals also the interaction of different policy instruments and hence characteristics of the policy mix is important (Rogge and Reichardt, 2013). For the innovation impact of energy efficiency policies implemented in the residential sector Costantini et al. (2015) found that the comprehensiveness increases, while inconsistency problems can reduce the innovation impact. In line with previous findings (Hoppmann et al., 2013) the balance in technology-push and demand-pull is found to be important. While we focus in this study on clarifying the impact of the different policy types implemented in the household sector, we will investigate interaction effects of household and industry demand-pull as well as technology-push policy.

2.2. *Innovation impact of different demand-pull policy types*

Literature dealing with the innovation impact of different types of demand-pull policies in the household sector is scarce. In the following section, we describe the particularities of the household sector and energy-efficiency technologies, and their implications for the effectiveness of policy types. We also review the different types of policy deployed in the household sector to promote efficient energy use and derive an indication of their effectiveness.