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When households go solar: Determinants of uptake of a Photovoltaic Scheme and policy insights

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ABSTRACT

The need to reduce dependence on fossil fuels has resulted in escalating interest in renewable energy generation. Yet few countries have seriously tested household potential to produce energy from PV panels. Propelled by mandatory EU targets for renewable energy, and constrained with limited territory, the Government of Malta launched a subsidy scheme with a view to encouraging PV installation by households. The scheme reached the desired adoption levels within a very short period of time. The study takes an entire-country dimension to assess the determinants of household investment in PV panels. A unique dataset is specifically constructed for this study. We find that the prevalence of younger households, higher incomes, dwelling ownership and unshared roof space results in higher rates of uptake. Neither higher educational levels nor the participation in other environmental schemes (recycling) contribute any explanatory power to uptake of PV panels. Pro-government sentiment (captured by voting outcomes) significantly and positively influences the take-up of the grant and installation of PV panels. We conclude by identifying some pointers for policy makers interested in harvesting the potential of households.

1. Introduction

Climate change has spurred several international bodies to adopt ambitious targets for the reduction of climatic emissions, to reduce dependence on fossil fuels, and to generate energy from renewable sources (UNFCCC, n.d.; European Commission, 2014). One technology that is receiving particular attention is that which employs Photovoltaic (PV) systems to convert solar power into electricity (Kwan, 2012; Wustenhagen et al., 2007). Efforts have mainly focused on diversifying energy *production* through the installation of solar farms, in several countries (Solangi et al., 2011). But such a strategy requires the availability of large tracts of land (see, for example, African Development Bank Group, 2014), with potential impacts on other productive activities (like agriculture), and the environment itself - for instance, on biodiversity.

A small number of countries have considered the potential of using households to produce energy from PV sources in their own dwellings. These include Australia and Belgium which have secured a 15 per cent and 7 per cent penetration rate in residential PV by 2015 respectively (Gifford, 2015; Energy Supply Association of Australia, 2015). Despite initial uncertainties, there has been exponential growth in the industry, specifically due to government policies contributing to PV panels' return on investment (Cherrington et al., 2013). Increasingly, across Europe, the use of feed-in tariffs has contributed positively towards adoption (Jenner et al., 2013). The European Union (EU) provides numerous financing schemes, among which are the European Energy Programme for Recovery (EEPR) and the European Energy Efficiency Fund (EEE-F), to help countries and regions in financing their energy projects (European Commission a., n.d.).

Propelled by a need to meet mandatory European Union (EU) targets for renewable energy, and faced with the constraint of limited territory, Malta was one of the first countries to rely almost exclusively on households to achieve its clean energy goals. A subsidy scheme was launched in 2009, encouraging households to install PV systems on their own premises, so as to feed the electricity supply grid. Understanding the conditions which led to the uptake of this scheme can provide useful insights not only for the extension of the scheme in Malta itself, but also for application in other territories (including insular), whose governments may be interested in harvesting the clean energy production potential of households. The availability of regional data describing the scheme's uptake and data on the characteristics of the regions themselves make it possible to assess the determinants of uptake in Malta. Moreover, diversity in vote at regional level, makes it possible to assess the role of pro-government sentiment in the initial uptake of a PV scheme. This, we argue, could be an issue which merits particular attention in the design and roll-out of a PV scheme, given the

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nature of PVs as a public-good with links to government, and whose return may only accrue in the longer term.

While a number of studies in the economics literature have examined the determinants of green energy *consumption* or energy reduction behaviour by households, far fewer studies have examined the question of what induces households to invest in systems, and to actually produce renewable energy themselves. Of these, only a handful have looked at the role of political preferences and none have examined pro-government sentiment specifically. Section 2 of this paper provides a review of the relevant literature on the topic. This informs our conceptual model of investment in PV systems by households, which we consider to be driven by economic motivation and environmental preferences and constrained by limitations, like income and space, which households may face. We then set out to test whether government intervention and pro-government sentiment also help explain the uptake in PV systems. Following a description of the data available in Section 3, Section 4 presents the analysis. Section 5 concludes with implications for policy and suggestions for further studies.

2. Literature review

In line with the developments on the ground, a rich academic literature has started to develop on household energy behaviour. In economics, this has mainly focused on energy consumption. Several studies have examined the willingness of households to pay for electricity produced from clean energy sources (Kotchen and Moore, 2007; Ozaki, 2009; Diaz-Rainey and Ashton, 2011; Zoric and Hrovatin, 2012), including the behavioural motives for willingness-to-pay for green electricity (Welsch and Kühling, 2009; Shi et al., 2013). Research close to our own investigation includes that by Palm and Tengvard (2011), which employs in-depth interviews to investigate the motives for, and barriers to, household adoption of PV or micro-wind turbines in Sweden (Palm and Tengvard, 2011). Similar studies investigate the determinants of uptake of PV systems, and citizen participation initiatives (CPI) in PV (Faiers and Neame, 2006; Bollinger and Gillingham, 2012; Zhai and Williams, 2012; Lange et al., 2014; Fleiß et al., 2017), while others focus on *intent* to adopt (Sardianou and Genoudi, 2013). A number of authors have focused on the role of government policies on uptake of PV (Gadenne et al., 2011; Solangi et al., 2011; Hsu, 2012; Kwan, 2012; Cherrington et al., 2013; Jenner et al., 2013; Bauner and Crago, 2015). Relevant studies, conducted in the same context as our study, include Gauci and Bezzina (2012), who investigate the sustainable energy behaviour, and Briguglio et al. (2015) who conduct a similar regional study to examine the determinants of recycling uptake (Gauci and Bezzina, 2012; Briguglio et al., 2015).

In assessing the drivers of household investment in PV production, the most obvious motive from an economic perspective is that PV systems yield financial benefits in the shape of savings on electricity bills. A survey-based study in Austria finds that economic motives are the main drivers behind participation in two PV-CPIs (Fleiß et al., 2017). A key determining factor which affects demand, is the price of substitutes - namely the price of conventional electricity (Fokaides and Kylili, 2014). By this reasoning, a shorter pay-back period would also stimulate more investment (e.g. households with higher energy consumption). Small scale farmers are more willing to invest as the payback period gets shorter (Brudermann et al., 2013). Larger households are also found to be more likely candidates of PV investment (Welsch and Kühling, 2009) - even if household size can have a negative impact on voluntary contributions towards a clean energy programme (Kotchen and Moore, 2007). It is also reasonable to expect that the younger the household, the longer the scope for enjoyment of payback from the investment. Lange et al. (2014), in fact, find that older individuals have a lower propensity to install renewable energy sources (Lange et al., 2014). A negative relationship between age and willingness-to-pay is likewise found in the context of potential adopter of green energy tariffs in the UK (Diaz-Rainey and Ashton, 2011), and of green electricity in Slovenia (Zoric and Hrovatin, 2012). Shi et al. (2013) offer a nuanced conclusion, namely that younger individuals are more likely to enter the market for green electricity but that they are willing to pay less than their older cohorts due to lower earnings (Shi et al., 2013).

Beyond financial motives, a different set of reasons for investment in PV panels stems from their nature as a cleaner energy source, and their positive environmental effects. Energy produced from renewable sources lowers demand for electricity reliant on fossil fuels thereby reducing air and climatic pollution. When a household generates renewable energy, society as a whole benefits (Kotchen and Moore, 2007). This dimension of energy production suggests that another type of motive which could co-determine household uptake is the fulfilment of pro-environmental preferences (Clark et al., 2003). In the broader field of pro-environmental household behaviour, the concept of 'warm glow' altruism (Andreoni, 1990) has proved to be a useful theoretical construct by which to explain why some households contribute to the environment rather than free-ride on the efforts of others. According to this theory, it is possible that individuals derive private utility from the very act of contribution to a public good. In their US survey, Kotchen and Moore (2007) find that altruistic motives are positively and significantly related to a household's voluntary contributions towards a clean energy programme (Kotchen and Moore, 2007). Environmental attitudes and ecological concern had positive and significant effects on willingness-to-pay for green electricity in the UK and a number of OECD countries (Diaz-Rainey and Ashton, 2011; Shi et al., 2013). Similar results are also obtained on awareness and willingness-to-pay for green electricity in Slovenia (Zoric and Hrovatin, 2012). There is evidence that efficacy belief (making a difference) can be a driver to adoption of green electricity (Ozaki, 2009), as well as feelings of responsibility towards future generations (Palm and Tengvard, 2011). In contrast, however, Fleiß et al. (2017) do not obtain statistically significant results for pro-environmental desires in PV-CPI participation in Austria (Fleiß et al., 2017).

For similar reasons, education, which can proxy both environmental awareness as well as understanding of the incentives for renewable energy has also been found as a positive and significant determinant of PV uptake (Shi et al., 2013). Social motives for uptake of PV schemes have also been documented. Bollinger and Gillingham (2012) find that peer effects have a significant impact on consumer behaviour in purchasing PV systems: individuals in California are influenced by their neighbours' decisions, especially if they live in a large household or have longer commutes (Bollinger and Gillingham, 2012). Brudermann et al. (2013) document social reasons for adopting PV systems, including strengthening social standing in the community. Social influence, in turn, appears to be dependent on the level of trust and goodwill in the community (Brudermann et al., 2013).

Insights from the literature also suggest that household behaviour in the energy field responds negatively to costs, including perceptions thereof. In residential PV adoption in Arizona, both installation and maintenance costs suppress uptake (Zhai and Williams, 2012). The same is found in the context of consumers' intention to adopt PV in Greece: perceived high installation and maintenance cost affect negatively intentions to adopt (Sardianou and Genoudi, 2013). A review of the literature further suggests that there exists a perception of PV as being of excessively high cost (Bazilian et al., 2013). High initial outlays deter demand for PV systems in the US (EdwardBurns and Kang, 2012). Indeed, in some contexts, having the necessary cash (or access to credit) to finance the initial investment is an important consideration. Less wealthy individuals are less likely to use PV systems (Welsch and Kühling, 2009), while higher household income was also found to be a positive and significant determinant of willingness-to-pay for green energy (Diaz-Rainey and Ashton, 2011). Labour status is sometimes used as a proxy for credit constraint. White-collar, self-employed or civil servants are more likely to use solar systems (Welsch and