[*PAPER/POSTER TITLE*]
SHORT TERM AND LONG-TERM OF SOLAR PHOTOVOLTAIC ADOPTION ON ENERGY CONSUMPTION AMONG JAPANESE HOUSEHOLD

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Overview

This study investigates the temporal dynamics of residential solar photovoltaic (PV) adoption on household energy consumption patterns in Japan, examining both immediate and long-term effects across multiple energy sources. While previous research has primarily focused on changes in shrot-term electricity consumption[1,2], our study extends the analysis to include broader energy consumption patterns, including LP gas, city gas, kerosene, and gasoline, providing a comprehensive understanding of how PV adoption influences overall household energy behavior.

Recent literature suggests that renewable energy adoption can lead to complex behavioral responses, including potential rebound effects and spillover effects across different energy sources[3,4]. Building on these insights, we employ a rigorous empirical strategy combining propensity score matching (PSM) with regression analysis to address selection bias and quantify the effects of PV adoption on energy consumption patterns across different time horizons.

Methods

Our analysis utilizes a five-year survey dataset of Japanese households, implementing a two-stage empirical approach. First, we employ PSM to address potential selection bias in PV adoption, matching households based on pre-adoption characteristics including socioeconomic factors, dwelling attributes, and geographical location. The matching process ensures that treatment (PV adopters) and control groups are comparable across observable characteristics.

Following PSM, we estimate the following econometric model to capture the temporal effects of PV adoption:

$$Consumption_i = \alpha + \sum_{k \in \{bins\}} \beta_k \cdot 1\left(TimeSinceInstall_{bin_i} = k\right) + \gamma_{t(i)} + \delta X_i + \varepsilon_i$$

where $Consumption_i$ represents monthly energy consumption (electricity, gas, kerosene, or gasoline) for household i, $TimeSinceInstall_{bin_i}$ indicates time since PV installation (0-1 years, 1-4 years, 4+ years), $\gamma_{t(i)}$ represents survey year fixed effects, and X_i includes household-level controls such as income, total floor area, energy-saving index, solar radiation, city classification, and building characteristics. The model incorporates heteroskedasticity-robust standard errors and clustering at the region level to account for serial correlation.

Results

Our findings reveal nuanced temporal patterns in energy consumption following PV adoption. Electricity consumption shows immediate reductions (-0.221 units, $p < 0.001$) in the installation year, with sustained effects in the medium term (-0.120 units, $p < 0.001$), followed by a modest rebound effect in the long term (0.062 units, $p < 0.001$).

Gas consumption demonstrates persistent decreases, with effects strengthening over time (from -6.496 units, $p = 0.282$ in year 0 to -26.858 units, $p < 0.001$ in 4+ years), suggesting lasting changes in household energy preferences. Kerosene consumption shows consistent reductions across all time periods (-136.353 to -115.890 kWh, $p < 0.001$), while gasoline consumption exhibits an interesting pattern of initial decrease followed by significant increases in

medium and long-term periods (44.657 and 28.010 units respectively, $p<0.030$), potentially indicating broader lifestyle changes associated with PV adoption.

Conclusions

The findings highlight the nuanced impact of solar PV adoption on household energy consumption in Japan. Solar PV systems drive significant reductions in electricity, LP gas, city gas, and kerosene consumption in the short and medium term, with some energy forms, such as electricity, exhibiting rebound effects in the long term. The observed increase in gasoline consumption warrants further investigation into indirect effects of PV adoption on household behavior. By integrating PSM and regression techniques, this study provides evidence on the long-term benefits and trade-offs of residential solar PV adoption, offering critical insights for policymakers and stakeholders in promoting sustainable energy practices.

This research contributes to the growing literature on residential renewable energy adoption by providing novel evidence on the temporal evolution of energy consumption patterns. The findings suggest that PV adoption triggers both direct energy savings and indirect behavioral responses, with effects varying across different energy sources and time horizons. These insights have important implications for energy policy design, particularly in understanding the long-term effectiveness of residential solar incentive programs and their broader impacts on household energy consumption patterns.

The observed rebound effects in electricity consumption and increases in gasoline usage highlight the complexity of household energy behavior and the importance of considering multiple energy sources in evaluation of renewable energy policies. Future research could explore the mechanisms driving these behavioral changes and their implications for overall household carbon footprints.

References

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