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The impact of solar subsidies on California's non-residential sector

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ABSTRACT

Understanding how policies can be used to induce technological change, specifically in the area of renewable energy, is crucial for reaching environmental goals. This paper examines the impact of subsidies from the California Solar Initiative (CSI) on non-residential adoption of solar panels. We find evidence that firms do respond to higher solar subsides by increasing their intensity of solar energy. A 10% increase in the subsidy amount leads to an increase in solar capacity by between 1.36% and 2.55%. In addition, although peer effects seem to play an important role in solar adoption decisions, we do not find evidence of peer effects in the intensity of adoption. Both of these findings add a unique perspective to the growing literature on solar energy. This study is also of interest to policy makers who must understand the benefits and costs associated with higher subsidies for inducing technology adoption.

1. Introduction

In the past two decades, California has aggressively pursued environmental policies aimed at increasing renewable energy to improve environmental quality and prevent climate change. The most prominent policy in the state effort is the Renewable Portfolio Standards (RPS), which in 2008 mandated that 33% of electricity sales come from renewable sources by 2020. To encourage rooftop solar photovoltaic (PV) installations by residential and non-residential entities, the California Solar Initiative (CSI) established a large-scale rebate program from 2007 to 2016. Arguably, CSI is responsible for the proliferation of rooftop solar PV systems in the state. In 2016, California alone made up of 43% of the total U.S. rooftop solar PV electricity generation, with about 5100 MW (megawatts) of total capacity (U.S. Energy Information Administration, 2017a). As more state and national governments promote solar electricity generation and as California moves forward to meet the 2015 amendments of the RPS, which mandates that 50% of electricity sales come from renewable sources by 2030, the evaluation of CSI and rebate programs like it become even more important.

Although the literature on solar subsidies is growing, there are still unexplored areas of research.[2] For instance, households, commercial entities, non-profit organizations, and government entities have all installed solar PV systems and received subsidies under CSI in California, but the literature on solar subsidies almost exclusively focuses on the residential sector. Non-residential solar PV capacity is increasingly a significant portion of small-scale generation; in 2016, about 48% of all small-scale solar generation was non-residential (U.S. Energy Information Administration, 2017b). In addition, existing papers on solar subsidies focus on adoption rates (Bollinger and Gillingham, 2012; Hughes and Podolefsky, 2015), but looking at non-residential adoption allows for the examination on the size of the installation. Thus, the purpose of this paper is to address these unexplored topics and better understand the effect of CSI subsidies on the size of non-residential solar PV installations. Although there are other solar technologies, like solar water heating systems and utility-scale solar power plants that play a role in meeting RPS, this paper focuses exclusively on solar PV systems installed on rooftops by the owner or occupant of the building.

This research falls within the framework of technological change, with the technology change being the proliferation of solar energy in California in the last two decades, through the mechanism of induced innovation. Induced innovation refers to the response of firms to engage in profit maximizing R&D to create new technologies in a response to an environmental or general policy, that they would not otherwise have engaged (Jaffe et al. 2002). For California, we can think of the RPS

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[2] The terms subsidy, output subsidy, and rebate are used interchangeably throughout the literature. For consistency, we primarily use the term subsidy throughout the paper.

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regulation as a mechanism to induce innovations (a supply-side policy) in renewables and CSI a mechanism to induce solar adoption (demand side policy). The adoption of solar PV systems over time is the technology diffusion, which is the last stage of technological change.[3]

There are some fundamental differences that set solar PV systems apart from technologies typically studied in the technological diffusion and environmental policy literature. Empirical studies looking at the impact of diffusion from environmental policy changes often involve technologies used specifically to improve environmental outcomes (Kerr and Newell, 2003; Snyder et al., 2003) or energy efficiency improvements (Rose and Joskow, 2004); solar PV does not completely fit either of these categories well. To this point, Dastrup et al. (2012) find evidence that buyers of solar PV have both an investment value and consumption value in their purchase. Some studies provide a better understanding of how environmental policies impact technology diffusion. For example, Gray and Shadbegian (1998) examine the impact of state command and control regulations on technology diffusion in pulp and paper plants. Similarly, Frey (2013) focuses on the impact of a pollution permit system on the diffusion of abatement technologies in power plants. Again, the CSI output subsidies to residential consumers do not fit well in this literature, since subsides do not directly influence pollution abatement decisions of firms. Although, shifting the focus of solar PV adoption to non-residential adopters allows for comparisons to the research area of technology diffusion of firms.

The use of subsidies for green technologies more broadly is interesting and relevant for policy makers. Output subsidies are a policy instrument to encourage technology diffusion of green technologies to alleviate environmental externalities, like air pollution and climate change. Subsidies can be effective in encouraging the adoption of new technologies through economies of scale and learning by doing when knowledge based market failures exist (Nemet, 2012). However, the optimal policy tool depends on the goal of the policy maker. Fischer et al. (2008) show that in the case where there are more than one market failures, more than one policy instrument is optimal. Focusing on the subsidies offered under CSI, van Benthem et al. (2008) find that they are appropriate in maximizing net social benefits, if there is learning by doing and environmental externalities. Burr (2016) finds that the output subsidies from CSI results in more solar investment compared to an equivalent producer subsidy, but a producer subsidy is more cost efficient in displacing CO_2 emissions.

Fewer studies explicitly examine the impact of subsidies under CSI on the adoption rates of solar PV systems by households. Hughes and Podolefsky (2015) find that CSI had a significant impact on the number of installations over time, with a 7% increase in the rebate rate leading to a 7–15% increase in the number of daily installations. Bollinger and Gillingham (2012) compare residential areas that are geographically similar but face different CSI rates and show that areas with higher incentives have higher adoption rates. They show that higher adoption rates continue due to peer effects, even after incentives adjust to the same level. Graziano and Gillingham (2015) also attribute the spatial patterns of solar technology to the number of previously installed systems in the surrounding area, however, they do not control for subsidies. Our paper adds to this literature by testing for peer effects, measured by the cumulative amount of installation in the surrounding area.

Other related research focuses on various aspects of solar energy and solar policy, but not explicitly on the impact of subsidies on the diffusion of solar technology.[4] Zhang et al. (2012) identify the barriers of installing PV systems using survey data, with the primary obstacles to adoption including high costs of installation and repair, a long payback period, difficulty finding a suitable place for PV systems, and lack of policy incentives. Kwan (2012) finds that the number of state incentives has a positive impact on the number of residential installations in a zip code across the U.S. Local policies like favorable permitting practices (Dong and Wiser, 2013) or locally offered financial incentives (Li and Yi, 2014) have shown to increase the amount of solar PV installations by decreasing system costs.

Our paper falls within the even less explored area of the impact on environmental policy on the intensity or extent of technology diffusion by households or firms (Faria et al., 2003; Frey, 2012). A few studies explore aspects of this; for example, Bollinger and Gillingham (2012) find that larger solar PV installations result in a higher rate of adoptions in that zip code, which could be interpreted as evidence of peer effects. In addition, Shrimali and Jenner (2013) find that financial policy incentives did not impact the capacity adopted in the residential sector, but it did positively impact the capacity adopted in the commercial sector. There is a need for additional analysis on the effects of subsidies on the size of non-residential installations, which to the best of our knowledge, has yet to be explored.

There are several factors that may influence the size of the PV system installed, but there is more variability in the system size choice for non-residential customers who have greater average energy needs. First, factors that are external to the installation decision like available space and the ability of the building to support the system may limit the system size. Another factor that impacts the system size in California is Net Energy Metering (NEM), which allows electricity customers to receive credits for any surplus energy created from their system used by the grid, net of their total usage over a period of one year. To be eligible for NEM, the PV system typically cannot exceed the annual onsite load. As a result, most residential systems are uniformly set at the capacity needed to offset usage by 100%.[5] In contrast, non-residential entities, particularly those with more intensive energy needs or larger operations, may choose solar PV systems that offset less than 100% of usage. For example, consider a sample of well-known corporations that have committed to achieving 100% renewable energy by either procuring or producing renewable energy under a voluntary commitment known as RE100. Some firms met the 100% renewable goal years ago (Pearson in 2012 and Microsoft in 2014), some plan to meet the goal in a few years (Bank of America, Coca-Cola, and Philips by 2020), and some have announced it as part of a longer-term strategy (Facebook 50% by 2018 and eBay 100% by 2025).[6] This illustrates that for large commercial entities, conversion to renewable energy will occur over time. Not only that, but it is important to keep in mind that carbon or pollution neutrality can be met by other ways besides solar PV systems. As a result, our focus on the effect of CSI subsidies on the size of non-residential PV installations provides insight as to how much subsidies affect the system size.

This paper primarily examines the relationship between the solar capacity of a system and the corresponding amount of the subsidy awarded to an individual applicant in the CSI program between 2007 and 2014. Our contribution to the literature includes a unique focus on non-residential entities, which are often ignored in similar analyses, examination of the determinants of the size of the PV system rather than on the determinants of the installation decision itself, and testing for peer effects by firms. Empirical results show that for commercial and non-profit entities, an increase in subsidies by 10% leads to an

[3] According to Schumpeter (1942), technological change is the cumulative impact of invention, innovation, and diffusion. This definition is widely accepted in the technology diffusion literature.

[4] Baker et al. (2013) provide an excellent, unifying overview on the broader solar literature, specifically describing the benefits and costs of solar energy in the short run, medium run, and long run.

[5] As antidotal evidence, one author has recently completed the process of purchasing residential solar panels. Several competitive bids for PV systems from the leading California solar companies show that although the buyer could request a specific size for the PV system, the default system is designed at approximately 100% of the residents' annual electricity usage.

[6] Company info http://there100.org/companies, accessed 3/21/18.