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Adoption of energy-efficiency measures in SMEs—An empirical analysis based on energy audit data from Germany

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HIGHLIGHTS

- ► We empirically analyze barriers to the adoption of energy-efficiency measures in SMEs.
- ► We focus on firms participating in the German energy audit program for SMEs.
- ► The program overcomes information related barriers.
- ► High investment costs still impede the adoption even for profitable measures.
- ► Low audit quality also impedes the adoption of profitable measures.

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ABSTRACT

This paper empirically investigates factors driving the adoption of energy-efficiency measures by small and medium-sized enterprises (SMEs). Our analyses are based on cross-sectional data from SMEs which participated in a German energy audit program between 2008 and 2010. In general, our findings appear robust to alternative model specifications and are consistent with the theoretical and still scarce empirical literature on barriers to energy-efficiency in SMEs. More specifically, high investment costs, which are captured by subjective and objective proxies, appear to impede the adoption of energy-efficiency measures, even if these measures are deemed profitable. Similarly, we find that lack of capital slows the adoption of energy-efficiency measures, primarily for larger investments. Hence, investment subsidies or soft loans (for larger investments) may help accelerating the diffusion of energy-efficiency measures in SMEs. Other barriers were not found to be statistically significant. Finally, our findings provide evidence that the quality of energy audits affects the adoption of energy-efficiency measures. Hence, effective regulation should involve quality standards for energy audits, templates for audit reports or mandatory monitoring of energy audits.

1. Introduction

Improving energy-efficiency is typically seen as a key strategy to reduce greenhouse gas emissions, especially in the short and medium term. For example the results of modeling simulations by the IEA (2011) for the year 2035, suggest that under cost-minimization about half of the cumulative emission reductions required to meet the 2 °C target would have to be achieved through improved energy-efficiency. In the industry sector, this share is even higher with about 60% (IEA, 2011). Such an objective, however, would imply drastically accelerating progress in energy-efficiency improvements.

While engineering-economic studies (e.g., Granade et al., 2009) typically find substantial cost-saving potentials under current economic conditions for many energy-efficiency measures (EEMs), in reality, various "barriers" prevent households and organizations from realizing this potential (Worrell et al., 2009). Sorrell et al. (2004) classify these barriers into the following broad categories: *imperfect information, hidden costs, risk, access to capital, split incentives and bounded rationality.* Policies to overcome these barriers which target companies include energy management obligations or soft loan programs (Brown, 2001; Jochem and Gruber, 1990), subsidies for energy audits (Anderson and Newell, 2004; Schleich, 2004), best practice programs (Neale and Kamp, 2009), energy labeling schemes and minimum standards (Garcia et al., 2007). Recent policies also include combinations such as linking voluntary targets with energy management requirements or energy audits (Jochem and Gruber, 2007; Stenqvist and Nilsson, 2012; Thollander and Dotzauer, 2010). In any case, effective and

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welfare-improving policy design requires a thorough understanding of the barriers and the differences across sectors and companies (Allcott and Greenstone, 2012; DeCanio and Watkins, 1998; Schleich, 2009). For example, energy-intensive firms tend to allocate a higher priority to energy-efficiency projects than less energy-intensive firms and larger firms tend to adopt more EEMs than smaller firms (Schleich, 2009). In particular, small- and medium sized enterprises (SMEs) consider investments in energy-efficiency low priority projects, devote fewer resources to energy management, and exhibit lower adoption rates for EEMs (e.g., Cagno et al., 2010; Gruber and Brand, 1991). Thus, barriers related to information, hidden costs and transaction costs are expected to be more pervasive for SMEs, in particular for those with non-energy-intensive production processes.

Empirical analyses of barriers to energy-efficiency either rely on case studies, and therefore include only a few observations (e.g., de Almeida, 1998; O'Malley and Scott, 2004; Rohdin and Thollander, 2006), or on surveys involving larger samples. The survey results are often presented as descriptive statistics (e.g., total numbers or shares) of self-assessed barriers (e.g., Harris et al., 2000; Thollander and Ottosson, 2008). Some studies apply multivariate methods to analyze the determinants of EEM adoption (e.g., Anderson and Newell, 2004; Aramyan et al., 2007; DeCanio and Watkins, 1998; Schleich, 2009; Schleich and Gruber, 2008). However, survey-based analyses typically rely on a rather general description of EEMs and it is often not known whether the EEMs suggested are technically feasible for a particular company. Often, the profitability of the considered EEMs has to be assumed based on data taken from literature rather than empirically assessed at the individual company level.

In this study, we analyze factors influencing the adoption of EEMs by SMEs, focusing on the impact of barriers. Our empirical analysis is based on novel cross-sectional data obtained from a 2010 survey conducted in order to evaluate the German energy audit program for SMEs. Prior to the survey, all participating companies had been subject to (subsidized) in-depth energy audits. Hence, the information on the cost-effectiveness and other characteristics of the EEMs considered in the survey is specific to the individual firm. The survey also includes a set of questions (items) on barriers to the adoption of EEMs and information on general company characteristics. We employ factor analysis to empirically assess which of the barriers identified in the literature describe the same underlying factor. Grouping the items into these broader barrier factors facilitates the interpretation of the results and contributes to theory building as it allows to better relate the empirical findings to the barriers derived from the theoretical concepts. In our multivariate econometric analysis, these broader barrier factors serve as explanatory variables together with proxies for more objective barriers and for firm characteristics.

In Section 2 we review previous empirical work on barriers to energy-efficiency in industry, with a particular focus on SMEs. In Section 3 we describe the underlying data set, the variables and the analytical model used. Section 3 also includes the factor analysis of the barrier items of the survey questionnaire. Results of the econometric analyses are presented in Section 4. In Section 5 we discuss these results and derive policy implications. The final section concludes.

2. Literature review

Over the last two decades, a substantial body of literature drawing on a variety of concepts including neoclassical economics, institutional economics, behavioral economics, psychology, sociology, and management theory has analyzed why companies and individuals fail to adopt cost-efficient EEMs. The difference between the cost-efficient energy saving potential and the observed adoption of EEMs has been termed the "energy-efficiency gap" (Jaffe and Stavins, 1994). The energy-efficiency gap is the rationale for policy intervention to correct investment inefficiencies in addition to policy interventions to correct negative environmental externalities associated with energy use (Allcott and Greenstone, 2012; Brown, 2001).

For detailed discussions of different types of barriers and classifications, we refer to Brown (2001), Jaffe and Stavins (1994), Sathaye et al. (2001), Sorrell et al. (2004, 2011). We review the empirical work on barriers to energy-efficiency in the industry sector, distinguishing between case studies and surveys, and highlighting the studies which involve energy audit programs. A large share of recent empirical studies (Rohdin et al., 2007; Schleich, 2009; Schleich and Gruber, 2008; Sorrell, 2004; Thollander et al., 2007; Thollander and Ottosson, 2008; Trianni and Cagno, 2012) relies to some extent on the barrier taxonomy developed by Sorrell et al. (2004). Based on concepts taken from neoclassical economics, institutional economics and behavioral economics Sorrell et al. (2004) develop a taxonomy consisting of the following six broad categories of barriers:

- *Imperfect information*, which includes transaction costs (e.g., search costs) for identifying the energy consumption of products and services
- *Hidden costs*, which include the overhead costs for management, the transaction costs associated with gathering, analyzing and applying information, the costs associated with disruptions to production, or with staff replacement and training
- *Risk*, which captures the technical risks of energy-efficient technologies as well as the financial risks associated with irreversible investments and the uncertainty about the returns of EEMs (e.g., because future energy prices are uncertain)
- *Access to capital*, which includes lack of external and internal funds for energy-efficiency investments. In the case of external funds, the costs to assess the risks associated with the investor (e.g., small EEMs) or the technology might be too high. Internal funds may be inhibited by internal capital budgeting procedures, investment appraisal rules, or the short-term incentives of energy management staff
- *Split incentives,* which imply that the investor in EEMs cannot fully appropriate the benefits (e.g., landlord-tenant or user-investor problem)
- *Bounded rationality*, which means that constraints on time, attention, and the ability to process information prevent individuals from making "rational" decisions in complex decision problems. Rather than optimizing, they use heuristics and rules of thumb to decide on investments in EEMs.

Clearly, as pointed out by Sorrell et al. (2004) these barriers may overlap, co-exist and interact, and a phenomenon may fall under more than one barrier category. When interpreting the findings from surveys conducted after an energy audit has been carried out (e.g., Anderson and Newell, 2004; Harris et al., 2000; Thollander et al., 2007), it must be taken into account that the audit may have reduced or eliminated some barriers, such as *lack of information* and *lack of staff* (Schleich, 2004).

2.1. Case studies

Case studies are typically carried out for a few companies, and provide a better understanding of complex decision-making processes and structures within organizations. Theory-guided or explorative in-depth interviews are carried out, transcribed and analyzed to identify the relevant causal mechanisms (Yin, 1994) leading to the observed outcomes. In this sense, the findings of case