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Regional distribution of photovoltaic deployment in the UK and its determinants: A spatial econometric approach

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ABSTRACT

Photovoltaic (PV) panels offer significant potential for contributing to the UK's energy policy goals relating to decarbonisation of the energy system, security of supply and affordability. The substantive drop in the cost of panels since 2007, coupled with the introduction of the Feed-in Tariff (FiT) Scheme in 2010, has resulted in a rapid increase in installation of PV panels in the UK, from 26.5MWp in 2009 to over 5GW by the end of 2014. Yet there has been no comprehensive analysis of the determinants of PV deployment in the UK. This paper addresses this gap by employing spatial econometrics methods to a recently available data set at a fine geographical detail. Following a traditional regression analysis, a general to specific approach has been adopted where spatial variations in the relationships have been examined utilising the spatial Durbin model using the cross-sectional data relating to the UK NUTS level 3 data. Empirical results indicate that demand for electricity, population density, pollution levels, education level of households and housing types are among the factors that affect PV uptake in a region. Moreover Lagrange Multiplier test results indicate that the spatial Durbin model may be properly applied to describe the PV uptake relationship in the UK as there are significant regional spillover effects.

1. Introduction

UK climate change and energy policy goals legislate an 80% emissions reduction target from 1990 levels by 2050 via the Climate Change Act (CCA, 2008) while ensuring security of supply and affordability. Additionally, the European directive 2009/28/EC imposes a target for the UK to meet 15% of all energy consumption from renewable energy sources by 2020 (EC, 2009), a commitment reaffirmed in various UK policy documents (e.g., DECC, 2012a). Photovoltaic (PV) panels offer a significant opportunity to achieve both these goals. By transforming domestic consumers into 'prosumers'[1] PV allows them to self-generate and export remaining electricity, consequently reducing their purchases from the grid while contributing to decarbonising and diversifying UK electricity supply.

Installed global PV capacity has increased from 1.4GW in 2000 to 70GW in 2011 (IEA/IRENA, 2013), and on to 177GW by the end of 2014 (IEA, 2015), a rise both linked to and driving improved performance and efficiency due to technological progress and economies of scale. There is a growing literature focusing on large-scale, commercial PV applications, including comparison of their performance (Sueyoshi and Goto, 2014); analysis of their market value (Hirth, 2013); optimal size and timing of investments (Massetti and Ricci, 2013) and effect of policy framework on investor preferences (Lüthi and Wüstenhagen, 2012). Policy incentives such as the Feed-in Tariff (FiT) schemes have played a significant role in promoting domestic applications (Zhang et al., 2011). Indeed following the 2010 introduction of the UK Feed-in Tariff (FiT) Scheme, annual installation rates for PV panels has increased by a factor of nearly two hundred in the UK in under five years (from 26.5 MW in 2009 to over 5GW by the end of 2014, DECC (2015a)). The Government estimates that the FiT will engender 7.5GW of PV capacity by 2020, with other mechanisms stimulating a further 1.8–3.2 GW at larger scale capacity (DECC, 2013). A typical domestic PV (at 2.6kWp capacity) costs around £5300 according to data collected relating to FiT eligible PV installations (DECC, 2014b), a figure which has reduced significantly in a relatively short period of time as cell costs and thus overall installation costs have reduced sharply. FiT rates have been reduced significantly since 2010 to try to match the real world cost reductions.

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[1] Prosumers also includes consumers who produce their own power from a range of different onsite generators (e.g. diesel generators, combined heat-and-power systems, wind turbines, and PV systems) (IEA-RETD, 2014).

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However only a small fraction, (2.4%), of the UK's nearly 26 million households have installed a rooftop PV panel as of December 2014. A variety of factors, from social (e.g. reserving roofspace for PVs, Wolsink, 2012) to economic (e.g. cost reductions Muhammad-Sukki et al., 2013) to policy incentives (Faiers and Neame, 2006; Grau, 2014) have been highlighted in the literature to explain the drivers and barriers to the uptake of PVs. Thus far studies of domestic adoption of PV are characterised by either detailed, qualitative analysis based on interviews/surveys (Cherrington et al., 2013; Faiers and Neame, 2006) or quantitative analysis via econometric methods (Jenner et al., 2013; Zhang et al., 2011). Following the first law of geography, '*everything is related to everything else*, *but near things are more related than distant things*' (Tobler, 1970, p.236), there is an understanding that low carbon technologies like PV or electric vehicles are likely to form local clusters (Balta-Ozkan et al., 2014a). Yet, by ignoring the spatial proximity and clustering of PVs, we argue that these methods do not offer a framework to understand the spatially dependent nature of low carbon transitions (Bridge et al., 2013).

A key characteristic of this study is to analyse the determinants of PV uptake in association with neighbouring regions, building on a similar study carried out for Germany (Schaffer and Brun, forthcoming). Such a spatial analysis is important for a number of reasons. Firstly, the availability of solar energy varies by location as well as time (weather conditions and time of day/season). Secondly, distributed PV can create reverse flows on the networks that were designed for uni-directional electricity flows from centralised, dispatchable sources to demand points. These two factors jointly diminish predictability of load, voltage and demand flows, especially on low voltage networks. As a result, domestic PV, which is highly distributed, presents a key challenge for network operators in managing the grid such that there is enough capacity and voltage headroom available to accommodate these flows. Thirdly, an analysis based on large datasets, rather than a limited number of observations, is likely to produce more robust findings to understand PV deployment patterns and their determinants across the UK.

Moreover, in a related literature, the theory of social action highlights the importance of social associations on an individual's consumption decisions (among others, Bagozzi, 2000; Weber, 1978). Kaplan (1999) applies an adoption theory framework to understand the factors that influence electric utility managers' interest in solar power. He emphasises the importance of prior knowledge or familiarity with the new technology in diffusion of solar panels.[2] Similarly social influence, attitudes towards the environment and consumer lifestyles are key factors for energy consumption decisions (Lutzenhiser, 1992, 1993; Weber and Perrels, 2000; Wilson and Dowlatabadi, 2007). Jager (2006) discusses consumer motives for adopting photovoltaic systems from a behavioural–theoretical perspective. He identifies different types of needs, such as belongingness, the ownership of a PV system by friends/neighbours and participating/collaborating with other people in installing a PV system which may lead to peer effects. Installation of a PV panel creates a persistent signal that peers (neighbours) can observe which may generate externalities affecting the overall diffusion process (Bollinger and Gillingham, 2012; Snape and Rynikiewicz, 2012). Given that such peer effects will be stronger in spatially adjacent areas than more distant ones, to capture such social spatial spillovers a spatial analysis framework is needed in establishing the drivers of PV uptake. Spatial econometrics offers a framework to test the influence of these externalities using large data sets where the smaller the spatial unit of analysis the better capabilities to capture these effects.

This paper addresses this gap by applying spatial data analysis and spatial econometrics methods for the first time, to the best of our knowledge, to analyse the determinants of domestic PV uptake at a regional level in Great Britain.[3] The research highlights that rather than income, accumulated capital and financial savings are the key drivers for PV uptake in the UK. The consumers with high electricity demands are the early adopters, indicating consumers' understanding of the economics of PV tariffs.

The paper is organised as follows: Section 2 outlines UK PV policy while Section 3 offers a concise literature review. The methodology is presented in Section 4. Model specification and the data are summarised in Section 5. The results are presented in Section 6while the last section is devoted to conclusions.

2. UK policy on photovoltaics

After years of slow progress, the UK has had a sudden rapid increase in deployment of solar PVs. According to the latest statistics, in 2013, over 2TWh of electricity was generated by solar PVs, compared to 20GWh in 2009 (DECC, 2014a). This can be seen as a direct response to the 2010 introduction of the ongoing Feed-in Tariff (FiT) scheme and its co-incidence with a substantive drop in the cost of PV panels since 2007 (DECC, 2013).

The 2009 figure is indicative of the limited UK effort on PV until that point. Support prior to 2009 was largely limited to grants for small-scale applications, with the technology absent from early non-grant financial instruments like the Non-Fossil Fuel Obligation (NFFO) (Mitchell, 2000). The Solar Photovoltaics Major Demonstration Programme (2002 – 2006, £26 m, extended to £31 m) provided capital grants of 40–50% of costs, supporting 1200 domestic and 180 commercial installations. The Low Carbon Buildings Programme (2006–2010, £30 m, extended by £50 m) superseded this and included support for PV. The Energy Efficiency Commitment (EC) (2005–2008), Carbon Efficiency Reduction Target (CERT) (2008–2011) and the Energy Company Obligation (ECO) (2012 onwards) each obligated large UK utilities to improve energy efficiency or reduce carbon emissions among domestic consumers. Micro-generation technologies, including PV, counted towards the CERT and ECO targets but cheaper options meant this did not happen in significant volume.

The Renewables Obligation (RO) is at time of writing the main source of financial support in the UK for renewable energy sources of electricity (RES-E) above 5 MW, though it is currently being phased out. It is a form of quota mechanism which places an obligation on supply companies to source RES-E (Woodman and Mitchell, 2011). The RO included PV from its 2002 inception though its initial technology blind approach primarily directed financial support to more mature – and less costly – technologies. The RO was split into bands in 2009 and PV awarded two Renewables Obligation Certificates (ROCs) instead of one for every MWh generated. PV was then separated into two bands from April 1st 2013, 'building mounted solar PV' and 'ground mounted solar PV', with the latter receiving slightly more ROCs per unit energy, as in Table 1. Once a project is online it receives the specified number of ROCs per MWh generated for its start date over its eligible lifespan (Woodman and Mitchell, 2011). These two bands are expected to be available to new entrants until March 31st 2017 when the RO will close to new applicants.

The low UK PV capacity to 2009 is indicative of the RO's failure to provide any significant stimulus to PV. The few PV plants active by 2010 were under 50 kW and at this point became eligible for transfer to a new Feed-in Tariff (FiT) scheme introduced for RES-E (only about 20 kW remained within the RO) (Ofgem, 2013c).

The UK's FiT is a fairly straightforward example of a tariff mechanism, though it has increased in complexity since its introduction. The FiT pays qualifying RES-E technologies a fixed sum per unit of electricity generated, varying with the technology and the scale of the development. The PV tariffs have 'degressed' (that is, reduced according to a formula) on a quarterly basis since August 2012 to try to mimic the falling

[2] On a related point, Hargadon and Douglas (2001) discuss how Edison framed incandescent light around contemporaneously familiar gas lighting system and how this impacted its acceptance and diffusion.

[3] While the study refers to the United Kingdom, the empirical analysis is limited to Great Britain, that is, the UK excluding Northern Ireland.