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Small-scale solar panel adoption by the non-residential sector: The effects of national and targeted policies in Australia

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Abstract

Use of solar photovoltaic (PV) panels by the non-residential sector can contribute to climate-change mitigation and boost economic outcomes. Prior studies have primarily focused on the residential sector. Using data from 1,595 postcodes across the Australian National Electricity Market, we investigate five novel research questions for non-residential solar-panel adoption. National and sectoral policies, business size, and cross-sectoral influences are found to be key drivers of non-residential solar PV uptake. We find a subsidy elasticity of about 1.2 for Australia's Small-scale Renewable Energy Scheme (SRES), an economy-wide renewable portfolio standard for small-scale renewables. Residential solar capacity is positively associated with future adoption by the local non-residential sector, and geographical convergence effects are observed. The findings align with the principle that investment is spurred by policies that lower upfront capital costs. Following Australia's experience, a small-scale renewable portfolio standard is particularly worthy of consideration for further adoption.

Keywords:
business; policy; peer effect; solar photovoltaic panel; sustainability

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1. Introduction

Solar panels are a key green innovation given the importance of electricity as an input, the need to reduce emissions, and the fact that business processes are expected to continue to electrify over coming years (Helm and Hepburn, 2019). However the non-residential sector has generally lagged the residential sector in the adoption of distributed solar photovoltaic (PV) technology in Australia; as of June 2021 the cumulative capacity of small-scale solar PV installations by the residential sector was about four times that of the non-residential sector (AEMO, 2021). The substantial potential for growth in the use of solar PV by the non-residential sector motivates further analysis (Yoshino et al., 2019).

In this paper we make an early contribution on factors affecting non-residential uptake of solar PV panels, with a focus on distributed systems. While there have been numerous studies for the residential sector, including consideration of household-level factors such as household wealth (Best, 2022), our focus is the effect of policy interventions on non-residential solar adoption. We seek to answer a set of research questions that have not previously been specifically explored for either the non-residential or residential sector:

(i) How much of an effect has the national Small-scale Renewable Energy Scheme (SRES) had on the adoption of solar PV by Australia's non-residential sector?

(ii) Is there evidence of effects of solar PV adoption policies targeted at specific economic sectors such as agriculture?

(iii) Is non-residential solar PV uptake influenced by the sizes of businesses in an area?

(iv) Are there cross-sector solar PV adoption influences from the residential sector to the non-residential sector?

(v) Is there convergence in non-residential solar PV adoption across postcodes?

We pursue modelling approaches that utilize cross-sectional postcode-level data for Australia, the leading country in terms of per capita solar PV uptake, with over 600 watts of cumulative capacity per capita as of 2019 (IEA, 2020). Cross-sectional estimations are suitable given the rich cross-sectional variation available and constraints on panel data availability (Kwan, 2012; Crago and Chernyakhovskiy, 2017). In addition, we focus on the effects of variables that mostly vary geographically such as the SRES subsidy factor – a multiplier used to calculate the number of small-scale technology certificates (STCs) issued for new small-scale solar PV installations under the SRES. We control for various location effects such as Australia's climate zones. We also include a lagged dependent variable in some estimations to control for unobserved heterogeneity, allow a focus on factors influencing recent changes, and test for convergence effects over time. We also estimate a negative binomial model.

Our analysis differs to earlier studies in three key ways. First, we focus on the non-residential sector, whereas the prior literature has primarily focused on the residential sector (Reindl and Palm, 2021). This paper is the first on policy effects on non-residential solar PV adoption in Australia, a global frontier country when it comes to small-scale solar PV adoption. Second, our analysis considers sectoral and cross-sectoral influences, such as efforts to boost uptake of solar panels in the agricultural sector and possible impacts of residential uptake on non-residential uptake. Third, our inclusion of a lagged dependent variable in key specifications differs from the common approach in the literature and provides useful insights.

Understanding the factors that affect non-residential uptake of solar PV has the potential to inform broader narratives on private-sector corporate social responsibility (Kong et al, 2022) – an important research area given the links between energy, climate change, and financial outcomes (Bremer and Linnenluecke, 2017; Dodd and Nelson, 2019). For example, having solar panels may potentially boost the market valuations of businesses by lowering their exposure to emission reduction policies and costs and by promoting an environmentally friendly reputation (Choi et al. 2021).

The National Energy Law and the Australian National Energy Retail Rules (Australian Energy Market Commission, 2021) require energy retailers to classify distributed solar systems in Australia as either residential or "business" installations. The latter includes entities such as schools, government entities, and community organizations in addition to commercial businesses, so we refer to it as the "non-residential" sector. We use data on non-residential distributed installations from the Australian Energy Market Operator (AEMO, 2021). These installations do not include utility-scale solar farms built to export large volumes to the grid.

The organization of this paper is as follows. Section 2 discusses relevant prior research and a review of the economic and policy context. Section 3 discusses the methods and data. Section 4 presents the results. The final section is a concluding discussion.

2. Background

A discussion of existing research is provided in sub-section 2.1 and background on solar PV adoption in Australia's non-residential sector in sub-section 2.2. The policy context is then discussed in sub-section 2.3.

2.1 Overview of previous literature

Research on small-scale solar panel uptake has predominantly focused on the residential sector. There have been recent contributions for many countries (for example Palm and Lantz, 2020; Gillingham and Bollinger, 2021; Horne et al., 2021; Hossain et al., 2021; Irwin, 2021; Reindl and Palm, 2021; Best, 2022). The predominant focus on the residential sector is in part likely to be because uptake by the non-residential sector has to date tended to be slower (Crago and Koegler, 2018). However solar PV is a technology that has recently become much more economically competitive.[1] Given the huge potential, solar PV adoption in the non-residential sector will likely be a growing focus of research and policy interest.

Peer influences and imitative adoption behavior have been extensively studied for the residential sector (Bollinger and Gillingham, 2012; Rode and Weber, 2016; Wolske et al., 2020; Balta-Ozkan et al., 2021). Studies have often found positive peer effects, with installations in an area encouraging further local uptake (Bollinger and Gillingham, 2012; Wolske et al, 2020). We are unaware of evidence of solar PV peer influences for the non-residential sector.

Perceptions, such as those relating to autonomy and independence, have also been identified as an important enabler of solar panel uptake in the residential sector. For instance, gaining greater independence from the energy retailer is known to have been a motivator for solar panel uptake in Australia and Denmark (Zander, 2020; Hansen et al., 2022). A sense of attachment to local communities has been described as being important for solar uptake decisions in California (Corbett et al., 2022). Political participation has also been correlated with solar panel uptake among US households (Mildenberger et al., 2019). There may be business-sector analogues for some of these influences.

There are some recent studies on the effects of various policies on solar PV uptake in the residential sector, including policies targeted at low-income households (O'Shaughnessy, 2022). Gillingham and Bollinger (2020) found a large impact of an economic and community-marketing policy intervention in the US. Palm and Lantz (2020) found that an information campaign had significant impacts on solar panel adoption by Swedish homeowners. De Groote and Verboven (2019) analyzed the effects of both upfront and ongoing policies in Belgium. There has also been residential-sector analysis of the effects of ongoing (Zander et al., 2021)

[1] Even a decade ago, solar panels were often viewed more as a promising than a mainstream technology (Ma et al., 2013). Costs have declined substantially and solar purchase decisions are now much more common.

and upfront subsidies (Best et al., 2021) in Australia. Our paper extends the application of policy-focused analysis to the non-residential sector.

Economic and physical factors have been found to be important for distributed solar PV uptake by the residential sector. For example, household wealth has been found to be important for uptake rates (Best et al., 2019a; Best et al., 2021; Best, 2022). Renting is also known to reduce the likelihood of residences having solar panels (Zander, 2020; Best, 2022), and living in apartments can also constrain household ability to install solar PV (Roberts et al, 2019). Similar effects may exist for the business sector – for example businesses without access to their own roof space face a major constraint to adopting solar PV. While data on access to roof space are not available, it is likely that small businesses are less likely to have their own roof space, all else equal. We use the number of employees as a general proxy for the size of businesses, although note that some businesses with large capitalizations might not have a particularly large number of employees.

The enablers of and barriers to residential solar panel uptake appear to have changed over time. Environmental concern was often an important enabler in the early years when panel costs were high (Palm, 2018; Palm, 2020). Interest in new technology can also be a motivator for some personality types (Palm, 2018; Palm, 2020; Hansen et al., 2022). On the other hand, aversion to new technology by some members of the public can inhibit adoption (Palm, 2018). Financial motivations may be increasingly important for late adopters given that they did not adopt for environmental or other reasons earlier on (Palm, 2020). Businesses may well also be relatively more likely to be motivated by financial considerations.

Nearly all prior studies on solar PV uptake by the non-residential sector have been forward-looking rather than based on observed historical data. Reindl and Palm (2021) assessed possible barriers and enablers in Sweden and summarized prior studies of a similar nature for other countries. Mah et al. (2018) reported interview-based perceptions among potential solar PV adopters in Hong Kong, including commercial operators. They found that policy preferences differed between residential and non-residential sectors, with residential interviewees often preferring upfront subsidies and commercial interviewees often preferring feed-in tariffs.

There have been a small number of studies of non-residential solar PV uptake in the US. Crago and Koegler (2018) found that multiple types of policies have been important for commercial-scale solar PV capacity in the north-east, while Frey and Mojtahedi (2018) focused on the positive impact of the California Solar Initiative. Given the scale of the solar PV opportunities for businesses around the world, more attention to key factors in a solar early-mover such as Australia may be useful.

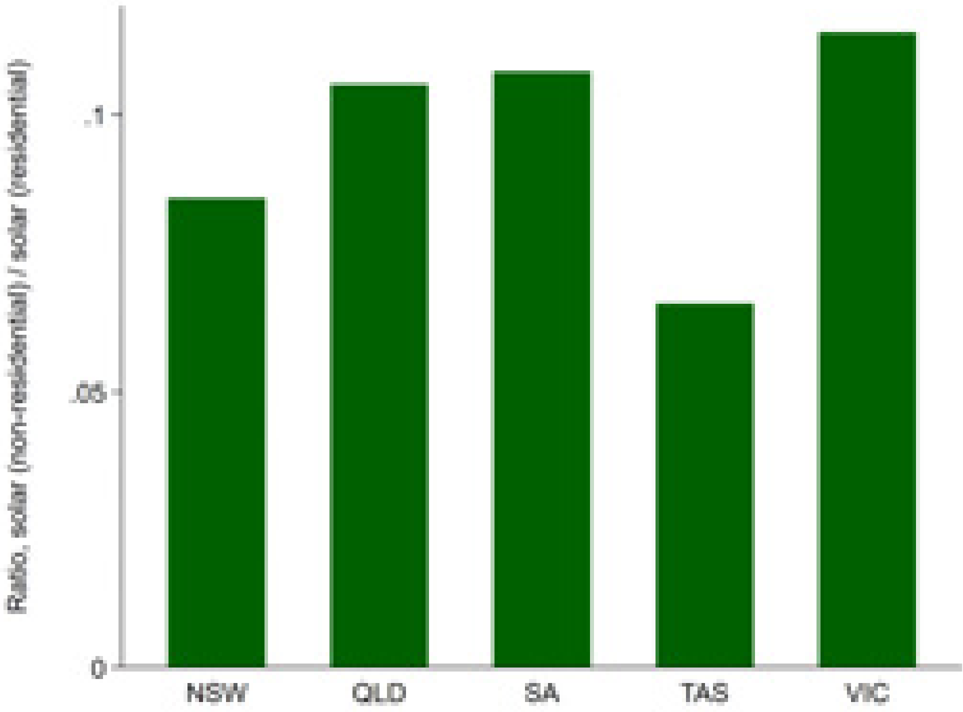
2.2 Non-residential sector solar uptake in Australia

This paper focuses on factors affecting uptake of solar PV panels by the non-residential sector in Australia’s National Electricity Market (NEM), a region that includes much of the country’s population outside of Western Australia and the Northern Territory. Postcode-level information on distributed energy installations and capacity by customer type from the Distributed Energy Resources Register AEMO (2021) are used. As noted, the data exclude utility-scale operations producing electricity primarily for the grid.

The average size of non-residential solar PV systems for the non-residential sector was about 18 kilowatts as of June 2021. For the residential sector, this was about 4 kilowatts. An example of a larger non-residential installation is the 280 kilowatt McLean Farms installation in Queensland (AEMO, 2021; Todae Solar, 2021). The output from this solar system is predominantly used to help power an egg farm.

Figure 1 shows that the ratio of non-residential solar installations to residential installations among NEM states tends to be about 0.1, with substantial geographical variation. The highest ratio is for Victoria – a state with relatively high non-residential uptake and relatively low residential uptake (AEMO, 2021).

Figure 1. The ratio of distributed non-residential to residential-sector solar installations in each jurisdiction of the National Electricity Market for June 2021.



Note: The Australian Capital Territory (ACT) is not shown as it is an outlier, with a value of 0.45. Data: AEMO (2021).

2.3 Policy context

The key small-scale solar adoption policy at the national level has been the Small-scale Renewable Energy Scheme (SRES), part of Australia's Renewable Energy Target (RET). In place since 2011, the SRES is a renewable portfolio standard (RPS) that provides varying support per kilowatt of solar PV capacity based on solar exposure, with Australia divided into four zones to achieve this. This scheme is not a traditional subsidy paid by the government. Instead, the installation of small solar systems leads to the generation of small-scale renewable energy certificates (known as STCs), and these can be used by electricity retailers and others to meet compliance requirements under the SRES. The SRES applies for installations of up to 100 kilowatts (AEMO, 2021), which covers the majority of the non-residential installations in our dataset. Larger systems fall under the Large-scale Renewable Energy Target (LRET).

The SRES subsidy for a new small-scale solar PV system is a product of four terms: a subsidy factor; the system's power generation capacity; a deeming period that has reduced by one year annually since 2016; and a certificate price that has typically remained close to the fixed available clearing house price of A$40. The subsidy factor is the only aspect of SRES scheme design that has varied cross-sectionally, with a higher factor applied for locations better suited to solar PV production. There are four zones, with subsidy factors of 1.185, 1.382, 1.536, and 1.622, respectively. Minor changes to the SRES saw some postcodes reallocated between zones on 1 January 2020 (Australian Government, 2019). This affected about 9% of postcodes in this study.

Solar promotion policies have also been introduced by Australia's states and territories, including some early premium feed-in tariff schemes and a range of policies targeting the upfront cost of solar panels. The Australian Government (2021) lists nine initiatives that aimed at reducing upfront costs and commenced prior to 2020. These include the NSW *Farm Innovation Fund* that provides loans for on-farm infrastructure, an ACT battery discount scheme that applies to solar-battery installations, and seven schemes in Victoria, Australia's second-most populous state, which are:

- An *Agriculture Energy Investment Plan* (AEIP), which aims to help Victorian farms reduce energy costs via grants (Victorian Government, 2021a). Over 450 grants totalling A$22 million had been awarded by March 2021 (Victorian Government, 2021b). An example is a grant to a vineyard in central-west Victoria that had an energy assessment carried out in June 2019 and subsequently installed a 21-kilowatt solar PV system under the AEIP (Victorian Government, 2020). The AEIP was initially in place from late 2018 to mid-2020 and then extended in the 2020–2021 state budget.
- An *Environmental Upgrade Finance* scheme for commercial buildings. For example, a 15-kilowatt system on the Rubato Building in Brunswick, Melbourne benefitted from this scheme in 2019 (Moreland City Council, 2019).
- Five variants of the *Sustainable Finance for Energy Solutions* scheme run by Sustainability Victoria. These use financial instruments with various specifications regarding collateral, repayments, and purchase options.

3. Methods and data

Our approach to modelling non-residential solar panel installations at the postcode (p) level in the NEM is:

$$B_p = \alpha + \boldsymbol{P'_p}\boldsymbol{\psi} + \boldsymbol{D'_p}\boldsymbol{\delta} + \boldsymbol{L'_p}\boldsymbol{\lambda} + \rho R_{p,t-1} + \mu B_{p,t-1} + \varepsilon_p \quad (1)$$

We use several dependent variables for non-residential solar PV installations (B) in each postcode. The first is the log of the cumulative count of solar installations in the postcode. Others include the number of new installations during the year (unlogged) and the log of the cumulative non-residential solar capacity. The dependent variables are measured as of June 2021 (AEMO, 2021) and only include non-residential distributed solar PV systems. Solar thermal installations (typically for hot water supply) are not considered. The model has α as the constant term and ε as the error. We use both ordinary least squares and negative binomial estimations.

P represents a policy vector that includes the log of the SRES subsidy factor. Higher factors accord with sunnier conditions and stronger policy support per kilowatt of capacity installed. Figure 2 shows the 2020 values of these subsidy factors.[2] Conditioning on climate zone variables (discussed further below), we seek to identify the effect of the log SRES subsidy factor. An alternative that we also pursue is to control for the log solar exposure instead of climate zones, although this leads to high multicollinearity. ***P*** also includes an interaction between a binary variable for the state of Victoria and the agricultural proportion of businesses in a postcode to test whether Victoria's agriculture-focused policy interventions have had a detectable effect on adoption.

The ***D*** vector includes business and building characteristics. The coefficient vector is $\boldsymbol{\delta}$ in this case.[3] The log of the number of businesses is included to control for a scale effect, as postcodes with more businesses would likely have more non-residential solar installations, all else equal. ***D*** also includes variables measuring the proportions of businesses in several size ranges based on the number of employees. Small businesses operating within a shopping centre or an office building often face physical constraints such as not having their own roof, making it difficult or impossible to install solar PV. Medium and larger businesses are more likely to have their own roof space. The proportion of residential dwellings that are apartments is also used as a proxy for building density in the postcode.

[2] The analysis in Section 4 uses the pre-2020 zones to explain the level of non-residential installations because the majority of installations were prior to 2020. Specifications that control for the lagged dependent variable effectively evaluate factors affecting the change in non-residential installations for the year to June 2021. For these, the post-2020 zones are used.

[3] Coefficients are also shown for each other vector or variable.