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Investment inefficiency and the adoption of eco-innovations: The case of household energy efficiency technologies

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HIGHLIGHTS

- We explore the factors driving household adoption of energy efficiency technologies.
- We employ two high quality nationally representative cross sectional surveys.
- There is a negative relationship between investment return and level of diffusion.
- Adopters display characteristics broadly consistent with diffusion theory.
- Policy interventions, tenure effects and spill-over effects also influence adoption.

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ABSTRACT

This paper examines the factors determining household adoption of energy efficiency eco-innovations. We do so by testing hypotheses grounded in diffusion and finance theory and the literature on the barriers to energy efficiency. Using two large surveys of UK households, we explore the adoption of nine technologies. Our results indicate 'investment inefficiency' amongst household adopters occurs for two reasons. First, contrary to notions of rational choice, we find a negative relationship between the investment return of technologies and their level of diffusion. Second, we show adopters of these technologies display characteristics broadly consistent with diffusion theory, contradicting the prediction of finance theory that investment return, not individual characteristics, should drive adoption. We also find that policy has played a role in inducing the diffusion of these technologies and that tenure and spill-over effects are important in adoption. Finally, adoption is motivated more by a desire to save money than by environmental concern. We conclude by giving examples of how our research can lead to better policy timing and targeting.

1. Introduction

This paper explores the factors determining adoption of space and water heating energy efficiency eco-innovations by UK households. We do so by developing hypotheses grounded in diffusion and finance theory and the literature on the barriers to energy efficiency. Specifically, the paper seeks to answer a number of related questions: What factors drive the adoption of energy efficiency eco-innovations? Do adopters make rational choices (i.e. adopt innovations with a high investment return)? Do adopters display characteristics that are consistent with diffusion theory? Do policy interventions 'induce' the diffusion of these innovations?

The focus on space and water heating energy efficiency technologies stems from the recognition that many energy efficiency measures have high investment returns (measured by large and positive internal rates of return (IRR) or net present values (NPV) or negative cost curves) and come with corollary benefits, most notably helping to tackle fuel poverty or increasing thermal comfort (Diaz-Rainey and Ashton, 2009; Enkvist et al., 2007). From an investment theory or rational agent perspective, households and individuals should adopt these high investment return technologies even if they have insufficient capital. Thus, a technology with an IRR of 30% should, all other things being equal, be adopted by everyone who can borrow at a rate of less than 30%; in effect all households, other than the most marginalised people in society. However, numerous studies have demonstrated that an adoption 'energy efficiency gap' exists (Allcott and Greenstone, 2012; Diaz-Rainey and Ashton, 2009). This means the rate of adoption or level

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of diffusion of these technologies is below the level expected under models of 'rational' choice that narrowly focus on pecuniary incentives.

As a result, a range of targets and policies have been implemented at national and transnational levels (e.g. at the EU level, see EU Commission 2007) to 'induce' the adoption of these technologies. For the UK, the focus of this study, the national policies implemented include regulations, fiscal incentives and information provision (Diaz-Rainey and Ashton, 2009).

This paper contributes to the literature on the adoption and diffusion of energy efficiency eco-innovations in a number of ways. First, we explore the adoption of nine energy efficiency technologies at very different stages of their diffusion path, thereby allowing for one of the most comprehensive examinations of household adoption of these technologies to date. The nine technologies are triple glazing windows (TG); condensing boiler (CB); radiator/room thermostats (RT); cavity wall insulation (CWI); energy-saving light bulbs (ESLB); double glazing windows (DG); other boiler (OB – an inefficient option relative to CB); draught proofing (DP); and loft insulation (LI).[1] This is possible as we employ two high-quality, nationally representative datasets only available to the researchers and that were derived from industry–university collaboration.

Second, in order to enhance the understanding of the heterogeneity of energy efficiency technology adopters, this study examines whether household adopter characteristics are consistent with those expected by innovation diffusion theory (Mahajan et al., 1990; Rogers, 1995). Diffusion theory suggests that early adopters of an innovation have different socioeconomic status, personality values and communication behaviour to later adopters (Rogers, 1995). For instance, the earliest adopters, known as 'innovators', tend be from higher social status groups, have had more education, tend to be rational, display greater empathy and have greater social interaction. While prior studies (Bale et al., 2013; McMichael and Shipworth, 2013; Nair et al., 2010) have drawn on diffusion theory in the context of the adoption of energy efficient eco-innovations, this study extends this body of work by considering if adopter characteristics are consistent with the predictions of diffusion theory. Accordingly, our research extends the literature on the barriers to energy efficiency which has found that, contrary to the assumptions of rational choice/investment theory, adopters display adopter characteristics (deCanio and Watkins, 1998; Murray and Mills, 2011; Nair et al., 2010; Tovar, 2012).

Finally, our results allow us to observe and infer the success or otherwise of policies employed to induce the adoption of these technologies, thereby contributing to the emerging literature on induced diffusion (Davies and Diaz-Rainey, 2011; Diaz-Rainey, 2009; Jaffe et al., 2002; Rixen and Weigand, 2014).

The rest of the paper is structured as follows: Section 2 outlines the methods used, including the theoretical framework and research design; Section 3 reports the results; Section 4 provides a discussion of the results; and Section 5 contains concluding remarks.

2. Methods

This section outlines the theoretical framework and research design. Section 2.1 develops research hypotheses, Section 2.2 describes the datasets used, Section 2.3 outlines the variables employed to test the hypotheses and Section 2.4 elaborates the econometric approach.

2.1. Theoretical framework and hypotheses development

2.1.1. Rationality and investment incentives

The disparity between the observed adoption of energy efficiency eco-innovations and the higher levels of adoption expected under assumptions of rational choice have underpinned the development of the 'efficiency gap' literature (Allcott and Greenstone, 2012; Brown, 2001; Golove and Eto, 1996; Sanstad and Howarth, 1994; Schleich, 2009). The efficiency gap is caused by a variety of market imperfections, including asymmetric information, hidden costs, limited access to capital and transaction costs. While these imperfections are not contested, whether price-based policies alone can resolve the efficiency gap has become a focus of discussion. Underpinning this discourse is a wider disagreement as to the appropriateness of assumptions of rational choice among economics agents. By implication, evidence of bounded rationality would imply the use of non-price regulatory policies as well as price interventions. Allcott and Greenstone (2012) describe this problem as 'investment inefficiencies', which are differentiated from other barriers to energy efficiency that can be addressed via the price mechanism.

The preponderance of empirical evidence indicates these investment inefficiencies exist, even if their extent is uncertain (Allcott and Greenstone, 2012). The arguments advanced in support are twofold. First, the interest rates implied by economic agents when evaluating the attractiveness of energy efficiency eco-innovations range from 20% to 300% (Brown, 2001; Sanstad et al., 1995). As most agents will be able to borrow at lower interest rates, these implied interest rates are not consistent with assumptions of rational choice.

The second argument advanced in favour of the investment inefficiencies hypothesis relates to the expectation under a rational choice framework of the absence of adopters' characteristics. As noted by DeCanio and Watkins (1998, p.95) the 'discount rate for computing the present value of a project should be the return available on other projects in the same risk class, and therefore should not depend on characteristics of the firm'. Negating this, a growing empirical literature (discussed below) demonstrates that agent characteristics and heterogeneity are associated with the adoption of energy efficiency eco-innovations. From this we develop our first hypothesis;

Hypothesis 1a. In line with the literature on the barriers to energy efficiency, individuals do not make rational investment decisions as predicted by investment theory and will, ceteris paribus, display adopter characteristics.[2]

Acknowledging the existence of investment inefficiencies means that the efficiency gap debate can be advanced by exploring the 'substantial heterogeneity in investment inefficiencies across the population' and 'identify what types of consumers are induced [by policy interventions] to be more energy efficient' (Allcott and Greenstone, 2012, p. 25).

2.1.2. Adopter characteristics

The comprehension of individual and household adopter characteristics has been advanced using models of diffusion and in

[1] Hereafter and for the purposes of brevity, we refer to all energy saving innovations by these abbreviations.

[2] This does not mean that all adopter characteristics are by definition evidence of bounded rationality. The ceteris paribus qualifier in the hypothesis covers cases such as a policy intervention targeted at, say, the elderly. This would make age-related variables significantly associated with adoption but would not prove bounded rationality, since there is a logical reason for the association. Should an age-related variable be significant in the absence of a clear reason like a policy intervention, then this would indicate evidence of bounded rationality.