Ecological Economics 136 (2017) 240–254

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Adoption of Energy Efficiency Measures for Non-residential Buildings: Technological and Organizational Heterogeneity in the Trade, Commerce and Services Sector

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ARTICLE INFO

Article history:
Received 17 May 2016
Received in revised form 31 December 2016
Accepted 18 February 2017
Available online 7 March 2017

JEL Classification:
Q40
Q41

Keywords:
Energy efficiency
Barriers
Agency
Absorptive capacity
Adoption
SMEs

ABSTRACT

Drawing on agency theory and absorptive capacity literature, this paper empirically analyzes factors of adoption and barriers to adoption of four crosscutting, ancillary energy efficiency measures (EEMs) for non-residential buildings (efficient lighting, building insulation, heating system replacement, and optimization of heating system operations). The empirical analysis employs a large representative sample of organizations in the German trade, commerce and services sector. Results from econometric analyses provide evidence for a negative effect of principal–agent relationships (landlord-tenant; owner-user of energy supply equipment; parent-subsidiary) and for a positive effect of organizational attributes that contribute to absorptive capacity (energy manager in place; energy audit conducted; experience with decentralized low carbon energy). However, the significance of these effects varies by measure. For non-adopters, heterogeneity of crosscutting ancillary EEMs has little impact on the ranking of barriers to adoption. The most relevant barriers for all EEMs are rented spaces, high investment costs, and other priorities; least relevant are technical risk to production and risk to product quality. Finally, we find little evidence for differences in the factors of adoption and barriers to adoption between manufacturing and non-manufacturing organizations. These findings are robust to alternative model specifications.

1. Introduction

For nearly four decades, scholars have shown an interest in understanding the energy efficiency paradox (Blumstein et al., 1980; DeCanio, 1998), the phenomenon whereby the adoption of profitable energy efficiency potential, which almost all carbon abatement strategies rely on, is only partial (e.g. IEA, 2012). The paradox concerns both households and organizations and has received renewed interest in recent years (Gillingham and Palmer, 2014; Gerarden et al., 2015). This paper is concerned with efficient exploitation of organizational energy efficiency potential. A key challenge involves learning where generic energy efficiency policies are cost-efficient and where to adapt to specificities of users and measures. Determining how to balance these options requires a thorough understanding of the relevant dimensions of heterogeneity of both adopter organizations and energy efficiency measures (EEMs). However, assessments of the extent of the paradox tend to neglect relevant differences between organizations. Organizational heterogeneity causes a measurement or modeling flaw (Gerarden et al., 2015) and a systematic positive bias in assessments of efficiency potential, which is why user heterogeneity is a commonly acknowledged explanation of the observed, slower-than-expected rate of adoption of EEMs (Jaffe and Stavins, 1994a; Sorrell et al., 2004; DeCanio and Watkins, 1998; Cohen and Levinthal, 1990). Few studies, however, have investigated how organizational differences affect barriers to adoption.

The heterogeneity of EEMs has long been ignored in empirical studies that are aimed at explaining adoption and barriers to adoption (Fleiter et al., 2012a), thus corroborating the argued need for a better theoretical and empirical understanding of heterogeneity's role in the efficiency paradox.

This paper aims to make a contribution by decomposing the heterogeneity of organizations and measures and empirically investigating factors of adoption and barriers to adoption of crosscutting ancillary

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http://dx.doi.org/10.1016/j.ecolecon.2017.02.022
0921-8009/

EEMs in non-residential buildings. The paper mainly draws on literature on agency theory and absorptive capacity for explaining the role of organizational heterogeneity, and looks at the theory of diffusion of innovations to explore the heterogeneity of measures.

An original, large-sample dataset that is representative of organizations in the German trade, commerce and services sector is used for our empirical analysis.[1] This dataset enables the comparative analysis of adoption and barriers to adoption in relation to organizational characteristics for four different measures. Moreover, it mitigates hypothetical bias in its assessment of barriers by soliciting barriers to adoption from rejection cases only. The paper also explores potential differences in the factors of adoption between manufacturing and non-manufacturing organizations in the trade, commerce and services sector. Finally, it integrates more theoretical concepts of agency theory and absorptive capacity with the more applied literature on energy efficiency adoption.

The remainder of the paper starts, in Section 2, with a brief literature review related to the heterogeneity of organizations and measures in energy efficiency studies. Section 3 discusses the conceptual framework and develops the study's hypotheses. Section 4 explains the data and method. Section 5 presents the results of descriptive and econometric analyses, which are then discussed in Section 6. Section 7 concludes by summarizing our findings and discussing policy implications.

2. Literature on Adoption of Energy Efficiency: Heterogeneity of Organizations and Measures

In this section, we briefly review the literature on organizational adoption of EEMs for how it has considered and addressed heterogeneity of users and measures. We focus the review on empirical studies of adoption and barriers to adoption of EEMs in non-residential settings.

2.1. Organizational Heterogeneity in the Context of EEM Adoption

Literature on adoption of EEMs has addressed heterogeneity of organizations in a practical way: it tends to distinguish organizations by sector and/or size.[2] Studies focus on the industrial sector (e.g. Velthuijsen, 1995; de Groot et al., 2001; Sorrell et al., 2004; Sardianou, 2008) or the trade, commerce and services sector (Schleich, 2004; Schleich and Gruber, 2008; Schleich, 2009). Within the industrial sector, the literature distinguishes between the energy-intensive (Cooremans, 2012) and non-energy-intensive industry (Rohdin and Thollander, 2006; Thollander et al., 2007). Energy-intensive firms typically allocate a higher priority to energy-efficiency than less energy-intensive firms. Another focus of the literature is on small to medium-size enterprises (SMEs) (e.g. Gruber and Brand, 1991; Kostka et al., 2011; Cagno and Trianni, 2014) and within SMEs on manufacturing SMEs (Anderson and Newell, 2004; Muthulingam et al., 2011; Trianni and Cagno, 2012; Trianni et al., 2013, 2016). In their review of the empirical literature on barriers to energy efficiency in SMEs, which also form a large part of this study, Fleiter et al. (2012b) conclude that the most relevant barriers for SMEs are lack of capital, and for less energy-intensive SMEs, in particular, lack of information and lack of staff time. Most specific are studies that focus on one particular sector only, such as horticulture (Diederen et al., 2003; Aramyan et al., 2007), foundry or primary metal (Rohdin et al., 2007; Trianni et al., 2013; Cagno et al., 2015), pulp and paper (Thollander and Ottosson, 2008), or breweries (Sorrell, 2004). Such differentiation by sector and size implicitly acknowledges organizational heterogeneity and addresses it by an easily observable, practical dimension. Several of these studies that look at sectoral differences call for a more theoretical look at sources of behavioral differences in firm-specific factors (Fleiter et al., 2012b; Trianni and Cagno, 2012; de Groot et al., 2001; Sardianou, 2008). Trianni et al. (2013) make a contribution in that regard, investigating how perception of barriers to energy efficiency depends on such firm-specific factors as energy expenditures and complexity of the production, and on sector-specific factors such as variability of demand and strength of the competition. Nonetheless, empirical work on organizational antecedents of adoption of EEMs is lacking. Likewise, since empirical studies often rely on convenience sampling, the findings may not be characteristic for the population of the organizations studied. This calls for more analyses employing representative data, as is the case in this study.

2.2. Heterogeneity of EEMs

Fleiter et al. (2012a) observe that the characteristics of EEMs are a "neglected dimension" in the literature on their adoption. For example, while accounting for sectoral differences, Schleich and Gruber (2008) and Schleich (2009) rely on an aggregate indicator of measures to explore factors (including barriers) related to adoption of EEMs. In these and other studies, barrier analyses rely on subjective assessments by respondents, but it is typically not clear, whether organizations had considered adoption of a particular technology prior to rejection. Thus, responses may suffer from hypothetical bias.

The empirical analyses have only rarely distinguished between process-specific and crosscutting measures. A few case studies have looked at adoption of individual technologies or technology groups, whether crosscutting or process-specific (de Almeida, 1998; Ostertag, 2003). More recently, scholars have begun exploring the heterogeneity of measures more seriously in relation to both adoption (Fleiter et al., 2012a; Trianni et al., 2014) and barriers to adoption (Cagno and Trianni, 2014). However, representative large sample surveys substantiating the case study findings are rare (Fleiter et al., 2012b). The scant empirical literature on factors driving adoption also tends to focus on measures related to the core processes of firms, such as product and process innovations (Gruber and Brand, 1991; Sorrell, 2004; Anderson and Newell, 2004; Thollander and Ottosson, 2008; Cagno et al., 2015), but much potential is thought to reside in ancillary processes and crosscutting measures (e.g. lighting, HVAC[3]). Trianni et al. (2014) break ground as they identify no less than 192 crosscutting EEMs applicable to industrial contexts and propose a framework of 17 attributes to explain adoption rates. They group the measures in four functional categories: motors, cooling, lighting, and HVAC. Our paper addresses two of those measures: lighting and HVAC. According to Trianni et al. (2014), HVAC measures tend to have characteristics that are less favorable to adoption than lighting; they tend to have higher investment costs and higher degrees of complexity and customization, which are associated with increased hidden costs and thus possibly greater than estimated payback times. Fleiter et al. (2012a) and Trianni et al. (2014) bring lessons from the innovation diffusion literature on how innovation characteristics influence adoption (e.g., Tornatzky and Klein, 1982; Rogers, 2003; Gatignon et al., 2015) to the context of adoption of EEMs. To gain a better understanding of how the heterogeneity of EEMs affects organizational adoption, empirical studies are needed that draw on this literature and that enable insights that are representative for the organizations studied.

3. Hypotheses

We derive our hypotheses from two streams of literature to improve understanding of decision-making regarding the adoption of EEMs in organizational contexts. First, agency theory emphasizes incentive structures created by contractual arrangements and sheds light on agents' goals that guide their decisions. Second, the literature on absorptive capacity helps explain decisions regarding available alternative

[1] The scope of the sector will be described in detail in the data collection section (Section 4.1).

[2] Fleiter et al. (2012b), Cagno et al. (2013), Gerarden et al. (2015), and Gillingham and Palmer (2014) offer recent reviews of the literature on barriers to adoption of EEMs.

[3] HVAC = heating, ventilation, and air conditioning