INCENTIVES FOR THE ENERGY TRANSITION: FEED-IN TARIFFS, REBATES OR A HYBRID DESIGN?

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Section 1: Overview

In the last decades a rich variety of policy tools have been introduced around the world to support the uptake of residential solar photovoltaic (PV) and other technologies to help decarbonize the grid. While the literature has focused on determining the optimal level of incentives and their schedule through time (Langer and Lemoine, 2018; van Benthem et al., 2008) or on identifying the impact of given policies (De Groote and Verboven, 2019), less has been done on how different design choices affect the uptake of the technology, their siting, and therefore the cost-effectiveness of the decarbonization effort.

In this paper, I analyse two design features that policymakers have to consider: (i) whether to provide the incentive upfront or through periodic payments over time, and (ii) whether to pay per system installed (system-based incentive) or per electricity generated (output-based incentive). Common incentive schemes, such as rebates and feed-in tariffs (FITs), use opposite combinations of these features. Rebates decrease the upfront cost of installing a system, while a FIT pays the PV owner for the electricity that their system generates and transfers to the grid over time. Different combinations of these features are nevertheless possible, and, depending on the elasticity and time discounting parameters, might even have advantages over the existing policies.

To assess this possibility, I set up a model of the policymaker's decision of incentive design and of the household decision to install a PV system, and empirically estimate the parameters of interest, obtaining the elasticities of demand for residential PV with respect to the FIT payments and with respect to the installation cost. As system-based upfront incentives are effectively a discount on the installation cost, changing the sign of the latter provides the elasticity to this type of incentives.

To isolate the role of each of the two features of interest, I first look at how households trade off the upfront installation cost and the future FIT payments, obtaining the implicit time discount rate of households needed to compare the cost-effectiveness of upfront as opposed to periodic payments. To assess the choice of system-based or output-based incentives, I then construct an hypothetical payment scheme that is identical to the existing FIT in terms of schedule over time and frequency and duration of the payments, but pays a fixed amount per system rather than an output-dependent amount (set to be revenue neutral for comparability). Fitting the estimated parameters to this new variable and to the existing FIT, I predict the number and location of PV systems that would be installed under each design, net of the infra-marginal installations that would have occurred even without incentives. Finally, I calculate the cost per kWh generated and per emission reductions of each design to compare their cost-effectiveness.

The paper contributes to the economic literature on technology adoption, the future of electricity system regulation, load and capacity management, and integration of renewables, and discusses practical policy alternatives to improve cost-effectiveness of renewables incentives, given budgetary pressure. As many incentive schemes for PVs are being phased out citing high cost and regressivity concerns, assessing the cost-effectiveness of this type of policies and ways to improve them is extremely relevant for policy and to inform future incentive designs.

Section 2: Data and research approach

Data come from the UK FIT scheme, which was in place between 2010 and 2019. The reason for this choice is that this is a purely output-based design, where households are paid periodically for each kWh generated in the period, no matter whether the electricity is then self-consumed or goes into the grid, and with no net-metering. This simplifies the modeling and data requirement to isolate the effects of interest. The second reason for this choice is that the FIT rate changed multiple times a year, providing useful variation to identify the parameters and remove seasonality effects. The rate the household receives for each kWh generated depends on when the system is installed and is then paid for 20 years, indexed for inflation. Changes in the rate only affect new applicants, while nothing changes for households who have already installed.

For the empirical analysis I compile a novel dataset from several sources. The unit of observation is the Middle-Layer Super Output Area (MSOA), a statistical construct developed within the UK census to ensure within-homogeneity and between-comparability of socio-demographic characteristics and comparable population size in each unit (2,000-6,000 households). The final dataset is a monthly panel of observations for the entire duration of the FIT program. The date of installation, location, and capacity of residential PV systems come from Ofgem (Office of Gas and Electricity Markets), as do the data on the FIT rate at each point in time. The expected annual FIT payment per kW of installed capacity is obtained as the product of expected electricity generation in each location (range: 700-1125 kWh/year; from the Photovoltaic Geographical Information System, PVGIS) and the FIT rate in place at the time of installation (range: 4-50p/kWh). Data on the cost of installing each system are provided by the Microgeneration Certification Scheme (MCS). Other covariates including electricity prices, average electricity consumption, population density, type of housing, median house price, socio-economic and employment information, and age composition come from the census, employment datasets from the office of national statistics, and various government departments.

To empirically estimate the demand for residential PV, I use a Poisson regression (Silva and Tenreyro, 2006; Wooldridge, 2010, Chapter 18). To address measurement errors and endogeneity concerns, as well as omitted variable bias, I use an estimator based on Gillingham and Tsvetanov (2019) which is consistent for a Poisson regression with endogenous regressors and fixed effects. The model is based on the control function approach and standard errors are bootstrapped. The cost of installation is instrumented using an international PV price index following Gillingham and Tsvetanov (2019) and De Groote and Verboven (2019). The FIT payment is instrumented using the tentative FIT rate schedule drafted before the policy was first introduced. Several robustness checks are performed, including linear and tobit models.

Section 3: Preliminary results

The elasticity parameters estimated are high, pointing to the fact that households are highly responsive to changes in the incentives and costs of solar PV systems. When comparing system-based (i.e. geographically undifferentiated) incentives with output-based ones, both provided periodically, I find that the latter insures that systems are sited in locations with higher solar generation potential. In fact, the predicted siting under the hypothetical system-based incentive is even negatively correlated with the solar generation potential. Looking at the role of covariates in the model and their distribution over the country, I find that the latter result is due to some contextual drivers of PV adoption, e.g. low population density, high electricity consumption, owner-occupied houses and working from home, which in the UK happen to be more likely in areas with low generation potential. These covariates could be used to better target the incentives and achieve more efficient siting.

The implied annual discount rate is also estimated to be high, at 14-20%. As long as the incentive provider can borrow at a lower rate, this level of discounting suggests that upfront payments would be more cost-effective. In fact, when I calculate the cost of the policy in terms of electricity generated and avoided emissions. Using conventional 5% discount rate the avoided emissions and clean electricity generated are very expensive: 313 GBP per metric ton of CO_2-eq avoided; 0.16 GBP per kWh generated. Yet, when using the estimated implicit discount rate the cost of the policy drops to 0.06 GBP per kWh generated and 135 GBP per metric ton of CO_2-eq avoided, comparable with estimates for upfront rebates in California. This suggests that a large part of the incentive goes to cover households 'impatience', and that the cost of the policy could be lowered by providing the incentive upfront.

Section 4: Conclusions

To conclude, the results of the paper suggest that incentives that are provided upfront and in an amount dependent on the generation potential would be a more cost-effective solution for decarbonization than periodical output-based payments and upfront system-based rebates. Contextual factors and their distribution over the territory are also relevant for the siting of the systems and can be leveraged for policy targeting.

As budgetary and distributional concerns are putting green incentive schemes under scrutiny, rigorous assessments of these policies and their design is critical and urgent. This paper contributes to these efforts, so that we can learn from past experiences and improve future policy design in the energy sector and beyond.

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