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The diffusion of domestic energy efficiency policies: A spatial perspective

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ABSTRACT

National domestic energy-efficiency policies are unlikely to be implemented in a geographically uniform manner. This paper demonstrates the importance of socioeconomic, contextual, and local policy conditions in shaping the spatially heterogeneous response to a national policy. Through an assessment of the geographical and temporal variation in domestic energy-efficiency assessments provided under the United Kingdom's Green Deal, the factors underpinning the spatial diffusion of this policy are identified. Spatial regression models show that the presence of young families, university educated residents, detached homes, and large households positively affects the uptake of energy-efficiency assessments whereas property market activity, personal incomes, the presence of self-employed residents, and the efficiency levels of the existing housing stock has a dampening effect. National incentives for policy implementation that are distributed through selected local authorities also work to promote the uptake of energy-efficiency assessments. Overall, the analysis clearly shows the importance of local factors in determining how national policies are implemented on the ground. This has important implications for policymakers in designing and administering national policy frameworks, in trading-off targeted implementation with fairness and uniformity, and in evaluating the local effectiveness of national policies.

1. Introduction

Achieving a successful transition to an environmentally sustainable energy system will be contingent on the widespread adoption of low-carbon technologies amongst consumers. This requirement is apparent in different energy sectors, such as the uptake of electric vehicles to service mobility needs (Dijk et al., 2013), solar photovoltaic systems to provide decentralised energy generation (Dewald and Truffer, 2012; Allan and McIntyre, 2017) and retrofits to the fabric of existing buildings to enhance their energy-efficiency (Wilson et al., 2015). Research which investigates the adoption of these low-carbon technologies tends to approach the subject either by considering the characteristics of the consumers that are likely to be receptive to the unique features of the innovation or by forecasting future rates of uptake based on expectations of demand. An important issue which has received less attention concerns how these technologies will diffuse across space (Balta-Ozkan et al., 2015). This lack of spatial sensitivity is also present in the development of policies to support diffusion, with governments tending to implement national policies including financial incentives to promote adoption, information campaigns to raise awareness, and industry grants to stimulate market development. However, the effectiveness of these policies will be dependent on local socioeconomic and environmental conditions which shape how the policy is received in a given location. Research that approaches adoption from a spatial perspective can help in identifying the effect that local conditions have on the diffusion of low-carbon technologies, assist in locating areas with the strongest adoption propensities, and provide evidence on the geography of sustainability transitions.

The objective of this paper is to demonstrate how local conditions affect the propensity of areas to adopt low-carbon technologies. This objective is pursued through an analysis of the geographical variation in the uptake of domestic energy-efficiency assessments under the United Kingdom's (UK) Green Deal energy policy to determine which factors effect spatial diffusion. Spatial regression models are used to evaluate the significance of socioeconomic characteristics of the population and the attributes of the properties to explain the observed spatial variation in Green Deal uptake. The analysis also tests whether the funding allocated to local governments to enable the pursuit of locally-designed strategies stimulated uptake. In doing so, this paper sheds light on the spatial processes at play in the diffusion of low-carbon technologies and demonstrates that the transition towards a sustainable energy system is unlikely to occur in a spatially uniform manner.

This paper is structured as follows. First, the existing literature on

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spatial issues in energy policy and low-carbon technology adoption is discussed. Second, the Green Deal as a specific example of energy-efficiency policy is explained, alongside a synthesis of previous empirical research on the factors affecting household investment in energy efficient technologies. Third, the methodology and variables used in the spatial analysis are set out. Fourth, the results of the analysis are presented and interpreted, building up from descriptive statistics to spatial regression modelling. To conclude, the paper draws implications for energy policy, and argues that spatial heterogeneity is an important factor in national policy design, implementation, and evaluation.

2. Background

2.1. Spatial perspectives on energy policy implementation

The literature which considers the effectiveness of national policies aimed at enhancing domestic energy-efficiency employs a variety of approaches including temporal analyses of policy development (Geller et al., 2006; Mallaburn and Eyre, 2014), extensive reviews of existing scientific and policy evidence (Abrahamse et al., 2005; Harmelink et al., 2008; Kerr et al., 2017), and proposals for future strategies based on past experiences (Boardman, 2004; Jollands et al., 2010; Gooding and Gul, 2017). However, geographical issues such as space, location, and environmental context do not feature as prominent topics to date. Part of this might be due to lack of data, with Harmelink et al. (2008) noting that this represents a reoccurring problem when conducting ex-post policy assessments.

The need to account for geographical issues when considering the transition to a low-carbon society is increasing in prominence with researchers describing how regional and local situations can generate substantial impacts on transition pathways (Coenen and Truffer, 2012; Coenen et al., 2012; Hansen and Coenen, 2015). The benefits of introducing a spatial perspective to energy transitions are set out by Bridge et al. (2013), who note that energy systems are spatially situated (i.e. energy infrastructures have a geographical imprint) and are embedded in particular settings. To illustrate the ways in which geographical processes influence transition trajectories, Bridge et al. (ibid.) outline a set of geographical concepts which can be translated into transition studies. One of these concepts reflects the geographical variation which is inherent across the energy system, covering the spatial differences in such issues as energy generation, demand, and low-carbon resource availability. A similar perspective is put forward by Balta-Ozkan et al. (2015), who note that demographic structures are not spatially homogenous and that this will likely affect how receptive areas are to certain low-carbon technologies. The concept of geographical variation is also a prominent feature in Raven et al. (2012) proposed extension of transition frameworks to acknowledge the impact of spatial heterogeneity in endowments and circumstances on the processes of transition.

These conceptual contributions are complemented by a growing body of empirical studies which investigate the spatial diffusion of energy technologies. To date, the majority of such research has concentrated on the adoption of domestic solar photovoltaic (PV) systems (Allan and McIntyre, 2017; Dharshing, 2017). This is likely due to the prominence of solar PV in low-carbon transition pathways, their targeting by national energy policies (such as feed-in tariffs), as well as the 'visibility' of installed PV systems. Kwan (2012) investigates the effect that climate, economic, social, and political factors have on the installation rates of PV across different zip codes in the United States. He finds that the level of solar irradiance is the most useful factor in explaining spatial variation in PV adoption, with the cost of electricity and the presence of local incentives to encourage adoption also being relatively important. Davidson et al. (2014) similarly explore the rate of PV deployment at the zip code level in the state of California. They examine the effect of factors such as household size, car availability, home tenure, foreclosures, and the registration rates of alternative fuel vehicles (e.g. hybrid electric vehicles). Their modelling finds that property size, rate of foreclosure, and rate of hybrid electric vehicle adoption are important factors in the rate of PV uptake. Recently, attention has turned to investigating the importance of peer effects on the adoption of PV (Bollinger and Gillingham, 2012), with the work of Graziano and Gillingham (2015) clearly demonstrating that the installation of nearby PV systems in the past effects the likelihood of neighbours adopting PV systems in the present. These peer effects have also been observed in the work of Noonan et al. (2013) for heating, ventilation, and air conditioning systems, whereby the adoption of these systems in certain neighbourhoods is found to positively affect the rate of adoption in nearby areas.

The empirical analysis of Green Deal uptake presented in this paper contributes to this growing body of literature in two ways. First, it examines geographical variation in energy efficient technologies within the home, which is an under investigated area of critical importance to national emission reduction strategies. Second, it demonstrates that spatial heterogeneity in national policy implementation is linked to local socioeconomic population characteristics, property attributes, and local government strategies for channelling national incentives. More generally, the case study provides an example of how transitions towards a low-carbon society can progress in a spatially uneven manner, which has implications for how policies are designed and evaluated in both public institutions and commercial settings.

2.2. The Green Deal

The Green Deal was a domestic energy-efficiency policy implemented by the Department of Energy and Climate Change (DECC) in the UK. Introduced in January 2013, the Green Deal ran for over two years before financial support was withdrawn in July 2015. Although certain elements of the Green Deal remain in place, activity levels fell sharply after July 2015 (see Fig. 1). The structure of the Green Deal was quite innovative in nature, involving a number of different components designed to address widely-recognised barriers to energy-efficiency investments (Weber, 1997; Pelenur and Cruishank, 2012; Pettifor et al., 2015; Wilson et al., 2015). Mallaburn and Eyre (2014, p. 23) define the Green Deal as "a market-based, demand-led financial mechanism providing up-front loans for energy-efficiency measures, which are repaid using the energy savings". The implementation of the Green Deal in a particular household progressed through a series of stages shown in Fig. 2.

The research presented in this paper concentrates on the uptake of Green Deal Assessment (GDAs) by households. These technical assessments involved the evaluation of the energy profile of a property by a qualified assessor with the production of an Energy Performance

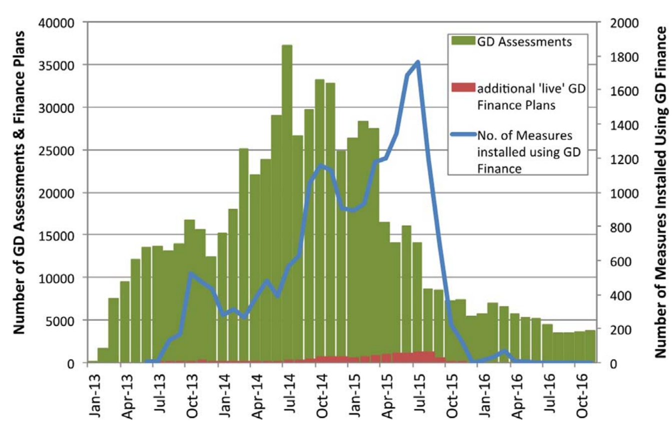

Fig. 1. Numbers of Green Deal Assessments (green columns, left y-axis), Green Deal Finance Plans (red columns, left y-axis) and measures installed using Green Deal Finance (blue line, right y-axis). (*Source*: BEIS, 2017). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).