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Conservation Spillovers: The Effect of Rooftop Solar on Climate Change Beliefs

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Abstract

Biased beliefs about climate change may lead to under-regulation of emissions. We study a new channel by which the public form beliefs about climate change: visible mitigation actions. By exploiting the rapid growth of rooftop solar panels, a large survey, and differences in incentives to install solar, we find that visible mitigation actions have a positive impact on belief in basic climate science. However, we also find that higher solar penetration reduces concern about the impacts of climate change, which may dampen demand for additional mitigation policy and individual abatement effort. Our results suggest that government policies that incentivize technology adoption can have subtle but important spillover effects on beliefs and other behaviors.

Keywords Solar power · Green energy · Climate change · Beliefs · Motivated reasoning · Peer effects · Policy spillovers · Instrumental variables

1 Introduction

The general public is far more skeptical about climate change than the scientific community. Recent surveys indicate that only half of the population of major industrialized countries such as the United States[1] and Australia[2] believe that climate change is real and caused by human action. In contrast, 97% of climate scientists and virtually all of the world's

[1] Source: http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/.

[2] Source: http://www.smh.com.au/environment/climate-change/csiro-survey-most-coalition-voters-reject-humans-to-blame-for-climate-change-20151103-gkpgf8.html.

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leading scientific bodies agree that humans are the main cause of climate change (Cook et al. 2013) and 93% of climate economists agree that climate change requires immediate action (Howard and Sylvan 2015).

Since mitigation of climate change requires substantial political and public support, public perception is crucially important. Of particular concern to economists is whether institutions aggregate information efficiently, which depends on whether beliefs reflect unbiased knowledge of costs and benefits of a given course of action (Millner and Ollivier 2016). The economics literature therefore focuses on understanding the causal pathways that determine beliefs. For instance, previous studies have shown that beliefs and concern about climate change are affected by external factors such as weather (Deryugina 2013; Herrnstadt and Muehlegger 2014), economic conditions (Kahn and Kotchen 2011), information on the scientific consensus (Deryugina and Shurchkov 2016) and media coverage (Beattie 2017). These add to a body of evidence from social science linking beliefs about climate change to individual characteristics such as political identity (McCright and Dunlap 2011), scientific literacy (Kahan et al. 2012) and gender (Dastrup et al. 2012; McCright 2010).

This paper explores a new causal channel by which individuals may form beliefs about climate change: visible mitigation actions. Governments devote considerable resources towards encouraging individuals to adopt a range of environmentally friendly technologies. Adoption of these technologies may in turn affect beliefs about climate change via a number of mechanisms. According to theories of motivated reasoning, individuals selectively form beliefs that align with their interests or justify their behavior (Bénabou and Tirole 2016). This can arise from strong preferences for consistency, self-image and self-signaling. Using this model, if households are incentivized to take an environmental action they may update their beliefs towards a higher level concern about climate change for the purpose of consistency. Desire for consistency or consonance of beliefs and models of social learning would also predict that individuals may modify their beliefs upon observing environmental actions of their neighbors (Golman et al. 2016). Households may interpret the climate-friendly actions of their peers as signals that they should be more concerned about climate change. On the other hand, visible mitigation actions may also reduce concern about climate change if seeing mitigation efforts is reassuring (Werfel 2017).

We evaluate whether rooftop solar installation affects beliefs about climate change. Rooftop solar is a particularly good example of a visible and salient mitigation action: it involves installing large photovolatic panels that are often easily visible to neighbors and passers-by and produce zero-emission electricity from sunshine. We contribute to the literature that studies determinants of the decision to adopt solar panels, such as subsidies and peer behavior (Bollinger and Gillingham 2012; Burr 2014; Graziano and Gillingham 2014; Hughes and Podolefsky 2015; Kraft-Todd et al. 2018). This paper is also closely related to (Comin and Rode 2013), which studies the effect of adoption on voting patterns (Comin and Rode 2013),[3] although we focus on the effects of installation on direct measures of belief in and concern about climate change.

The setting for our study is Australia, which has experienced a particularly dramatic rise in installations—by 2016, more than one in six households had installed solar panels. We match survey data collected by the Commonwealth Scientific and Industrial Research Organization (CSIRO) to postcode level solar penetration data. Demonstrating a causal

[3] Voting patterns could reflect changes in beliefs about climate change, but they could also reflect changes in support for solar panel subsidies.

link between solar installation and beliefs requires care as a correlation between solar penetration and beliefs is not necessarily causal—households that are more concerned about climate change may be more likely to install solar panels. To overcome this, we use an instrumental variables strategy—we first predict solar penetration using the interaction between solar irradiance and feed-in tariffs (FITs), the per-unit price at which electricity produced by rooftop solar and not used by the household can be sold back to the grid.[4] This variable measures the economic incentive to install solar as it is highest where solar panels are most productive and when the electricity produced provides the most revenue. This economic incentive is highly correlated with solar installation and is plausibly unrelated to environmental preferences. We then model beliefs as a function of this predicted installation to generate causal estimates of the effect of solar installation. We also control for permanent differences across postcodes and years to ensure that our results are not driven by systematic differences between regions of the country or by common time-specific shocks.

We find that visible mitigation actions affect beliefs about climate change. Our first result is that living in postcodes with more solar panels makes households more likely to subscribe tof the scientific consensus about climate change. An additional 1000 solar panels in a neighborhood increases the share of that neighborhood that believe climate change is primarily caused by human action by 7 percentage points. This equivalent to a one standard deviation increase in solar panels increasing the share of that believes climate change is primarily caused by humans by 0.28 standard deviations. For context, Kahn and Kotchen (2011) find that a one standard deviation increase in unemployment causes a 0.16 standard deviation decrease in the probability that respondents believe climate change is happening, and Deryugina (2013) finds a similar decrease from a one standard deviation increase in the fraction of days of abnormally cold weather.

Our second result is that living in postcodes with more solar panels makes individuals less worried about the consequences of climate change. The addition of 1000 solar panels causes concern about the effects of climate change to fall by 6 percentage points, which is equivalent to a one standard deviation increase in panels causes a 0.24 standard deviation reduction in the share of a neighborhood that is concerned about climate change. Taken together, these findings suggest that households surrounded by solar panels are more likely to be convinced that climate change is real but less likely to be concerned.

We explore heterogeneity of these effects along demographic characteristics. We find evidence that solar panels have different effects across subgroups. Solar panels have the largest effect on the beliefs of those with lower than average education and above median age. In contrast, men are more likely to reduce their concern about climate change. Finally, we demonstrate the robustness of our results to alternative measures of solar installation and sample restrictions.

Our results highlight the existence of important spillovers from visible mitigation actions to beliefs. A policy that is successful in changing a household's behavior may also change their beliefs and the beliefs of those around them towards support for the goals of the policy. Yet in the case of an environmental public good, the action may also reassure and reduce other contributions to similar public goods. The net effect of these two mechanisms on environmental outcomes and support for additional policy effort is unclear. We find very little evidence that, on average, solar panels have a net effect on other environmental actions or policy support. We then explore whether solar panels could have a

[4] We use the interaction term because solar irradiance itself does not vary at over time, so cannot be used in a panel data context with a full set of fixed effects.

differential impact via changes in beliefs and concern. Our back of the envelope calculations indicate that solar panels, by increasing the share of people who believe in climate science, generally have small and insignificant effects on environmental actions and policy support. However, we do find that by decreasing the share of people who are concerned about climate change, solar adoption could result in a 1–1.5 percentage point reduction in the share of people voluntarily enrolling in Green Power purchasing, using public transit, and supporting a carbon tax. Although we demonstrate this relationship for the case of solar subsidies in Australia, it may well occur in other areas of environmental policy, particularly in cases where the behavior change is salient to the household and visible to those around her.

The remainder of this paper is structured as follows. Section 2 provides some background on rooftop solar and climate change in Australia. Section 3 describes the data. Section 4 outlines our empirical strategy while Sect. 5 presents the main results. Finally, Sect. 6 concludes.

2 Background

In the late 2000's Australian federal and state governments instituted multiple programs to subsidize and encourage solar installation. These subsidies, together with an abundance of sunshine and high electricity prices, led to the unprecedented uptake of rooftop solar. Over the period between 2001 and 2015 the number of solar panels went from 500 to over 1.5 million, or approximately one in six households. We exploit this rapid take up to study the impacts of visible mitigation actions on beliefs about climate change.

There are a number of reasons for households to install solar panels such as a desire to contribute to climate change mitigation, pecuniary or financial benefits, or a preference for the technology. The mechanism studied in this paper relies on a perceived link between solar panels and climate change mitigation. As the majority of electricity production in Australia is coal based, solar panels clearly produce fewer emissions than electricity bought from the grid.[5] Most government programs had the explicit purpose of reducing greenhouse gas emissions and mitigating climate change (Byrnes et al. 2013), but many also claim that their objective is to help households manage their electricity bills. For our purposes, it is crucial to determine not just whether there is a relationship between rooftop solar and climate change, but also whether the general public makes this association. Solar subsidy programs, and in particular the accompanying political statements and media coverage, provide anecdotal evidence of a link between rooftop solar and climate change. In order to demonstrate the plausibility of this link empirically, we look for further evidence in Google searches.

2.1 Google Trends Analysis

Google searches provide insight into the salience of particular topics, and have been shown to be a good predictor of economic activity (Choi and Varian 2012). We test for an

[5] Source: https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aes/2016-australian-energy-statistics.pdf.

association between solar panels and climate change by comparing Google search data for 'climate change', 'global warming', and 'solar'.

The Google search data provided by Google Trends only allows for cross sectional or time series (as opposed to panel) queries. It also does not provide values that are consistent across queries, only relative values within a query. Specifically, a value of 100 for a given state in a cross sectional query indicates that the search term formed a higher share of all Google searches in that state than in all other states in the query. A value of 50 for another state in the same query indicates that the search term formed half as large a share of Google searches in that state than it did in the state with the highest share. Time series queries allow for similar relative comparisons over time. In order to construct a panel, we perform a cross sectional query by state to get comparisons of search levels between states. We then interact this with weekly time series queries for each state, which provide within-state time series variation, to construct a state-week level panel of searches for each term.

Figure 1 and Table 1 show a significant positive correlation between searches for 'solar' and searches for 'climate change' and 'global warming'. This result is robust to inclusion of both state and week fixed effects. Within a given state, when households search more often for information about solar panels they are also search more often for information about climate change. While this does not necessarily imply a causal relationship, it shows that when solar panels are salient, climate change is also a salient issue and thus motivates the rest of our analysis, which analyzes the causal relationship between these variables.

3 Data

In order to estimate the effect of rooftop solar adoption on beliefs about climate change, we use measures of climate beliefs from the Australian Climate Attitudes Survey and rooftop solar installation data from the Australian Photovoltaic Institute. In this section, we present an overview of these data sources and the construction of the variables we use for our analysis.

The Australian Climate Attitudes Survey is a repeated cross-sectional survey of Australians, comprised of five national surveys conducted annually in July and August of each year between 2010 and 2014. A total of 17,493 Australians completed the surveys, which were administered online by the Commonwealth Scientific and Industrial Research Organization using a representative sample of respondents from across metropolitan, regional, and rural Australia.[6]

The survey elicits respondents' attitudes to climate change along with responses to a series of demographic and behavioral questions. We focus on questions that are asked in all years and are particularly relevant to our three outcomes of interest: belief in climate science; concern about climate change, and other environmentally friendly behaviors. In particular, the questions we use to analyze beliefs about climate science ask whether the respondents believe climate change is happening and whether they think humans are the dominant cause; the question we use to analyze concern about climate change asks respondents whether they think it will harm them personally; and the questions we use to analyze other mitigation behaviors asks respondents whether they voluntarily purchase power from renewable energy sources from the government administered program called

[6] Approximately 5000 respondents answered more than one survey.

Green Power, switch off lights, catch public transit, support a tax on emitting industries, and whether they support policies to encourage renewable energy. Table 8 shows the exact wording of these questions as well as the available answers. Figure 2 shows the time series and cross-sectional variation in whether respondents believe climate change is caused by humans.[7] There is considerable variation both across space and time but no obvious trend in beliefs over the period of study.

Our main independent variable is the number of rooftop solar installations, which we source from from Australian Photovoltaic Institute (APVI). APVI is a not-for-profit research institution funded by the Australian Government. Their rooftop solar data are sourced from the Clean Energy Regulator, the government agency responsible for administration of renewable energy policies in Australia. For each postcode, we calculate annual installation of solar panels and cumulative installation of panels with capacities smaller than 10kW, capturing rooftop solar installations while excluding larger solar power plants. Cumulative installations are a more natural measure of the salience of solar panels and thus their potential to influence beliefs than an alternative measure, such as annual installations. For instance, if there is a large number of installations in a particular postcode 1 year, we would expect those installations to continue to be salient through the following year, even if fewer new panels were installed.

Finally, we collect measures of temperature and irradiance from the Australian Bureau of Meteorology. We match each postcode with the nearest 3 weather stations and assign it the average temperature of these three stations.

Figure 3 plots national monthly solar installation data from the beginning of 2005 and the end of 2014, highlighting the months during that period during which the climate attitudes surveys were conducted. There was a dramatic increase in solar installation over the period of our analysis, including two spikes in mid-2011 and mid-2012 that coincide with significant reductions in federal government rebates. Figure 4 illustrates both time series and cross-sectional variation in solar installation.[8] Solar installation is highest in suburban areas along the east coast, where the majority of the Australian population resides, and in particular in the north where there is more sunshine.

We limit our sample to households in postcodes with population densities[9] between 10 and 4000.[10] In densely populated areas, the majority of people live in apartments and there is little space available to install rooftop solar. On the other hand, in extremely sparsely populated areas, individuals can see very few of their neighbors, making it more unlikely that their behavior is observed by others. Our main results are qualitatively the same for different boundary choices.

Table 2 shows summary statistics of the variables of interest at the postcode level—our unit of analysis. Around 80% of the respondents believe that climate change is happening, but only half think that climate change is primarily caused by human actions and less than half believe that climate change will harm them personally. These numbers are comparable

[7] The map is produced at the Statistical Area 3 level, part of the Australian Bureau of Statistics statistical geography.

[8] The map is produced at the Statistical Area 3 level, part of the Australian Bureau of Statistics statistical geography.

[9] Here we use the 2016 population density data from Australian Bureau of Statistics.

[10] According to (Spencer et al. 2015), 3000 people per square kilometers is often cited as the lowest density that supports any form of mass public transit. In a robustness check, we vary the upper bound for suburban population density from 3000 people per square kilometer to 4000 people per square kilometer and the results are qualitatively identical.

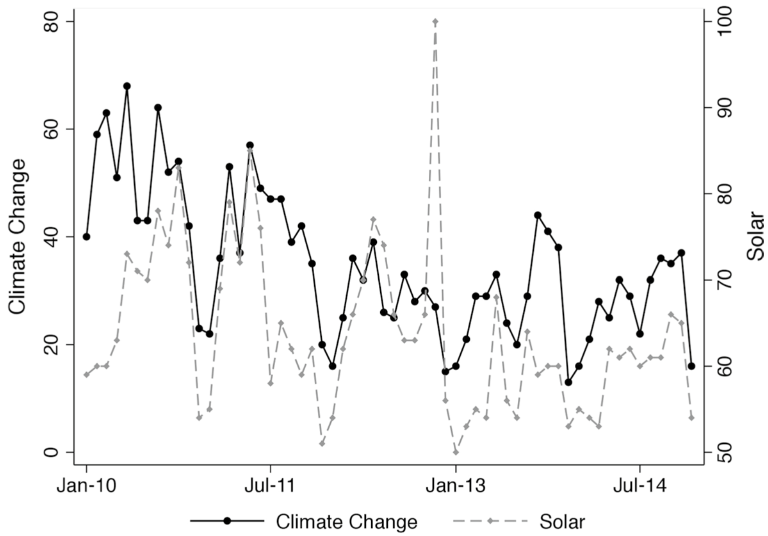

Fig. 1 National Trends of Google Searches for 'Climate Change' and 'Solar'. Figure plots the Australian Google search index for 'Climate Change' and 'Solar' at the monthly level. The Google search data consists an index for a given search term as a share of all searches. A value of 100 indicates that the search term was a higher share of all Google searches in that state than in all other states. A value of 50 indicates the search term had half that share

Table 1 Relationship between Google Searches for 'Climate Change', 'Global Warming' and 'Solar'

Dependent variables:	Google searches for			
	'Climate Change'		'Global Warming'	
'Solar'	0.094***	0.041***	0.106***	0.061***
	(0.012)	(0.011)	(0.008)	(0.008)
State FE	No	Yes	No	Yes
Week FE	No	Yes	No	Yes
Observations	3752	3752	3752	3752
R^2	0.017	0.659	0.046	0.604

The Google search data consists an index for a given search term as a share of all searches. A value of 100 indicates that the search term was a higher share of all Google searches in that state than in all other states. A value of 50 indicates the search term had half that share. Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

to other industrialized nations. In the United States 70% believe climate change is happening, 52% believe that climate change is caused by humans, and 40% believe that climate change will harm them personally.[11] In Britain, 87% of the respondents believe that climate

[11] Source: http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/.

(a) 2010 **(b)** 2014

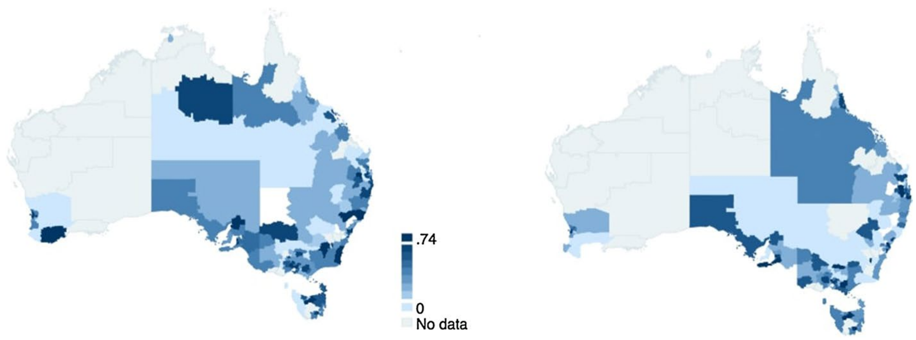

Fig. 2 Distribution of Belief in Climate Science. **a** Plots the share of each Statistical Area 3 that believe that climate change is human induced in 2010, the start of the sample period. **b** Plots the same for 2014, the end of the sample period. Colors depict quintiles of the distribution of the share in 2014. (Color figure online)

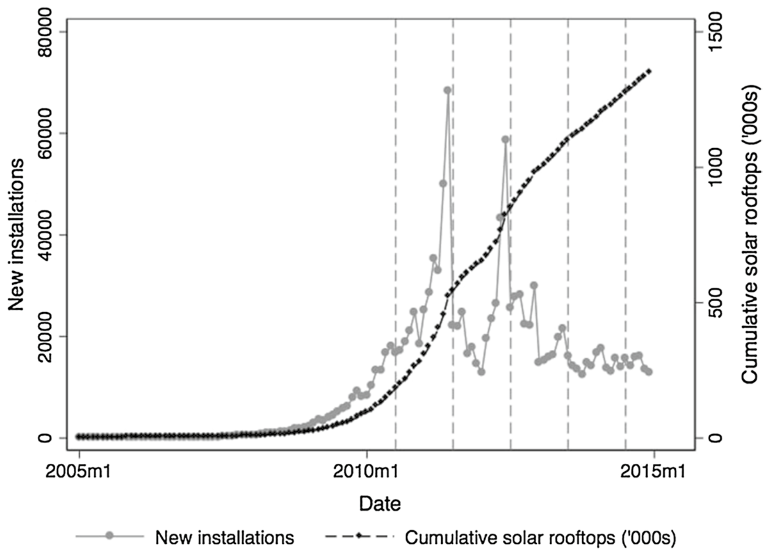

Fig. 3 Timing of Solar Installation and Survey Waves. Figure plots new solar installations, cumulative solar rooftops from the Australian Photovolatic Institute and the timing of the five waves of the Australian Climate Attitudes Survey

change is happening, 64% believe that climate change is caused by humans, and 80% of respondents worry about climate change.[12]

[12] Source: https://www.newscientist.com/article/2121132-more-people-now-believe-human-made-climate-change-is-happening/.

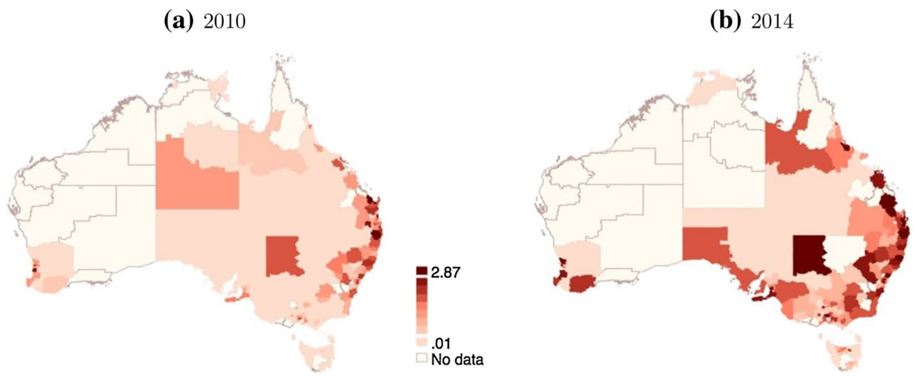

Fig. 4 Distribution of Solar Installations. **a** Plots cumulative solar installations (000s) at the Statistical Area 3 level for 2010, the start of the sample period. **b** Plots the same for 2014, the end of the sample period. Colors depict quintiles of the distribution of installations in 2014. (Color figure online)

Table 2 Summary statistics

Variable	Obs	Mean	SD
Is CC happening?	5362	.795	.226
CC caused by humans	5362	.461	.281
CC will harm you personally	5362	.463	.283
Buy green power from provider	5362	.303	.32
Number of solar installations (000s)	5362	1.013	1.124
Feed-in Tariff	5362	23.802	19.795
Solar irradiance	5362	17.217	1.718
Age	5362	50.857	9.436
Male	5362	.496	.278
% college-educated or above	5362	.326	.275
% household income ≥ \$60,000–\$89,999	5362	.579	.29
Have kids	5362	.285	.255

Data are aggregated at postcode-year level

4 Empirical Strategy

In our empirical analysis, we are interested in estimating the effect of the number of solar panels on climate beliefs in postcode p in year t. Specifically, we are interested in β_1 in the following equation:

$$\text{Beliefs}_{pt} = \alpha + \beta_1 \text{ Solar}_{pt} + \beta_2 X_{pt} + \phi_p + \psi_t + \epsilon_{pt} \tag{1}$$

where Solar_{pt} is the number of solar panels in postcode p in year t, X_{pt} is a vector of controls, including age, sex, education, income, children, and trust in institutions, and ϕ_p and ψ_t are postcode and year fixed effects that control for average differences across postcodes over all time periods, and average differences across years over all postcodes. Beliefs_{pt} and X_{pt} are collected for each survey respondent and then used to generate a postcode-year average.

Our treatment variable—the number of solar panels a respondent interacts with—does vary within postcode, but we are only able to observe a postcode level measure. Given this, the most intuitive unit of analysis is the postcode-year. We do weight by postcode population to provide nationally representative estimates and include individual level results in the "Appendix" for comparison.

Ordinary least squares (OLS) estimates of β_1 are potentially affected by simultaneity bias. Section 2 showed evidence that there is an association between climate change and solar panels. This not only motivates the causal relationship illustrated in Eq. 1, it also motivates potential reverse causality. Concern over climate change may induce households to install solar, which would lead to a positive value for β_1 in Eq. 1, which cannot be interpreted as causal. Further, it is possible that an omitted variable, such as a local 'green' campaign, could affect both beliefs about climate change and solar installation.

The set of control variables and fixed effects do ameliorate some of this potential bias but do not eliminate it entirely. If, during the period of our analysis, areas of the country receive differing shocks to beliefs about climate change and adjust solar installation accordingly, our estimate of β_1 in Eq. 1 will be biased.

We address this simultaneity bias using an instrumental variables strategy that exploits the economic incentive to install solar. The decision to install rooftop solar panels has both economic and environmental components. Installation costs represent a substantial fixed cost, but once installed, households can sell power that they do not use back to the grid at a rate which is often subsidized and consequently can be much higher than the rate electricity is sold at. When installing panels, households are able to sign a contract to receive this subsidized rate, or Feed-In Tariff (FIT), for several years into the future. When FITs are higher, households have a larger economic incentive to install rooftop solar, so there are more new solar installations. FITs are determined by state governments, and, as Fig. 5 shows, vary substantially over the period of our sample. Importantly from the perspective of allowing us to use it as an instrumental variable, during our sample period these changes almost exclusively consist of decreases in FITs that are scheduled well in advance. This allows us to exploit strategically timed purchases of household solar panels and makes it less likely that these changes are a function of shocks to beliefs. Since we use postcode and year fixed effects in all of our preferred specifications, in order to violate our exclusion restriction a shock to beliefs would have to not only be state-specific, but it would also have to be noticed and reacted to by state governments rapidly. We find no evidence of this type of response in public discussion of FITs.[13]

The return from selling electricity back to the grid depends not only on the per unit price households can receive, but also on the expected amount of electricity they can produce. This can be captured by average solar irradiance, the amount of energy from the sun hitting a given area of land. We therefore use the following approximation of the returns to solar ($Return_{pt}$) available to households installing panels in postcode p up to year t:

$$\text{Return}_{pt} = \sum_{m=1}^{12*m} \text{FIT}_{pm} \cdot \text{Irradiance}_p \tag{2}$$

[13] FIT schedules were determined based on targets for payback periods and solar uptake. This schedule was monitored by state regulators, who were not elected officials and thus made decisions that were plausibly exogenous from shocks to public pressure. For an example of a government report discussing this process in Victoria, see https://www.dtf.vic.gov.au/sites/default/files/2018-02/inquiry-into-feed-in-tariffs-and-barriers-to-distributed-generation.pdf.

where FIT_{pj} is the Feed-In Tariff available in postcode p in month m (thus $\sum_{m=1}^{12*t} \mathrm{FIT}_{pm}$ is the sum of monthly FITs up until year t), and $\mathrm{Irradiance}_p$ is historical average solar irradiance in postcode p. Return_{pt} consists of the product of FITs, which vary by state-year, and irradiance, which varies by postcode. Thus the unit of analysis for the instrument is postcode-year.

Return_{pt} is a proxy for the economic return to installing solar panels up to year t, so it should have a causal effect on aggregate installations at t.[14] It is higher when consumers can receive a higher payment for selling electricity back to the grid, particularly if those consumers live in areas where they can expect to receive more sunshine.

Further, since the instrument affects only the economic incentives to install solar, and not the environmental incentives, it should affect beliefs about climate change only through solar installations. Any correlation between the instrumental variable and beliefs can therefore be interpreted as occurring via solar installation.[15]

We use our proxy for the economic return to install solar to implement two staged least squares strategy (2SLS). In the first stage, we regress Return_{pt} on Solar_{pt} to predict installations that are generated by economic incentives and not by climate change beliefs. In the second stage, we use this prediction $\widehat{Solar}_{pt}$ in Eq. 1. The resulting β_1 coefficients can then be interpreted as the causal effect of solar panels on climate change beliefs.

5 Results

We are interested in three responses to solar panels: beliefs about climate change, concern about climate change, and other mitigation actions. This section discusses each of these outcomes in turn.

5.1 Belief in Climate Science

If a household installs solar panels, there may be an effect on the beliefs of both individuals in that household and those around them. Within the household, installing solar panels may cause household members to investigate climate change or to use climate change as further justification for their investment. Neighbors may see the installation as a signal of concern about the household's beliefs about climate change, which may lead them to update their own beliefs or do further investigation.

Table 3 reports both OLS and 2SLS estimates of the effect of solar panels on people's beliefs about climate change. Panel A shows that solar installations increase the share of people who believe that climate change is caused by humans. Column 1 reports the OLS

[14] The actual net-present value (NPV) of residential solar depends on a number of factors that vary significantly over the period of our sample (including capital costs, subsidies such as feed-in tariffs and electricity prices) and that vary across households (including the volume and timing of electricity consumption, electricity prices, solar irradiance, panel orientation). An analysis by the think tank The Grattan Institute found that in 2015, the average NPV for installing a 3kW system was positive in five out of six states, assuming a five per cent discount rate (Wood and Blowers 2015). This implies that households responding only to economic incentives might well choose to install solar during our period of analysis. The Grattan Institute also notes that the major differences in NPV across households can be explained by differences in electricity consumption and in solar irradiance.

[15] If those observing the installations identified by our instrument interpret these installations as motivated purely by economic incentives, then we should not expect to see any effect on beliefs. As we will show, the fact that we identify effects on beliefs and concern suggests that people continue to interpret solar panels as a signal about climate change even if they were motivated by economic incentives.

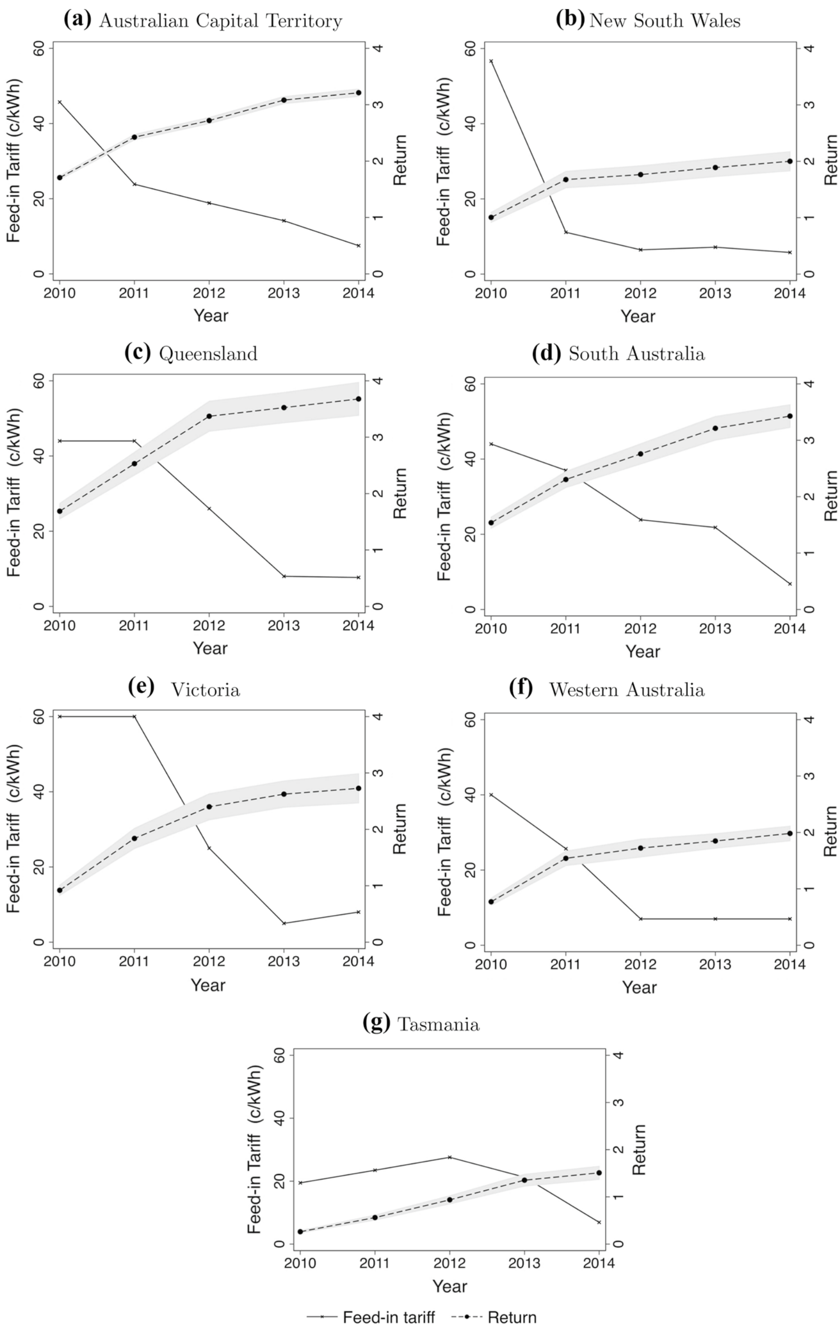

Fig. 5 Feed-in Tariffs and Return to Installation by State. Each sub-figure plots Feed-in Tariffs and a 95% confidence interval for the mean of the instrumental variable $Return_{pt}$ (defined in Eq. 2) through the sample period. Data are weighted by postcode population in 2016. *Note*: Because the return variable represents the cumulative incentive to install solar, it increases over time even as FITs decrease

Table 3 The effect of solar panels on belief in climate science (IV results)

Dependent variable	CC caused by humans			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel A				
Number of solar installations (thousands)	0.006 (0.008)	0.047 (0.038)	0.068* (0.036)	0.071** (0.036)
Dependent variable	CC is happening			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel B				
Number of solar installations (thousands)	0.013* (0.007)	0.038 (0.030)	0.044 (0.028)	0.044 (0.028)
	First-stage for number of solar installations			
		(1)	(2)	(3)
Panel C				
$Return_{pt}$		0.640*** (0.131)	0.639*** (0.127)	0.645*** (0.127)
Dem. controls	N	N	Y	Y
Temperature	N	N	N	Y
Year FE	Y	Y	Y	Y
Postcode FE	Y	Y	Y	Y
Observations	5362	5362	5362	5362
Number of postcodes	1301	1301	1301	1301
F-test of first stage		23.91	25.31	25.64

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Data at postcode level are weighted by postcode population in 2016. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children and trust. The temperature controls are the average minimum and maximum temperature

estimates showing that a 1000 unit increase in solar installations is correlated with 0.6 percentage point increase in the share of the population who believe climate change is caused by humans, and columns 2–4 report the corresponding 2SLS estimates, which include a strong first-stage relationship between the cumulative return to solar ($Return_{pt}$) and installation of solar panels.[16] Column 4 shows results where a full set of postcode and year fixed effects along with demographic controls for age, gender, education attainment, income levels, and children are employed, as well as measures for trust in government and community, which might affect how people form and update their beliefs about climate change.

[16] The 2SLS estimates are larger in magnitude than the OLS estimates. While this is not what would be predicted if simultaneity bias was the only difference between the OLS and 2SLS estimates, it is consistent with attentuation bias in the OLS estimates due to measurement error or with differences in the local average treatment effect isolated by the 2SLS estimates. Measurement error in solar installations is plausible for a number of reasons. First, the data are from government records and may well be subject to human error in data collection. There may also be natural delays between when panels are put up, when people notice

Furthermore, since weather fluctuations may influence what individuals believe about climate change and their decision to install solar panels, we control for average maximum and minimum temperatures. The parameter estimates suggest that 1000 additional solar installations in a postcode lead to a 7 percentage point increase in the share of people who believe that climate change is caused by humans, which is equivalent to a one standard deviation increase in solar panels leading to a 0.28 standard deviation increase in the share of a postcode that believes climate change change is caused by humans.

Panel B of Table 3 shows a similar set of specifications, where the dependent variable is the share of respondents who believe that climate change is happening. The estimates indicate that increasing solar installations by 1000 causes a 4.4 percentage point increase in the share of people who believe climate change is largely caused by humans, although this result should only be interpreted as suggestive, since it is not quite significant at the 90% level.[17] This magnitude is equivalent to a one standard deviation increase in solar panels leading to a 0.22 standard deviation increase in the share of a postcode that believes climate change is real.

These results show evidence of a positive spillover from beliefs and actions. If people take more environmentally friendly actions, environmental literacy increases. Conceivably, this could motivate further environmental actions. It is also evidence of a positive spillover effect for policies that incentivize environmental actions, as these actions can have positive effects on belief in climate change.

5.2 Concern About Climate Change

Our next set of specifications examine the effect of solar installations on concern about climate change. To that end, the dependent variable in Table 4 is the share of respondents in a postcode who believe that climate change will harm them personally. We find that people living in postcodes where solar panels are installed become less worried about the consequences of climate change. The magnitude of the coefficient in column 4 indicates that increasing solar installations by 1000 reduces the share of people who believe climate change will harm them personally by 6 percentage points. Equivalently, a one standard deviation increase in solar panels reduces the share of a neighborhood that are concerned about climate change by 0.24 standard deviations.

These results have a quite different interpretation from those in the previous subsection. They show evidence of a negative spillover from actions and beliefs. Solar panel installation seems to have a reassuring effect on respondents, perhaps because they interpret it as a signal of current levels of mitigation or the willingness of individuals and governments to undertake further mitigation efforts. Alternatively, if households initially hold beliefs about

Footnote 16 (continued)

them and when they are registered. Finally, some people may neglect to submit the paperwork to register their panels. It is also possible that the effect of incentivized solar installation, which is the local average treatment effect the IV strategy isolates, is larger than the effect of solar panels installed for environmental reasons. For example, individuals (and their neighbors) who only install solar because they are incentivized to do so have more malleable beliefs than those in areas where most people care about the environment and install solar panels regardless of incentives. In the concern results shown in the next section, we also find that the 2SLS results are larger in magnitude than the OLS results, but with negative coefficients. This is also consistent with the OLS results being systematically biased towards 0 or greater local average treatment effects for incentivized solar panels, but is not consistent with simultaneity bias in the 2SLS estimates.

[17] Given that almost 80% of respondents believe that climate change is happening, there is not as much potential for beliefs to be updated towards the scientific consensus. This may partially explain why the effect on this variable is not as significant as the effect on beliefs about whether climate change is caused by humans.

Table 4 Effect of solar panels on concern about climate change (IV results)

Dependent variable	CC will harm you personally			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel A				
Number of solar installations (thousands)	− 0.008	− 0.070*	− 0.059*	− 0.062*
	(0.007)	(0.037)	(0.034)	(0.034)
	First-stage for number of solar installations			
		(1)	(2)	(3)
Panel B				
$Return_{pt}$		0.640***	0.639***	0.645***
		(0.131)	(0.127)	(0.127)
Dem. controls	N	N	Y	Y
Temperature	N	N	N	Y
Year FE	Y	Y	Y	Y
Postcode FE	Y	Y	Y	Y
Observations	5362	5362	5362	5362
Number of postcodes	1301	1301	1301	1301
F-Test of first stage		23.91	25.31	25.64

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Data at postcode level are weighted by postcode population in 2016. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children, and trust. The temperature controls are the average minimum and maximum temperature

climate change that are too alarmist, seeing solar panels and being nudged to learn more about climate change may have a reassuring effect.

5.3 Heterogeneity

Previous research has found that women and more educated people are more concerned about climate change (Dastrup et al. 2012). In this spirit, we explore whether the effect of solar panels on beliefs varies by demographic characteristics. To do so, we restrict our sample to a subgroup of interest and aggregate to the postcode level before estimating the effect of solar panel installation on beliefs with the full set of controls and our Feed-In Tariff instrument. Table 5 presents results for those with above/below median education, above/below median age, and by gender.[18] These results can be interpreted as the effect of solar panel installation—installed by someone in any demographic group—on beliefs of respondents in particular demographic groups.[19]

[18] The cut off point of education is college education and the cut off point of age is 51 years old.

[19] We split the sample before aggregating to the postcode level. For example, the analysis of older respondents uses the average values for older respondents respondents in each postcode. An alternative methodology is to split the sample after aggregating so that the analysis of older respondents uses average values for the entire sample in postcodes within which the average age is older. This results of regressions using this sample splitting methodology, which yield qualitatively similar results, are shown in "Appendix" Table 10.

Table 5 Heterogeneous effects of solar adoption on beliefs (IV results)

Dependent variable	CC is caused by humans					
	Education		Age		Gender	
	Below median (1)	Above median (2)	Below median (3)	Above median (4)	Male (5)	Female (6)
Panel A						
Number of solar installations (thousands)	0.050 (0.043)	0.062 (0.052)	− 0.007 (0.045)	0.133*** (0.050)	0.065 (0.044)	0.061 (0.043)
Observations	4280	3426	3593	4145	3886	3977
Number of postcodes	1131	918	974	1082	1003	1083
First stage F-test	25.44	21.30	23.23	23.37	25.52	23.29
Dependent variable	CC will harm you personally					
	Education		Age		Gender	
	Below median (1)	Above median (2)	Below median (3)	Above median (4)	Male (5)	Female (6)
Panel B						
Number of solar installations (thousands)	− 0.037 (0.040)	− 0.072 (0.062)	− 0.017 (0.044)	− 0.041 (0.039)	− 0.073* (0.044)	0.022 (0.043)
Observations	4280	3426	3593	4145	3886	3977
Number of postcodes	1131	918	974	1082	1003	1083
First stage F-test	25.44	21.30	23.23	23.37	25.52	23.29

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Sample is split before aggregating to the postcode level. Median education is college education and median age is 51. All models control for age, gender, educational attainment, income, children, trust and temperature. Postcode fixed effects and year fixed effects are also included

We find evidence of a heterogeneous effect of panels on beliefs and concern. Specifically, we find that solar panel installation only affects the likelihood that those older than the median age think climate change is caused by humans, and does not affect the beliefs of younger people.[20] We also find that solar panels reduce concern about climate change among men but not among women.

Taken together, these results show that solar panels affect different subgroups in different ways. The spillover effects from actions to beliefs about climate change are stronger in some subgroups while the spillover effects on concern are stronger in others. This in turn suggests that programs that have differential take up rates among subgroups will likely have different average spillovers.

[20] In "Appendix" Table 9 we show similar demographic differences for the effect of solar panels on whether climate change is happening.

Table 6 Alternative measures of solar (IV results)

	Caused by humans (1)	Is happening (2)	Will harm you (3)
Panel A			
Total solar capacity	0.016**	0.010	− 0.013*
(MWh)	(0.008)	(0.006)	(0.007)
F-Test of first stage	56.06	56.06	56.06
Panel B			
Installations per million	1.78**	1.09	− 1.56*
residents	(0.823)	(0.676)	(0.811)
F-Test of first stage	236.72	236.72	236.72
Panel C			
Installations per km^2	9.65*	5.90	− 8.31*
(thousands)	(5.33)	(4.15)	(4.68)
F-Test of first stage	14.61	14.61	14.61
Dem. controls	Y	Y	Y
Temperature	Y	Y	Y
Year FE	Y	Y	Y
Postcode FE	Y	Y	Y
Observations	5362	5362	5362
Number of postcodes	1301	1301	1301

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Data at postcode level are weighted by postcode population in 2016. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children, and trust. The temperature controls are the average minimum and maximum temperature

5.4 Robustness

We perform a number of robustness checks to show that our results are not sensitive to using alternative specifications. One choice that is particularly worth examining in greater detail is the measure of solar installations in a postcode, which is a proxy for the number of solar panels that an individual living in the postcode interacts with regularly. There are a few alternative measures for this variable. For instance, a measure of the total capacity of solar panels in a postcode attaches more weight to larger installations, especially utility grade installations that might be particularly salient. Alternatively, using solar installations per capita or solar installations per square kilometer accounts for differences in the size of postcodes, either in terms of population or of area. Table 6 shows that each of these measures gives results that are consistent with our baseline results. Further, "Appendix" Table 11 shows that the results are consistent if we replace solar installations with lagged solar installations.

A second specification choice is the choice of sample restriction. Thus far we have presented results from a sample restricted to households in postcodes with population densities between 10 to 4,000 people per square kilometer. Although these restrictions are justifiable, given that solar panels are extremely difficult to install in high density areas and spillovers are hard to generate in remote areas where people live far apart, the precise boundaries of the sample restrictions are somewhat arbitrary. To ensure the results are robust to the choice of sample, "Appendix" Fig. 7 shows that our conclusions are qualitatively unchanged as we vary the upper and lower bounds.

Finally, it is worth examining the use of postcode-year as the primary unit of analysis. As Sect. 4 discusses, postcode is an intuitive unit of analysis since the treatment is an individual level treatment but is only observable at the postcode level. Further, since we are capturing a combination of the effect of individuals installing solar themselves and people observing their neighbors' installation, there is an additional argument for analysis at the neighborhood level. In Table 12 we perform individual level analysis on the nationally representative survey data. The results are very similar to our baseline results, further validating the postcode level analysis.

5.5 Actions and Policy Implications

The implications of the results presented in the previous section are mixed. On the one hand, we expect that solar panels, by increasing the number of households who believe in climate science, would have a positive effect on individual mitigation actions and support for climate change policy. However, we also find that solar panels reduce concern about climate change. This reassurance effect may reduce both individual mitigation efforts and support for further mitigation policy. The net effect is therefore of uncertain sign, and one effect could cancel out the other.

The rich survey data allows us to explore whether solar panels have an effect either on individual mitigation actions and/or support for mitigation policy. Table 7 shows instrumental variables results of the effect of solar panel installation on the share of households stating that: voluntarily purchase power from renewable energy sources via the Green Power program, switch off lights, catch public transit, support a tax on emitting industries, and support policies to encourage renewable energy. Overall, we find very little evidence for an effect. We do find that additional solar panels in a postcode make it less likely that households sign up to a Green Power program. However, at the postcode level, we cannot distinguish whether this effect is from direct substitution of individual households from enrolment in Green Power to installing solar, or whether there is evidence of a more general crowd out effect. It is thus not clear whether reduced Green Power participation is the result of changes in climate change concern or not.[21]

To explore the differential impact that solar panels may have via changes in beliefs and concern, we undertake a back of the envelope calculation using the correlation between beliefs and actions observed in the survey data. First, we regress measures for actions and support for policy on our measures of beliefs and concern. "Appendix" Table 13 reports the coefficients from a series of OLS models. We find a statistically significant and positive relationship between belief in climate science and concern about the impacts of climate change and both environmental actions and support for environmental policy measures. We then combine these coefficients with our causal estimates of the effect of solar panels on beliefs to generate a rough measure of the likely effect of panels on other mitigation actions, and on policy support. To generate standard errors, we bootstrap the estimates clustering at the postcode level.[22]

[21] Our survey data only identifies respondents with solar panels for two waves. Using this data, we find suggestive evidence that the reduction in Green Power enrollment comes from solar panel installers and not their peers, however the vastly reduced sample size does not allow us to draw strong conclusions.

[22] We report results for 500 replications but the findings are qualitatively invariant to the number of replications.

Table 7 Effect of solar panels on abatement actions (IV results)

Dependent variables	Actions			Policy Support	
	(1) Green Power	(2) Lights	(3) Transit	(4) Carbon Tax	(5) Renew. Energy
Number of solar	− 0.087**	0.023	− 0.031	0.217	0.320
installations (thousands)	(0.036)	(0.015)	(0.033)	(0.343)	(0.362)
Observations	5362	5362	5363	1844	1844
Number of postcodes	1301	1301	1301	922	922
First stage F-test	25.64	25.64	25.64	7.99	7.99

Standard errors clustered by postcode in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Green Power is the share of the postcode that voluntarily opt to purchase a percentage of their electricity from grid-based renewable energy sources. Lights and Transit are the share of people that turn lights off to save energy, and catch public transit. Carbon Tax and Renewable Energy are the share of people that support an emissions tax and that support renewable energy policies.. Data at postcode level are weighted by postcode population in 2016. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children, and trust. The temperature controls are the average minimum and maximum temperature

The resulting point estimates and 90% confidence intervals are plotted in Fig. 6. As we expected, solar panels appear to have a positive (albeit noisy and not statistically significant) effect on actions via positive changes in the share of people who believe that climate change is happening and that it is caused by humans. On the other hand, solar panels reduce concern about the dangers of climate change, which reduces the share of people participating in environmental actions and the share of people indicating they support either a tax on carbon emissions or policies that increase the amount of renewable energy on the grid. The reassurance effect of solar panel installation is associated with a fall of approximately 1 to 1.5 percentage points in the share of respondents that opt to purchase Green Power, that catch public transit, and that support the introduction of a carbon tax. This offsets the positive effects, and makes the total spillover effect of solar installation on other environmental actions ambiguous.

6 Conclusion

In this paper, we look at the effect of installation of rooftop solar panels on perceptions of climate change. Solar panels, which are prevalent in Australia, are highly visible actions that affect climate change through emissions reduction. Households might use installation of solar panels, either on their own roofs or roofs of neighbors, as signals about climate change. They then may use these signals as an impetus to do more research about climate change or to update their beliefs directly. Indeed, we find that Google searches of both ‘climate change’ and ‘global warming’ are strongly correlated with searches for ‘solar’.

The effects we study are the other side of a standard model of beliefs informing actions. Since it is possible that changes in beliefs about climate change motivate solar installation, we adopt an instrumental variables strategy, exploiting variation in subsidies and solar irradiance, to isolate the causal effect of actions on beliefs. This methodology excludes environmental motivations to install solar and isolates the economic motivation.

We find that solar panel installation affects perceptions of climate change along two major dimensions that work in two very different ways. On the one hand, solar panel

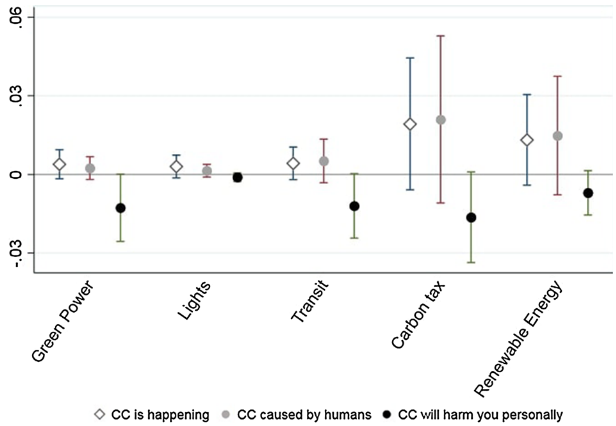

Fig. 6 Effects of Solar Panels on Actions via Beliefs. Figure plots point estimates and 90% confidence intervals for the effect of solar panels on environmental actions via changes in beliefs and concern about climate change. Green Power is the share of the postcode that voluntarily opt to purchase a percentage of their electricity from grid-based renewable energy sources. Lights and Transit are the share of people that turn lights off to save energy, and catch public transit. Carbon Tax and Renewable Energy are the share of people that support an emissions tax and that support renewable energy policies

installation increases belief in the basics of climate science, as survey respondents in postcodes with more solar installation are more likely to believe that climate change is largely caused by human actions. On the other hand, they are less likely to be concerned about climate change. We show that these responses are driven by different subgroups. Solar panels cause older respondents to update their beliefs regarding climate science, but reduce concern about and reassure male respondents about the potential harm of climate change.

The results of this paper provide insight into how environmental actions spillover into beliefs, and show evidence of both positive and negative spillovers. They also highlight spillover effects from environmental policies. The subsidies we use as an instrument are an example of a policy intended to encourage environmental actions, and these actions in turn affect beliefs about environmental issues and thus willingness to undertake alternative environmental behaviors. We present back of the envelope calculations suggesting that on average, the positive spillover to beliefs that would encourage individual mitigation is almost exactly offset by the negative spillover to concern. Importantly, we find evidence that the reassurance effect of solar panels reduces participation in alternative environmental behaviors, and reduces support for additional climate mitigation policy.

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Appendix

See Tables 8, 9, 10, 11, 12, 13; Fig. 7.

Table 8 Selected Australian Climate Attitudes Survey Questions, 2010–2014

BELIEFS
1. Do you think that climate change is happening?
Yes
No
2. Given what you know, which of the following statements best describes your thoughts about climate change?
I don't think that climate change is happening
I have no idea whether climate change is happening or not
I think that climate change is happening, but it's just a natural fluctuation in Earth's temperatures
I think that climate change is happening, and I think that humans are largely causing it
3. How much do you think climate change will harm you personally?
A great deal
A moderate amount
Only a little
Not at all
4. I am on Green Power electricity
Mostly for environmental reasons
Mostly for other reasons
I don't do this
5. I switch lights off around the house whenever possible
Mostly for environmental reasons
Mostly for other reasons
I don't do this
6. I usually walk/ cycle/ carpool/take public transport
Mostly for environmental reasons
Mostly for other reasons
I don't do this
To what extent would you support the following policy initiatives?
7. Taxing industries that emit high levels of greenhouse gases
Oppose strongly (1)
Neither support nor oppose (4)
Support strongly (7)
8. Increased government investment in renewable energy sources
Oppose strongly (1)
Neither support nor oppose (4)
Support strongly (7)

Table 9 Heterogeneous effects of solar adoption on beliefs: alternative question

Dependent variable	CC is happening					
	Below	Above	Below	Above		
	Median education (1)	Median education (2)	Median age (3)	Median age (4)	Male (5)	Female (6)
Number of solar installations (thousands)	0.073* (0.039)	− 0.027 (0.036)	0.015 (0.033)	0.077* (0.040)	0.039 (0.039)	0.016 (0.035)
Observations	4280	3426	3593	4145	3886	3977
Number of postcodes	1131	918	974	1082	1003	1083
First stage F-test	25.54	21.30	23.23	23.37	25.52	23.29

Standard errors clustered at the postcode level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Median education is college education and median age is 51. All models control for age, gender, educational attainment, income, children, trust, and temperature. Postcode fixed effects and year fixed effects are also included

Table 10 Heterogeneous effects of solar adoption on beliefs (IV results—alternative sample splitting)

Dependent variable	CC is caused by humans					
	Education		Age		Gender	
	Below median (1)	Above median (2)	Below median (3)	Above median (4)	Male (5)	Female (6)
Panel A						
Number of solar installations (thousands)	0.037 (0.053)	0.129** (0.065)	0.093 (0.094)	0.063 (0.044)	0.060 (0.055)	0.030 (0.053)
Observations	1987	2791	2379	2398	2786	2017
Number of postcodes	665	874	765	781	877	717
First stage F-test	12.38	12.32	7.62	14.32	10.38	12.83
Dependent variable	CC will harm you personally					
	Education		Age		Gender	
	Below median (1)	Above median (2)	Below median (3)	Above median (4)	Male (5)	Female (6)
Panel B						
Number of solar installations (thousands)	− 0.027 (0.045)	− 0.105 (0.066)	− 0.011 (0.088)	− 0.079* (0.042)	− 0.103* (0.056)	0.037 (0.053)
Observations	1987	2791	2379	2398	2786	2017
Number of postcodes	665	874	765	781	877	717
First stage F-test	12.38	12.32	7.62	14.32	10.38	12.83

Standard errors clustered at the postcode level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Sample is split after aggregating to the postcode level. Median education is college education and median age is 51. All models control for age, gender, educational attainment, income, children, trust and temperature. Postcode fixed effects and year fixed effects are also included

Table 11 The effect of solar panels on belief in climate science

Dependent variable	CC caused by humans			
	OLS	IV		
Panel A				
Lag (Number of solar installations) (thousands)	0.007 (0.008)	0.065 (0.049)	0.083* (0.048)	0.095* (0.051)
Dem. controls	N	N	Y	Y
Temperature	N	N	N	Y
Year FE	Y	Y	Y	Y
Postcode FE	Y	Y	Y	Y
Observations	5362	5362	5362	5362
Number of postcodes	1301	1301	1301	1301
First sage F-test		14.78	15.72	13.80
Dependent variable	CC is happening			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel B				
Lag (Number of solar installations) (thousands)	0.014* (0.007)	0.059 (0.039)	0.060* (0.037)	0.071* (0.040)
Dem. controls	N	N	Y	Y
Temperature	N	N	N	Y
Year FE	Y	Y	Y	Y
Postcode FE	Y	Y	Y	Y
Observations	5362	5362	5362	5363
Number of postcodes	1301	1301	1301	1301
First stage F-test		14.78	15.72	13.80

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Data at postcode level are weighted by postcode population in 2016. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children, and trust. The temperature controls are the average minimum and maximum temperature

Table 12 Effect of Solar Panels on Belief in Climate Science—Individual level results

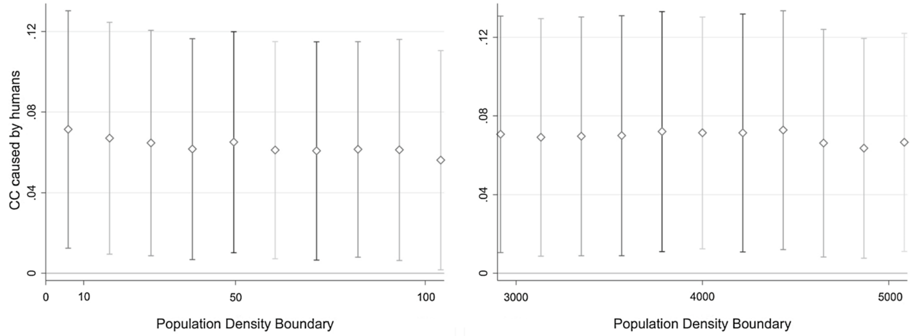
Dependent variable	CC caused by humans			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel A				
Number of solar installations (thousands)	0.010 (0.008)	0.042 (0.033)	0.051* (0.030)	0.056* (0.031)
Dependent variable	CC is happening			
	OLS	IV		
	(1)	(2)	(3)	(4)
Panel B				
Number of solar installations (thousands)	0.010 (0.006)	0.048* (0.029)	0.054** (0.027)	0.052* (0.027)
	First-stage for number of solar installations			
		(1)	(2)	(3)
Panel C				
$Return_{pt}$		0.655*** (0.142)	0.655*** (0.142)	0.660*** (0.142)
Dem. controls	N	N	Y	Y
Temperature	N	N	N	Y
Year FE	Y	Y	Y	Y
Postcode FE	Y	Y	Y	Y
Observations	18,810	18,810	18,810	18,810
Number of postcodes	1329	1329	1329	1329
F-test of first stage		21.30	21.42	21.65

Standard errors clustered at the postcode level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. The instrument is interaction between cumulative Feed-in Tariff and historical average solar irradiance. The demographic control variables are age, gender, education attainment, income levels, children, and trust. The temperature controls are the average minimum and maximum temperature

Table 13 Beliefs and alternative mitigation actions

Variables	Actions			Policy Support	
	(1) Green Power	(2) Lights	(3) Transit	(4) Carbon Tax	(5) Renew. Energy
CC caused by humans	0.027	0.029***	0.028	0.176***	0.091**
	(0.019)	(0.009)	(0.022)	(0.039)	(0.038)
Observations	5362	5362	5362	1844	1844
CC is happening	0.030	0.062***	0.026	0.171***	0.084*
	(0.024)	(0.013)	(0.024)	(0.049)	(0.049)
Observations	5362	5362	5362	1844	1844
CC will harm you	0.086***	0.015*	0.057***	0.029	0.007
	(0.019)	(0.008)	(0.020)	(0.034)	(0.029)
Observations	5362	5362	5362	1844	1844

Standard errors clustered by postcode in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Green Power is the share of the postcode that voluntarily opt to purchase a percentage of their electricity from grid-based renewable energy sources. Lights and Transit are the share of people that turn lights off to save energy and catch public transit, respectively. Carbon Tax and Renewable Energy are the share of people that support an emissions tax and that support renewable energy policies. Data at postcode level are weighted by postcode population in 2016. The demographic control variables are age, gender, education attainment, income levels, children, trust, and temperature



(a) Lower boundary **(b)** Upper boundary

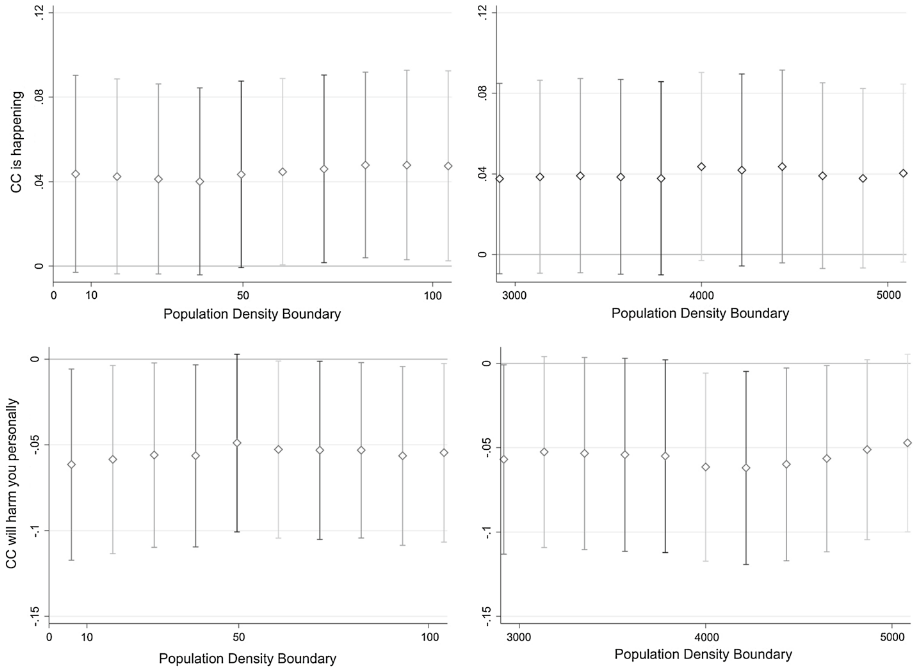


Fig. 7 Robustness to Sample Selection. Figures plot point estimates and 90% confidence intervals for the effect of solar panels on beliefs and concern about climate change. The left column changes the upper bound of population density from 3000 people per square kilometer to 5000 people per square kilometer and keep the lower bound at 10 people per square kilometer. The right column changes the lower bound of population density from 10 people per square kilometer to 100 people per square kilometer and keep the upper bound at 4000 people per square kilometer. In each specification standard errors are clustered at the postcode level and control for age, gender, educational attainment, income, children, trust, and temperature. Postcode fixed effects and year fixed effects are also included

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