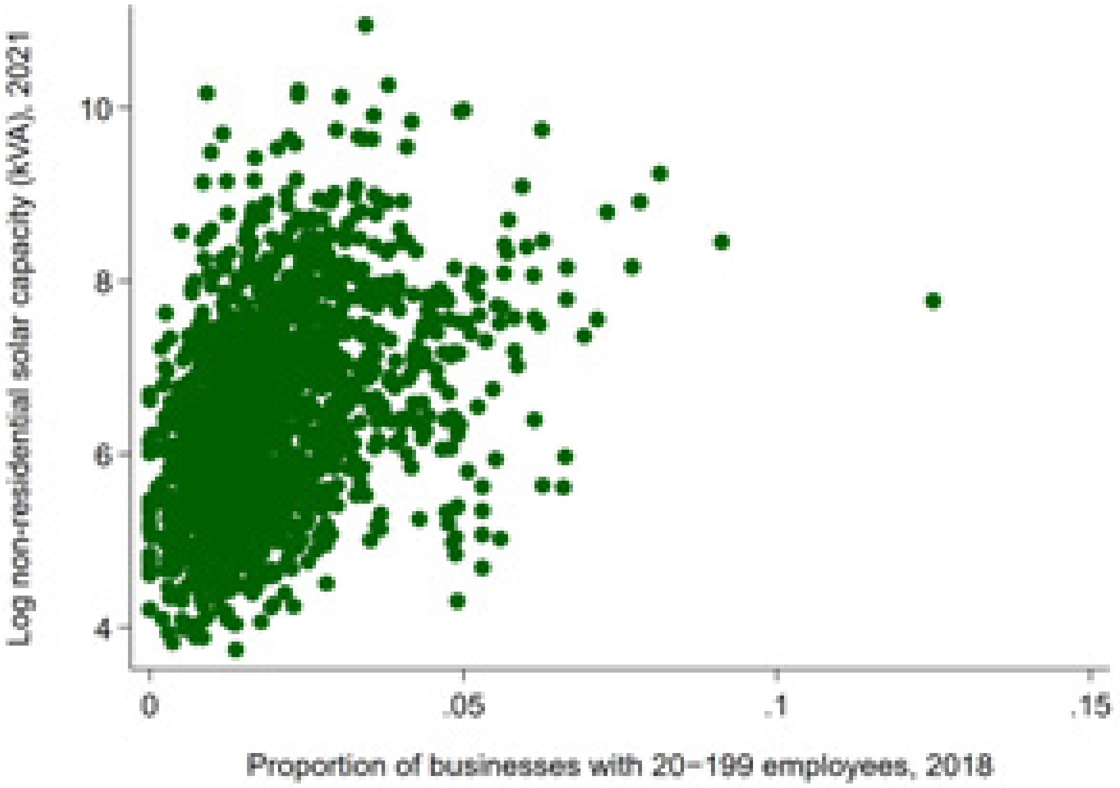
centre of Sydney or Melbourne. It is not possible to apportion business operations across postcodes based on the data we have. Given that central business districts tend to be highly dense, it might be expected that postcodes with many large businesses (based on overall employee counts) do not have a commensurately higher number of non-residential solar installations. An additional issue is that some businesses are registered to a residential address and able to benefit from a residential solar system (Small Business Commissioner, 2022), although the omission of businesses that do not register for GST reduces this issue.

Figure 3 is suggestive of a positive relationship between the proportion of businesses with 20–199 employees (mid-sized businesses) in a postcode and the log of non-residential solar capacity. This is an initial indication that having more mid-sized businesses tends to be associated with additional solar PV adoption by the non-residential sector. A positive relationship also exists if using the log of the count of businesses with 20–199 employees, although this also captures a scale effect. Relative to small businesses, medium-sized businesses are likely to have larger energy needs and greater access to resources for investment in solar panels.

Equation (1) also includes location-specific binary variables ($\boldsymbol{L}$) to control for policy and other differences across states and territories. Binary variables for four states and the ACT are included, with the reference state being Queensland. Binary variables are also included for a climate zone designation used by the Australian Energy Regulator (2019). Postcodes are assigned to one of six underlying climate zones, and then split into regional or city classifications in most cases. A total of 11 climate and city zone binary variables are included. The possibility of multicollinearity between these and the state variables will be considered by viewing variance inflation factors. The climate zones cut across state borders.

Industry momentum effects are interesting to consider. Having more non-residential solar PV installations could slow the subsequent growth rate in non-residential sector uptake of solar panels as the industry matures and the rate of expansion moderates. The subsequent rate of non-residential uptake of solar PV in a postcode could alternatively rise due to a positive demonstration effect, or due to having greater access to solar installers. Such effects will be tested by including a lagged cumulative installations variable. This is measured as of June 2020 ($t-1$), the first date for which solar PV data are available from AEMO (2021).

Figure 3. The proportion of businesses with 20–199 employees and the log of non-residential- distributed solar PV capacity (June 2021).



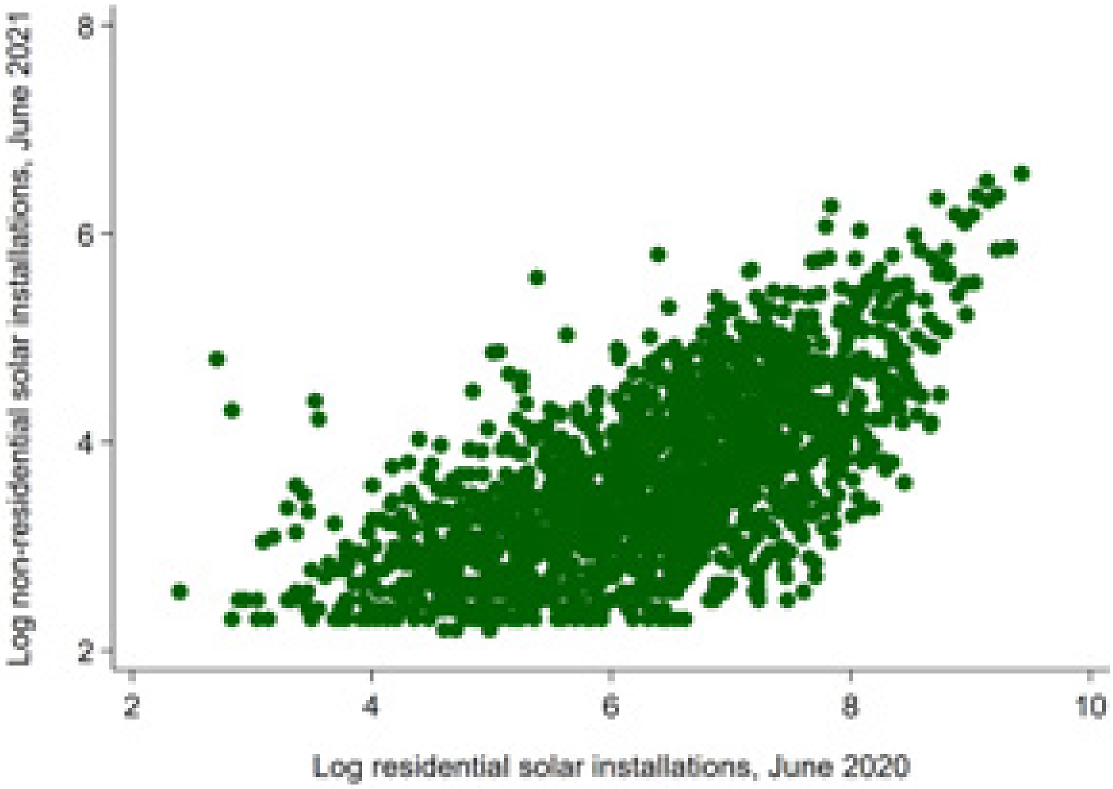
Note: Each postcode is shown by a dot. Data: AEMO (2021); ABS (2021).

When controlling for cumulative non-residential installations (logged) up to the prior year, estimated effects are on the annual change rather than the level of the dependent variables. This allows for the assessment of either convergence or divergence in solar PV adoption paths across postcodes over time. Lagged dependent variable approaches have also been applied in earlier contexts (e.g. Best and Burke, 2019).

It is also possible that having more residential installations in a local area encourages non-residential installations. This motivates the use of the explanatory variable *R*, the log number of cumulative residential solar installations as of June 2020. This variable is also likely to help control for key aspects of unobserved heterogeneity that underpin both non-residential and residential installation rates. A positive relationship is evident in Figure 4.

Correspondence tables (ABS, 2020) are used to match data for business size and type from the Statistical Area Level 2 (SA2) to the postcode-level solar adoption data. SA2 and postcode areas are roughly similar in size, although were developed for different purposes (the Australian Statistical Geography Standard and postal services, respectively). The conversion process introduces a degree of measurement error, however this is unlikely to be systematically correlated with the explanatory variables.

Figure 4. Log of cumulative non-residential distributed solar PV installations as of June 2021 versus the log of cumulative residential-sector distributed solar PV installations as of June 2020.



Note: Each postcode is shown by a dot. Data: AEMO (2021).

Table 1 provides the variable definitions and summarizes the data sources. Descriptive statistics are shown in Table 2. There was an average of 58 cumulative non-residential distributed solar PV installations per postcode as of June 2021, seven of which were new installations over the prior year. Due to privacy restrictions, data on non-residential solar PV installation data are not available for postcodes that have fewer than 10 distributed installations (AEMO, 2021).

Table 1. Variable descriptions

Variable	Vector	Description
Solar panels, 2021 (NR)	B	Count of non-residential (NR) solar PV panel installations as of June 2021 (cumulative).
Solar additions 2020-21 (NR)	B	Count of non-residential solar PV installations for the year to June 2021.
Solar capacity, 2021 (NR)	B	Capacity in kilovolt-ampere of non-residential solar PV installations (cumulative) as of June 2021. Kilovolt ampere (kVA) is a measure of apparent power, whereas kilowatt (kW) is a measure of real power. These two measures are equivalent if the power factor is one but will differ otherwise. Our key results are in the form of elasticities and semi-elasticities, so are independent of the underlying units of the dependent variable.
SRES factor	P	Small-scale Renewable Energy Scheme factor: 1.622 (zone 1), 1.536 (zone 2), 1.382 (zone 3), 1.185 (zone 4).
Count of businesses	D	Number of businesses (total). Multi-location businesses are attributed based on the main business address. Only businesses with an ABN and that are actively trading and remitting GST are counted.
Agricultural businesses	D	% of businesses in agriculture, forestry and fishing / 100
Reference: 0 employees		% of businesses employing no-one / 100
Business %/100, 1–4 employees	D	% of businesses with 1–4 employees / 100
Business %/100, 5–19	D	% of businesses with 5–19 employees / 100
Business %/100, 20–199	D	% of businesses with 20–199 employees / 100
Business %/100, 200+	D	% of businesses with 200+ employees / 100
Apartments per dwelling	D	The number of units divided by the number of dwellings.
Reference: Queensland		Binary variable equal to 1 for postcodes in Queensland.
Australian Capital Territory	L	Binary variable equal to one for postcodes in the ACT.
New South Wales (NSW)	L	Binary variable equal to one for postcodes in NSW.
South Australia	L	Binary variable equal to 1 for postcodes in South Australia.
Tasmania	L	Binary variable equal to one for postcodes in Tasmania.
Victoria	L	Binary variable equal to one for postcodes in Victoria.
Climate and city zones	L	11 zones designated by the Australian Energy Regulator. These are 1. Climate zone (CZ) 1 and regional; 2. CZ2 and city/suburban; 3. CZ2 and regional; 4. CZ3&4 and regional; 5. CZ5 and city and NSW; 6. CZ5 and city and SA; 7. CZ5 and regional; 8. CZ6 and city; 9. CZ6 and regional; 10. CZ7 and city; 11. CZ7 and regional.
Solar panels, 2020 (res)	R	Count of residential solar PV installations as of June 2020 (cumulative).
Solar panels, 2020 (NR)	B	Count of non-residential solar PV installations as of June 2020 (cumulative).
Solar capacity, 2020 (res)	R	Capacity (kVA) of residential solar PV installations as of June 2020 (cumulative).
Solar capacity, 2020 (NR)	B	Capacity (kVA) of non-residential solar PV installations as of June 2020 (cumulative).
Victoria * Ag (%/100)	P	An interaction variable: binary variable for Victoria * agriculture % /100
Financial % of businesses	D	% of businesses in Financial and Insurance Services / 100

Notes: Solar data are from AEMO (2021). Business size and type are based on 2018 data (ABS, 2021). The SRES factors are from Australian Government regulations (2019). Apartments and dwellings are from the 2016 census data (ABS, 2018). "Vector" refers to the categories in equation (1).

Table 2. Descriptive statistics

	Minimum	Mean	Maximum
Solar panels, 2021 (NR)	9	58.04	717
Solar additions during the year to June 2021 (NR)	0	6.76	125
Solar capacity, 2021 (NR)	42.1	1366.48	57344.58
Solar (NR) / solar (res), 2021	0.01	0.11	8.07
SRES factor	1.185	1.33	1.622
Count of businesses	13	1200.94	42127
Agricultural %/100 of businesses	0	0.21	0.71
Share (%/100) of businesses with:			
0 employees	0.38	0.63	0.83
1–4 employees	0.15	0.26	0.41
5–19 employees	0	0.09	0.23
20–199 employees	0	0.02	0.12
200+ employees	0	0.00	0.01
Apartments divided by dwellings	0	0.09	0.93
State or territory			
Queensland	0	0.22	1
Australian Capital Territory	0	0.01	1
New South Wales	0	0.27	1
South Australia	0	0.16	1
Tasmania	0	0.03	1
Victoria	0	0.30	1
Solar panels, 2020 (res)	11	1059.41	12402
Solar panels, 2020 (NR)	5	51.37	620
Solar capacity, 2020 (res)	41	4356.57	50595.02
Solar capacity, 2020 (NR)	29.6	1130.05	56333.96
Victoria * Ag (%/100)	0	0.07	0.71
Financial %/100 of businesses	0.01	0.06	0.40

Notes: SRES stands for Small-scale Renewable Energy Scheme. There are 1,595 observations. The mean for the agricultural share of businesses is relatively high because there are some small postcodes (by population) with high percentages of businesses in agriculture. The data are mostly from June, while census data (apartments per dwelling) are from August. The mean for the SRES factor of 1.33 is for pre-2020 zones. For post-2020 zones, it changes to 1.34.

4. Results

4.1 Main results

Table 3 shows ordinary least squares (OLS) results for the log of the cumulative count of non-residential solar systems as of June 2021. Column (1) excludes the climate and city zone locational variables. The variance inflation factor averages 2.18, suggesting that multicollinearity is not a major issue. When climate and city zone locational variables are included, this rises to 4.49, still well below the common threshold of 10. Further, the sign and significance of most variables is similar in column (2) and some magnitudes are also similar. We thus retain the climate and city zone variables for the subsequent estimations. Moderate multicollinearity has the somewhat benign implication of raising standard errors.

Table 3. Results: OLS regression for the log non-residential solar PV installation count as of June 2021

	(1)	(2)	(3)	(4)
Log SRES factor	1.948***	1.502***	1.474***	0.141*
	(0.324)	(0.336)	(0.334)	(0.080)
Log count of businesses	0.656***	0.679***	0.340***	0.019***
	(0.020)	(0.021)	(0.040)	(0.007)
Agricultural %/100 of businesses	0.914***	0.245**	1.031***	-0.023
	(0.098)	(0.122)	(0.129)	(0.027)
Share (%/100) of businesses with:				
1–4 employees	-1.095***	-0.752*	-1.146***	-0.172*
	(0.404)	(0.437)	(0.414)	(0.093)
5–19 employees	7.335***	5.627***	6.444***	0.248*
	(0.609)	(0.579)	(0.596)	(0.138)
20–199 employees	8.241***	9.807***	13.354***	0.839***
	(1.702)	(1.637)	(1.555)	(0.315)
200+ employees	-18.190	-8.944	-6.195	-1.972
	(14.704)	(14.140)	(12.183)	(2.901)
Apartments per dwelling	-1.505***	-1.362***	-0.069	-0.064**
	(0.102)	(0.109)	(0.156)	(0.030)
State or territory. Reference: Queensland				
Australian Capital Territory	-0.688***	-0.390**	-0.632***	-0.058
	(0.091)	(0.166)	(0.176)	(0.047)
New South Wales	-0.561***	-0.481***	-0.514***	-0.108***
	(0.039)	(0.050)	(0.047)	(0.009)
South Australia	0.190***	0.367***	0.091	-0.034**
	(0.042)	(0.060)	(0.063)	(0.013)
Tasmania	-0.297***	-0.389***	-0.486***	-0.001
	(0.077)	(0.096)	(0.092)	(0.025)
Victoria	0.106*	0.219***	0.170***	0.038**
	(0.056)	(0.063)	(0.062)	(0.017)
Log solar panels, 2020 (res)			0.387***	0.005
			(0.037)	(0.006)
Log solar panels, 2020 (NR)				0.970***
				(0.007)
Victoria * Ag (%/100)				0.083**
				(0.035)
Climate and city zones	No	Yes	Yes	Yes
Adjusted R^2	0.648	0.677	0.715	0.987
Mean variance inflation factor	2.18	4.49	5.16	5.56

Notes: ***, **, * show statistical significance at 1, 5 and 10 per cent levels respectively. Robust standard errors are in brackets below the coefficients. SRES stands for Small-scale Renewable Energy Scheme. There are 1,595 observations for each column. SRES zones are pre-2020 for columns (1)–(3) because most installations were from pre-2020. SRES zones are post-2020 for column (4), because this column effectively assesses the change in non-residential installations due to the introduction of the lagged dependent variable. Use of the post-2020 zones for columns (1)–(3) gives SRES coefficients that are similar but slightly smaller, as expected. The reference business size is 0 employees.

Positive and significant coefficients for the log SRES factor are obtained in each column of Table 3. Columns (2)–(3) show positive coefficients of 1.5, significant at the 1% level, even with the climate and other controls included. These coefficients are elasticities given that both the dependent and independent variables are logged, and indicate that a 1% increase in the subsidy factor is on average associated with a 1.5% increase in the count of non-residential solar systems, all else equal. Column (4) effectively gives an impact on the change in solar installations rather than the level.

As expected, the coefficients for the log of the number of businesses in each postcode are positive in Table 3, indicative of a scale effect. It is reasonable that the elasticity is less than one given that the average physical size of a business is likely to be smaller in postcodes with more businesses.

A positive coefficient is found for the agricultural share of businesses in column (2) of Table 3, with the coefficient indicating that a percentage point increase in the agricultural share is on average associated with 0.28 percent more non-residential installations of solar panels.[6] This is in line with expectations that farms and related businesses are particularly suited to solar PV given their space endowments and, in some instances, their energy needs.

Table 3 also provides evidence for effects of the size of businesses, with positive and significant coefficients obtained for the proportions of businesses with 5–19 or 20–199 employees. The reference case is the proportion of businesses without any employees. It is of interest that the coefficient for large businesses (200+ employees) is insignificant. This likely relates to the earlier discussion that these businesses tend to be headquartered in central business districts where there is high building density.

Table 3 also shows some significant coefficients for the state variables. There are positive and significant coefficients for Victoria, the state with the most extensive solar interventions for the business sector, despite receiving less sunshine than the base case of Queensland. Interestingly, the opposite was observed for the residential sector (Best et al., 2019a).

While not a non-residential variable, the proportion of residences that are apartments is included as a useful proxy of overall density. As expected, there are negative coefficients for this variable in Table 3. The variance inflation factor reaches around 10 if the log of solar exposure is included (estimates not reported). The signs and significance of key regression coefficients, including the log SRES subsidy factor, are similar either way.

Column (3) of Table 3 includes the one-year lag of the log of the cumulative count of residential solar panel installations in each postcode. There is a positive and significant coefficient for this variable. This may be picking up other influences in each postcode that are relevant for solar

[6] Calculated based on the exponential of 0.245 minus one.

panel adoption. It may also be at least in part picking up a cross-sectoral effect such that having more residential panels has a positive influence on subsequent installations by the non-residential sector.

Column (4) of Table 3 introduces the lagged log of the number of non-residential solar installations, making this a cross-sectional lagged dependent variable model. There is an elasticity of 0.97 for this variable. As this is significantly different from one at the 1% level, the coefficient reveals convergence over time across postcodes.[7] This means that the growth rate in non-residential solar uptake is lower in postcodes with higher initial levels.

The inclusion of the lagged variable in column (4) of Table 3 implies that the coefficients for other variables now represent the impact on the annual growth rate in non-residential solar installations from 2020 to 2021. It is likely that many coefficients would remain similar in sign given that many solar systems have been installed only recently. This is indeed the case, with the exception of the coefficient for South Australia – the overall findings indicate that South Australia has a high number of non-residential solar PV systems, but that uptake over the 12 months to June 2021 was relatively slow, all else equal. The SRES coefficient being less significant is reasonable given that the base level of installations was already likely higher in areas with a higher subsidy factor.

Column (4) of Table 3 also includes an interaction between the Victoria binary variable and the agricultural share of businesses in each postcode. A positive and significant coefficient is found. This may reflect effects of the state's solar PV promotion efforts targeting the sector, including the AEIP (Victorian Government, 2021a).

The estimates in Table 3 remain qualitatively similar when changing the proportional explanatory variables to log transformations of the counts and dropping the control for the log number of businesses. This induces greater multicollinearity, however. Key results are also qualitatively similar for a dependent variable equal to the ratio of non-residential installations to the number of businesses. This specification does not require the log count of business numbers as a control, as the dependent variable has the number of businesses in the denominator.

[7] To see this, one can subtract the lagged log non-residential uptake from both sides of the model. The left-hand side would then be the proportional growth rate. The coefficient for the lagged dependent variable would then equal 0.97 – 1 = –0.03. Thus postcodes with more non-residential solar PV installations in 2020 had a slower proportional growth rate in the number of installations over the subsequent year.

Further robustness tests (unreported) also support the result for the SRES subsidy factor. For example, state sub-samples produce some positive SRES coefficients, although reduced statistical significance of effects is obtained for these relatively small subsamples. A binary variable for SRES zone 4 (the zone with the lowest subsidy factor) is also negative and significant when used in place of the log SRES factor, as expected. In addition, log SRES coefficients are still positive and significant when further locational controls are added, for example 41 binary controls based on the first two digits of a postcode. This approach can control for geographical clusters to a reasonable extent.

4.2 Negative binomial model results

Table 4 displays the results of a negative binomial estimation, with the dependent variable here being the number of new installations of non-residential solar panels over the year to June 2021. A negative binomial model is suitable given the use of an integer dependent variable and the skewed distribution of non-residential solar installations across postcodes. The results are generally consistent with column (4) of Table 3, although statistical significance varies in some cases. The SRES variable remains positive and significant at the 1% level. A robust relationship is evident for the influence of the proportion of mid-sized businesses (20–199 employees).

A difference in Table 4 is that the coefficient for the agricultural share of businesses becomes negative and significant for outside Victoria, in contrast to the insignificant coefficient in column (4) of Table 3. This suggests that, outside Victoria, solar panel uptake during the year to June 2021 was on average lower in areas with a higher share of agricultural businesses, all else equal. The interaction between the Victoria binary variable and the agricultural share of businesses remains positive and significant at the 1% level, with the coefficient suggestive of strong growth in installations in rural areas of Victoria in the year to June 2021.

Table 4. Results: Negative binomial regression for additions to non-residential solar PV panels in the year to June 2021 (unlogged)

	Coefficient	Standard error
Log SRES factor	1.764***	(0.477)
Log count of businesses	0.159***	(0.055)
Agri. %/100 of businesses	-0.732***	(0.270)
Share (%/100) of businesses with:		
1–4 employees	-0.331	(0.743)
5–19 employees	0.287	(1.114)
20–199 employees	8.036***	(2.359)
200+ employees	-15.402	(15.939)
Apartments per dwelling	-0.586***	(0.227)
State or territory. Reference: Queensland		
Australian Capital Territory	-0.901***	(0.261)
New South Wales	-2.025***	(0.140)
South Australia	-0.659***	(0.139)
Tasmania	-0.142	(0.206)
Victoria	-0.216	(0.159)
Log solar panels, 2020 (res)	0.006	(0.052)
Log solar panels, 2020 (NR)	0.803***	(0.045)
Victoria * Ag (%/100)	1.395***	(0.279)

Notes: ***, **, * show statistical significance at 1, 5 and 10 per cent levels respectively. Robust standard errors are in brackets beside the coefficients. SRES stands for Small-scale Renewable Energy Scheme. There are 1,595 observations. The pseudo R-squared is 0.192. The number of non-residential installations is reported as lower in June 2021 compared to June 2020 for 89 postcodes (out of 1,595). A value of zero is used for the solar additions in these cases to allow for a non-negative dependent variable. 71 of the 89 postcodes report solar panels being lower by 1 in 2021. Climate and city zone controls are included. SRES zones are post-2020.

4.3 Solar capacity results

Table 5 investigates impacts on log non-residential solar capacity (rather than installation counts). Many of the estimated effects remain similar in sign and significance. The SRES coefficient is again positive and significant, with an elasticity of around 1.2–1.3 in columns (1)–(2). There is also a positive and significant influence in column (3) on the proportional change in installations over the year to June 2021. Scale effects are evident in the positive coefficient for the log number of businesses. The coefficient of 0.48 for Victoria in column (1) implies that non-residential solar capacity is 62% (100 * {exp(0.48) –1}) higher there than in Queensland, after accounting for the effects of the control variables.

Table 5. Results: OLS regression for log cumulative capacity of non-residential solar PV as of June 2021

	(1)	(2)	(3)
Log SRES factor	1.329**	1.209**	0.312*
	(0.520)	(0.522)	(0.165)
Log count of businesses	0.771***	0.387***	0.042*
	(0.031)	(0.056)	(0.021)
Agricultural %/100	-0.093	0.739***	
	(0.179)	(0.193)	
Share (%/100) of businesses with:			
1–4 employees	-1.400**	-1.964***	-0.127
	(0.650)	(0.645)	(0.248)
5–19 employees	6.249***	7.318***	0.188
	(1.072)	(1.086)	(0.477)
20–199 employees	19.996***	23.902***	2.375***
	(2.460)	(2.419)	(0.792)
200+ employees	-9.230	-4.902	-4.781
	(21.388)	(19.654)	(5.087)
Apartments per dwelling	-1.333***	0.193	-0.078
	(0.189)	(0.247)	(0.066)
Reference: Queensland			
Australian Capital Territory	0.251	-0.018	-0.098
	(0.260)	(0.249)	(0.079)
New South Wales	-0.542***	-0.566***	-0.266***
	(0.078)	(0.076)	(0.040)
South Australia	0.525***	0.212**	-0.169***
	(0.104)	(0.107)	(0.050)
Tasmania	-0.069	-0.133	-0.048
	(0.178)	(0.176)	(0.101)
Victoria	0.483***	0.491***	-0.034
	(0.098)	(0.097)	(0.045)
Log solar capacity, 2020 (res)		0.435***	0.030**
		(0.050)	(0.013)
Log solar capacity, 2020 (NR)			0.918***
			(0.018)
Financial %/100 of businesses			-0.518***
			(0.189)
Climate and city zones	Yes	Yes	Yes
R^2	0.578	0.603	0.949

Notes: ***, **, * show statistical significance at 1, 5 and 10 per cent levels respectively. Robust standard errors are in brackets below the coefficients. SRES stands for Small-scale Renewable Energy Scheme. There are 1,595 observations for each column. SRES zones are pre-2020 for columns (1)–(2) because most installations were from pre-2020. SRES zones are post-2020 for column (3), because this column effectively assesses the change in non-residential solar capacity due to the introduction of the lagged dependent variable.

Column (3) of Table 5 investigates the impact of the share of businesses in the financial sector. A strong negative association is found. This makes sense given that financial companies are often located in densely-populated areas that tend to have fewer opportunities for solar installations relative to other areas. Other regressions in the available Stata code show a positive and significant coefficient for the manufacturing share of businesses and an insignificant coefficient for the retail share.

A difference in Table 5 is the positive and significant coefficient for the log cumulative residential-sector solar system capacity from the prior year, even when controlling for a similar non-residential variable in column (3). Specifically, 1% more in the way of residential solar system capacity is found to be associated with 0.03% more non-residential solar PV capacity being added in the following year, all else equal. This may be suggestive of cross-sector peer influences such that higher residential solar capacity promotes additional non-residential capacity. It may also be due to other factors such as the beneficial effects of having a larger local installation sector.

Evidence of convergence is again observed in column 3 of Table 5, where it can be seen that postcodes with substantial non-residential sector solar PV capacity tend to subsequently have lower capacity growth rates. Such convergence effects make intuitive sense given that this is a technology that is broadly suitable across the whole of Australia and for which there are catch-up investment opportunities in locations that fall behind.

5. Discussion and conclusion

5.1 Discussion of the main results and context

The estimation results provide evidence that a national-level policy – the SRES – appears to have had an important effect in promoting distributed solar PV adoption by the non-residential sector in Australia. Targeted initiatives also appear to have been important, as evidenced by greater non-residential sector deployment of solar panels in agricultural areas in Victoria, a state with various initiatives to promote business-sector adoption of solar PV. Further, we found that postcodes with higher shares of businesses that are medium-sized have more non-residential solar panel adoption, all else equal. A positive influence of residential-sector capacity on non-residential capacity may be indicative of cross-sectoral peer effects. A supply-side explanation is also possible, as local availability of installers is likely to induce additional decisions to install. The variable may also possibly be picking up the effect of other local factors.

The effects of the SRES for the non-residential sector are similar to what has been earlier estimated for all small-scale systems in Australia. Specifically, the SRES subsidy factor elasticity of solar capacity is here found to be around 1.2–1.3 for the non-residential sector (Table 5), having earlier been estimated to be in the range 0.6–1.6 for all systems (Best et al, 2019b). An important difference to the residential sector is that the results suggest relatively high uptake of distributed solar PV by the non-residential sector in Victoria, including in agricultural areas. This may reflect the concerted policy efforts for the agricultural sector in particular in this state via initiatives including the AEIP.

While the existing literature has focused mainly on distributed solar PV uptake in the residential sector (Reindl and Palm, 2021), our analysis is for non-residential installations. Our results are most directly comparable to the studies of Crago and Koegler (2018) and Frey and Mojtahedi (2018) for the US, which also found an important general influence of business-sector policies. Frey and Mojtahedi (2018) found that a 10% increase in the per-kilowatt subsidy on average leads to about 2% more solar capacity in the non-residential sector in California. Our study shows a larger impact of around 12% in Australia. Our analysis also contributes in terms of its findings of business-size impacts and possible cross-sector influences.

The results also identify links between past solar uptake levels and subsequent growth rates. Specifically, greater non-residential solar uptake in a postcode is associated with a lower subsequent growth rate in uptake. This implies convergence over time such that areas with low initial uptake tend to catch up rather than fall even further behind. For regions that are yet to have much in the way of non-residential solar PV installations, the implication is that short-term support can be important to help get the industry started. Once an initial level of adoption has been seen, the growth rate of solar adoption is likely to be higher in such areas than in areas with more mature adoption levels.

5.2 Relating the results to the research questions

With regards to the first two research questions, we find that both national policy and targeted initiatives appear to have been important drivers of non-residential solar panel uptake in Australia. Our research provides the specific case studies of the SRES and agricultural sector policies, with the findings being consistent with the prior that subsidies are a key enabler for solar-panel uptake (Reindl and Palm, 2021). A key finding with respect to the third research question is a positive link between mid-sized businesses and solar-panel uptake. With regard to the fourth research question, some evidence of cross-sectoral peer influences from the residential to the non-residential sector has been found. This complements evidence of peer effects within the residential sector (Bollinger and Gillingham, 2012). With respect to the fifth question, evidence of geographical convergence in non-residential solar PV uptake has also been found.

Overall, the results provide evidence that state and federal governments in Australia have had important influences on non-residential solar PV adoption outcomes via policy schemes. Over time, these could be recalibrated to focus on emerging market shortcomings or policy goals. For example, policy could be focused on battery adoption or the encouragement of greater adoption of solar PV in remote regions where installation costs tend to be higher but where public benefits in the form of reducing the need to invest in transmission and distribution grid infrastructure may be larger. Other countries may also be able to learn from Australia's early experience, especially when it comes to the use of a renewable portfolio standard approach focused on small-scale installations in the form of the SRES. The estimates will also be able to inform understanding of likely future uptake patterns in Australia and elsewhere.

5.3 Limitations and future research

Limitations of the analysis include that we do not have access to solar PV installation data by type of non-residential premises (e.g. business; school; other). As noted, we also only have data on business headquarters rather than more detailed data on the location of all business activity. We also do not have access to data on the actual output of solar systems by postcode.

A range of extensions are possible for future research. Analysis distinguishing between channels of peer influences for the non-residential sector could be interesting. Studies of uptake rates by government agencies and non-governmental organizations would also be of interest, as would studies of battery adoption, which is starting to take off in Australia. It would also be useful to examine the effect of premises leasing on business solar PV uptake rates; while a renter disadvantage has been observed in the residential sector (Best, 2022), it has yet to be carefully studied for the non-residential sector.

If available, analysis using data that apportion the employees or business operations of large firms across postcodes would be valuable to further understand the link between business size and distributed solar uptake by businesses. Future research could also potentially explore additional factors affecting non-residential uptake of distributed solar PV. This research could potentially consider awareness levels of solar PV among the non-residential sector and business-manager perceptions of rooftop solar PV.

References

Balta-Ozkan N., Yildirim, J., Connor, P.M., Truckell, I., Hart, P., 2021. Energy transition at local level: Analyzing the role of peer effects and socio-economic factors on UK solar photovoltaic deployment. Energy Policy 148, 112004.

Best, R., 2022. Household wealth of tenants promotes their solar panel access. Economic Modelling 106, 105704.

Best, R., Burke, P.J., 2019. Is there regional lock-in of unemployment rates in Australia? Australian Journal of Labour Economics 22(2), 93–116.

Best, R., Burke, P.J., Nishitateno, S., 2019a. Understanding the determinants of rooftop solar installation: evidence from household surveys in Australia. Australian Journal of Agricultural and Resource Economics 63(4), 922–939.

Best, R., Burke, P.J., Nishitateno, S., 2019b. Evaluating the effectiveness of Australia's Small-scale Renewable Energy Scheme for rooftop solar. Energy Economics 84, 104475.

Best. R., Chareunsy, A., Li, H., 2021. Equity and effectiveness of Australian small-scale solar schemes. Ecological Economics 180, 106890.

Bollinger, B., Gillingham, K., 2012. Peer Effects in the Diffusion of Solar Photovoltaic Panels. Marketing Science 31(6), 900–912.

Bremer, J., Linnenluecke, M.K., 2017. Determinants of the perceived importance of organisational adaptation to climate change in the Australian energy industry. Australian Journal of Management 42(3), 502–521.

Choi, B., Luo, L., Shrestha, P., 2021. The value relevance of carbon emissions information from Australian-listed companies. Australian Journal of Management 46(1), 3–23.

Corbett, C.J., Hershfield, H.E., Kim, H., Malloy, T.F., Nyblade, B. Partie, A., 2022. The role of place attachment and environmental attitudes in adoption of rooftop solar. Energy Policy 162, 112764.

Crago, C.L., Chernyakhovskiy, I., 2017. Are policy incentives for solar power effective? Evidence from residential installations in the Northeast. Journal of Environmental Economics and Management 81, 132–151.

Crago, C.L., Koegler, E., 2018. Drivers of growth in commercial-scale solar PV capacity. Energy Policy 120, 481–491.

De Groote, O., Verboven, F., 2019. Subsidies and Time Discounting in New Technology Adoption: Evidence from Solar Photovoltaic Systems. American Economic Review 109(6), 2137–72.

Dodd, T., Nelson, T., 2019. Trials and tribulations of market responses to climate change: Insight through the transformation of the Australian electricity market. Australian Journal of Management 44(4), 614–631.

Frey, E.F., Mojtahedi, S., 2018. The impact of solar subsidies on California's non-residential sector. Energy Policy 122, 27–35.

Gillingham, K.T., Bollinger, B., 2021. Social Learning and Solar Photovoltaic Adoption. Management Science 67(11), 7091–7112.

Hansen, A.R., Jacobsen, M.H., Gram-Hanssen, K., 2022. Characterizing the Danish energy prosumer: Who buys solar PV systems and why do they buy them? Ecological Economics, 193, 107333.

Helm, D., Hepburn, C., 2019. The age of electricity. Oxford Review of Economic Policy 35(2), 183–196,

Horne, C., Kennedy, E.H., Familia, T., 2021. Rooftop solar in the United States: Exploring trust, utility perceptions, and adoption among California homeowners. Energy Research & Social Science 82, 102308.

Hossain, M., Yoshino, N., Taghizadeh-Hesary, F., 2021. Default risks, moral hazard and market-based solution: Evidence from renewable energy market in Bangladesh. Economic Modelling 95, 489–499.

Irwin, N.B., 2021. Sunny days: Spatial spillovers in photovoltaic system adoptions. Energy Policy 151, 112192.

Kong, X., Jiang, F., Zhu, L., 2022. Business strategy, corporate social responsibility, and within-firm pay gap. Economic Modelling 106, 105703.

Kwan, C.L., 2012. Influence of local environmental, social, economic and political variables on the spatial distribution of residential solar PV arrays across the United States. Energy Policy 47, 332–344.

Ma, D., Chang, C-C., Hung, S.W., 2013. The selection of technology for late-starters: A case study of the energy-smart photovoltaic industry. Economic Modelling 35, 10–20.

Mah, D.N., Wang, G., Lo, K., Leung, M.K.H., Hills, P., Lo, A.Y., 2018. Barriers and policy enablers for solar photovoltaics (PV) in cities: Perspectives of potential adopters in Hong Kong. Renewable and Sustainable Energy Reviews 92, 921–936.

Mildenberger, M., Howe, P.D., Miljanich, C., 2019. Households with solar installations are ideologically diverse and more politically active than their neighbours. Nature Energy 4, 1033–1039.

O'Shaughnessy, E., 2022. Rooftop solar incentives remain effective for low- and moderate-income adoption. Energy Policy 163, 112881.

Palm, A., 2020. Early adopters and their motives: Differences between earlier and later adopters of residential solar photovoltaics. Renewable and Sustainable Energy Reviews 133, 110142.

Palm, A., Lantz, B., 2020. Information dissemination and residential solar PV adoption rates: The effect of an information campaign in Sweden. Energy Policy 142, 11540.

Palm, J., 2018. Household installation of solar panels - Motives and barriers in a 10-year perspective. Energy Policy 113, 1–8.

Reindl, K., Palm, J., 2021. Installing PV: Barriers and enablers experienced by non-residential property owners. Renewable and Sustainable Energy Reviews 141, 110829.

Roberts, M.B., Bruce, A., MacGill, I., 2019. Opportunities and barriers for photovoltaics on multi-unit residential buildings: Reviewing the Australian experience. Renewable and Sustainable Energy Reviews 104, 95–110.

Rode, J., Weber, A., 2016. Does localized imitation drive technology adoption? A case study on rooftop photovoltaic systems in Germany. Journal of Environmental Economics and Management 78, 38–48.

Wolske, K.S., Gillingham, K.T., Schultz, P.W., 2020. Peer influence on household energy behaviours. Nature Energy 5(3), 202–212.

Yoshino, N., Taghizadeh–Hesary, F., Nakahigashi, M., 2019. Modelling the social funding and spill-over tax for addressing the green energy financing gap. Economic Modelling 77, 34–41.

Zander, K.K., 2020. Unrealised opportunities for residential solar panels in Australia. Energy Policy 142, 111508.

Zander, K.K,, 2021. Adoption behaviour and the optimal feed-in-tariff for residential solar energy production in Darwin (Australia). Journal of Cleaner Production 299, 126879.

Web references

ABS, 2018. 2016 Australian Census. Australian Bureau of Statistics. https://www.abs.gov.au/websitedbs/censushome.nsf/home/2016. Accessed 18 November 2021.

ABS, 2020. *ASGS Data correspondence*, *Postal Area to Statistical Area Level*. Available at: https://data.gov.au/dataset/ds-dga-23fe168c-09a7-42d2-a2f9-fd08fbd0a4ce/details. Accessed 18 November 2021.

ABS, 2021. *Counts of Australian Businesses, including Entries and Exits*. Available at: https://www.abs.gov.au/statistics/economy/business-indicators/counts-australian-businesses-including-entries-and-exits/latest-release. Accessed 18 November 2021.

AEMO, 2021. Distributed Energy Resource Register, Australian Energy Market Operator. https://aemo.com.au/en/energy-systems/electricity/der-register. Accessed 19 October 2021.

Ausgrid, 2018. *Business customer survey results: solar, batteries and energy efficiency*. Accessed 1 February 2022.

Australian Energy Market Commission, 2021. National Energy Retail Rules. https://www.aemc.gov.au/regulation/energy-rules/regulation. Accessed 18 November 2021.

Australian Energy Regulator, 2019. Values of Customer Reliability. https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability. Accessed 18 November 2021.

Australian Government, 2019. Renewable Energy (Electricity) (Zone Ratings and Zones for Solar (Photovoltaic) Systems) Instrument, F2019L01583. Accessed 18 November 2021.

Australian Government, 2021. *Rebates and assistance*. Available at: https://www.energy.gov.au/rebates. Accessed 18 November 2021.

IEA, 2020. IEA PVPS report - Trends in Photovoltaic Applications 2020. International Energy Agency. https://iea-pvps.org/trends_reports/trends-in-pv-applications-2020. Accessed 6 June 2022.

Moreland City Council, 2019. 'Inside Moreland'. Autumn 2019. Accessed 1 February 2022.

Small Business Commissioner, 2022. Getting approval for a home business. NSW Government. https://www.smallbusiness.nsw.gov.au/get-help/home-business/getting-approval-home-business. Accessed 18 June 2022.

Todae Solar, 2021. 'MW+ Commercial Solar Systems'. https://todaesolar.com.au/pace-farms-2. Accessed 18 November 2021.

Victorian Government, 2020. St Ignatius Vineyard and Winery Agriculture Energy Investment Plan – Case Study.

Victorian Government, 2021a. *Agriculture Energy Investment Plan Extension*. Available at: https://agriculture.vic.gov.au/support-and-resources/funds-grants-programs/agriculture-energy-investment-plan. Accessed 1 February 2022.

Victorian Government, 2021b. *Cutting energy costs for Victorian farmers*. Media release: 1 March 2021. Accessed 1 February 2022.