# Energy expenditure and electrification progress by household heterogeneity in Japan

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## Overview

Electrification has been cited as one of the important solutions for energy conservation and decarbonization in the household sector. Japan's Sixth Basic Energy Plan, approved by the Cabinet in October 2022, also points out the importance of promoting electrification with decarbonized electricity. However, the current progress of electrification in the Japanese household sector is not sufficient. In the previous studies, various factors including cost factor have been pointed out to promote or hinder energy conservation and electrification in the household sector(Klockner et al., Wilson et al.). We compiled a survey of nearly 40,000 data points on household energy demand in Japan, focusing on the diversity of households, including regional differences, housing type, income, household size, temperature, and electricity prices. Our study confirmed that energy expenditure burden is higher and electrification is less advanced in cold regions and low-income households. We used a logit model to find the barriers for all-electric in households. We confirmed that the increase in heating degree days and the rise in electricity prices are disincentives for all-electric, especially in cold regions.

## Methods

In this paper, we estimate a binomial logit model in which each household chooses to be all-electric or not, based on survey data from the Ministry of the Environment's "Statistical Survey of $CO_2$ Emissions from the Household Sector"(Hereafter abbreviated as "Household $CO_2$ Emissions Statistics")[1].

$$P(y_i = j) = F_{ij}(\boldsymbol{x'_{ij}\beta}), \quad i = 1,2,\dots N,\ j = 1,2 \qquad , P(y_i = 1) + P(y_i = 0) = 1 \qquad (1)$$

whare, $P(y_i = 1)$ : Probability that household i is an all-electric home, $P(y_i = 0)$: Probability that household i is a non-all-electric home, $\boldsymbol{x'_{ij}}$is a explanatory variable vector, $\boldsymbol{\beta}$is a model parameter vector.

As for the explanatory variable that takes the value of one or zero, we use single-family detached house, own house, households with PV, households 65 years old or older. The other explanatory variables are year of construction, number of household members (in the form of square root), household income, heating degree days, electricity rate/gas price (prefecture average), electricity rate/LPG price (prefecture average), electricity rate/heating oil price (prefecture average).

## Results

Table 1 shows the percentage of household energy expenditures of each region by household income. From the survey data, we confirmed that energy expenditure burden and the electrification rate are higher for households in cold regions and low-income households. This result is consistent to that of Hoshino and Ogawa (2021).

Table 1. Percentage of Household Energy Expenditures

| | | North Japan | Middle Japan | West Japan |
|---|---|---|---|---|
| Household Income | 250-500 | 6.0% | 4.5% | 4.7% |
| | 500-750 | 3.9% | 2.9% | 3.1% |
| | 750-1,000 | 3.0% | 2.2% | 2.3% |
| | 1,000-1,500 | 2.3% | 1.7% | 1.8% |
| | 1,500-2,000 | 1.7% | 1.3% | 1.3% |

Data source: Household $CO_2$ Emissions Statistics, Ministry of the Environment

Table 2 shows the estimation results for model (1). In all regions, the probability of all-electrification increases for detached houses with PV. By region, in Western Japan, being a detached house has a significant impact on the probability of going all-electric, while in Middle Japan, being a house with PV has a particularly significant impact on the probability of going all-electric. In contrast, in northern Japan, higher household income and newer houses increase the probability of all-electrification.

[1] The authors obtained permission to use the individual data of "Statistical Survey of $CO_2$ Emissions from the Household Sector" statistics from the Ministry of the Environment through the Japan Society of Energy and Resources.

As for the price effects, the results differ by region. Among the price variables, the parameter of relative price to kerosene price in northern Japan stands out as particularly large.

## Conclusions

While progress in electrification in the household sector will be important for achieving carbon neutral goals, it will be important to take into account the different level of energy cost burden by the household characteristics. This analysis, based on survey data of approximately 40,000 Japanese households by region and household demographics from 2016 to 2019, identifies factors driving the conversion to all-electrified homes. In northern Japan, the percentage of all-electrified homes is currently lower than in other regions of Japan due to the large energy demand for heating purposes.

In addition, since income effects play a larger role in the conversion to all-electrified homes in northern Japan, differences in household income will have a greater impact on the degree of conversion to all-electrified homes. In northern Japan, where the energy expenditure burden is higher than in other regions, the hurdle for low-income households to obtain the energy-saving benefits of all-electrification is even higher.

This analysis also confirmed the possibility that changes in the relative prices of electricity and competing energy prices will affect the conversion to all-electric homes. This suggests that stable electricity prices are important for electrification progress in the household sector.

Table 2. Estimation results of binary logit model

| | number of observations (positive) | Costant | single-family detached house | year of construction | households with PV | household income | heating degree days | electricity rate/gas price (prefecture average) | electricity rate/LPG price (prefecture average) | electricity rate/heating oil price (prefecture average) | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2017-2019 | Japan | -4.9371 | 1.4114 | 0.3628 | 1.2548 | 0.1917 | -0.2329 | | | | 0.179 |
| | | -4.9073 | 1.3882 | 0.3714 | 1.2617 | 0.3187 | | -1.4966 | | | 0.203 |
| | 29161 | -5.3024 | 1.3693 | 0.3669 | 1.2959 | 0.2404 | | | -0.5740 | | 0.185 |
| | (3492) | -3.8906 | 1.3827 | 0.3648 | 1.2869 | 0.2080 | | | | -1.4275 | 0.181 |
| | North japan | -6.5472 | 1.1644 | 0.5707 | 1.1683 | 0.6027 | | | | | 0.234 |
| | | -6.1986 | 1.1076 | 0.5858 | 1.1702 | 0.5629 | | -1.3247 | | | 0.255 |
| | 7970 | -6.9173 | 1.1936 | 0.5769 | 1.2196 | 0.6269 | | | -0.7900 | | 0.239 |
| | (866) | -3.1741 | 1.1234 | 0.5805 | 1.2061 | 0.5762 | | | | -3.8293 | 0.244 |
| | Middle Japan | -4.9212 | 1.0672 | 0.2830 | 1.4571 | 0.1189** | | | | | 0.128 |
| | | -4.1277 | 1.0350 | 0.2836 | 1.4112 | 0.1576* | | -1.5072 | | | 0.134 |
| | 11280 | -4.8934 | 1.0561 | 0.2845 | 1.4451 | 0.1371** | | | -0.3543 | | 0.129 |
| | (959) | -6.0179 | 1.0677 | 0.2822 | 1.4600 | 0.1148** | | | | 1.1441* | 0.129 |
| | West Japan | -5.0000 | 1.7769 | 0.3392 | 1.1519 | 0.4103 | | | | | 0.223 |
| | | -5.0160 | 1.7677 | 0.3409 | 1.1422 | 0.3963 | | 0.5678 | | | 0.223 |
| | 9911 | -4.9013 | 1.7662 | 0.3405 | 1.1526 | 0.4031 | | | 0.5307 | | 0.223 |
| | (1667) | -7.4830 | 1.7276 | 0.3440 | 1.1473 | 0.3879 | | | | 2.7639 | 0.224 |

note: * denotes p-value is grater than 0.05, ** denotes p-value is grater than 0.1

## References


Klockner, Christian A., Alim Nayum, Specific Barriers and Drivers in Different Stages of Decision-Making about Energy Efficiency Upgrades in Private Homes, Frontiers in Psychol, 08 September 2016

Wilson E, Christensen C, Horowitz S, Robertson J, Maguire J., Energy efficiency potential in the U.S. single-family housing stock., National Renewable Energy Laboratory (NREL), December 2017

Hoshino, Yuko, Junko Ogawa , The Heterogenous Impacts of Energy Price Changes on Household Expenditure from the Aspect of Different Types of Household in Japan, IAEE International Conference 2020, 2021

Iwafune, Yumiko, Toshiaki Kawai, Yuko Mori, Estimation of electrification potential of home appliances and private vehicles and its impact on $CO_2$ emissions by using the Survey on Actual Conditions of Carbon Dioxide Emissions from Redidential sector, *Proceedings of the 38th Annual Conference of the the Japan Society of Energy and Resources* 9-5, 2020/7/28-29

Ministry of the Environment, Statistical Survey of CO2 Emissions from the Household Sector, 2016 to 2017, Japan