EVIDENCE OF THE REBOUND EFFECT FROM INSTALLING ROOFTOP SOLAR IN A DEVELOPING COUNTRY

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Overview

Replacing fossil fuels with renewable energy sources is considered one of the most viable solutions to mitigate climate change (Arent et al., 2011). However, the success of solar installations in reducing carbon emissions depends heavily on their ability to substitute for other sources of energy, particularly grid electricity that runs on fossil fuels. If households that adopt solar panels also substantially change their energy consumption patterns, it is possible that the overall carbon emissions associated with energy use may be relatively unchanged. This phenomenon is known as a "rebound effect", where increased supply fails to induce substitution between solar and grid energy.

Results

In this paper, we examine whether residential solar energy effectively reduces carbon-intensive energy consumption. We are motivated by the idea that this rebound effect may occur via a raft of behavioral changes, some of which may paradoxically offset the environmental benefits of clean energy. Such an effect may occur, for example, if consumers consider solar energy as "free electricity" by temporarily ignoring the initial investment costs. Or they may occur due to the reinstatement of old habits or through cognitive biases associated with mental accounting.

Our models suggest that the total power demands of solar energy owners increased immediately after installing the solar system by approximately 16% more than in non-solar households. Meanwhile, the grid electricity consumption of solar users was reduced by only 3% compared to homes without solar energy. Thus, the potential for household solar panels to reduce carbon emissions appears to be heavily compromised.

We also examine the dynamics of total electricity demand and grid power demand over twelve lags after installing the solar system and discover further implications. In addition, the results on dynamics suggested a significant gap in total electricity demand between rooftop solar owners and non-solar households immediately after solar installation; however, this gap tent to close over time. Synergistically, the opposite pattern was observed in the grid electricity consumption. Those dynamics imply that the behaviors of solar owners had been reinstated to the old habits, and they could be linked to the synergistic impacts of a less attractive feed-in tariff, lack of battery adoption, and the rigidity associated with long term behavioral patterns.

Methods

The direct rebound effect was initially discussed in Khazzoom (1980) before being widely adopted in a series of analyses for various energy services, especially papers focusing on energy efficiency. However, only a handful of articles investigated the rebound effect of using solar energy ar, and they produce mixed implications. For example, in the most recent study, Boccard & Gautier (2021) provided evidence of a significant rebound effect in consumption commonly oversized installations by households in Wallonia (Belgium) because of the generous subsidy scheme. Qiu et al. (2019) applied a fixed-effects panel regression to share a positive indication of a rebound effect in Arizona, in which electricity consumption from solar increased by 18%. In a study for Australia, Deng & Newton (2017) examined the data of Sydney households from 2007 to 2014 to confirm the rebound effect with an increase of 20% in consumption of solar owners. In contrast, using a sample in Germany, Oberst et al. (2019) did not find any remarkable change in the consumption behavior of solar owners compared to non-solar households. Another study in Germany by Wittenberg & Matthies (2016) could not find any significant distinctions in energy demand between solar owners and non-solar households; however, there was an apparent substitute effect once households installed solar systems. Distinctively, Keirstead (2007) adopted survey data in the UK and testified that solar energy contributed to decreased power consumption by 5.6%.

Our study is one of the first pieces of work to examine the rebound effect of solar energy in a developing country. We examine this issue using a unique panel data set on the energy consumption habits of around 3,500 households in Hanoi, Vietnam. Using a difference-in-differences method, we measure structural changes in solar and grid energy use before and after households install solar panels. After obtaining these baseline results, we perform a set of model

diagnostics related to causality/identification. These include an examination of parallel assumptions, running placebo regressions, and using stability assessments to simulate the potential effects of unobserved confounding. Our models perform well in all instances, suggesting that our estimates are likely to be causal.

Conclusions

In this study, we have conducted a panel difference-in-deferences model to evaluate the impacts of residential rooftop solar installation on the energy-consuming behavior of households in Hanoi. To evaluate the performance of the models, we also implemented several diagnostics, which could cause severe non-causality issues in the difference-in-difference analysis and fixed effect regression. Furthermore, we performed the analysis of the dynamics to investigate the sustainability of solar energy's intervention on energy-consuming behavior.

Regarding policy implications, we found a rebound effect of rooftop solar adoption in Hanoi. The results implied that installing rooftop solar led solar energy owners immediately to increase the total power demand by approximately 16% while reducing grid demand by only 3% compared to non-solar households. This rebound effect is a significant concern that reduces the efficiency of residential solar energy programs and may fail the expectation to mitigate the carbon footprint of the power generation industry.

In addition, we found that the solar energy rebound effect in Hanoi was apparent in the short term but gradually faded out in the long run. However, this was not a signal of positive adjustment to eliminate the rebound effect. Instead, it reflected that rooftop solar consumers steadily reinstated their old habits of using more grid electricity at nighttime. It happened because most family energy-used activities occurred in the evening that was unable to switch to daytime, and rarely were users equipped with solar batteries to store energy.

To conclude, it is undeniable that solar energy has the potential to help mitigate the carbon footprint that causes global environmental concerns. Although the positive impact of solar energy on reducing grid demand was relatively small in our dataset, it still proved its contribution. More importantly, it is necessary to keep in mind that the solar energy development could not achieve the desired positive impacts without technical considerations such as equipping solar storage to use at a time without sunlight. Policies also play a vital role in delivering the highest outcome for solar energy development. Our analysis suggested that less attractive policies and inconvenient procedures were the main reasons for suppressing rooftop solar owners' motivation to utilize solar power or to sell it to the grid.