



Household Income Structure and Electrical Appliance Ownership: Evidence from Japanese National Household Survey

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ABSTRACT

Earlier research examined how total household income determines appliance ownership. However, this study uses micro data from the Japanese National Survey of Family Income and Expenditure to examine how income structure and wealth determine the number of appliances in a household. Household income structure does affect appliance ownership: Though non-labor income lowers the likelihood of dishwasher ownership, labor income raises it. Wives' incomes and non-labor income increase the number of televisions while a husband's income decreases it. Appliance ownership is predominantly determined by housing conditions. Households owning a detached house have more appliances, though more frequently install solar water heaters.

Keywords: Appliance Ownership, Household Income Structure, Micro Data

JEL Classifications: D12, D13, Q41

1. INTRODUCTION

Over the last few decades, countries have implemented various policies to reduce household energy consumption (OECD, 2011). Nevertheless, these policies have had little impact on energy saving. For instance, the EU28 reduced energy consumption in the industrial sector by 14% from 2005 to 2012, while it reduced household energy consumption by only 4%. In 2012, the share of household energy consumption of the total energy consumption was 26%, becoming equal to that of industrial energy consumption (European Environmental Agency, 2015).

Traditionally, households have used a lot of energy for heating. However, households have recently consumed a significant share for home appliances. For instance, the share consumed for heating in the US decreased from 53.1% in 1993 to 41.5% in 2009, while that for appliances increased from 24.0% to 34.6% in the same period (US Energy Information Administration, 2013). This suggests that policymakers must understand appliance ownership to reduce household energy consumption.

Many scholars have analyzed the process of diffusion for energy consuming durables. Farrell (1954) argues that an S-shaped curve appears when income level on the horizontal axis is compared to the rate of ownership of energy consuming durables on the vertical axis. The shape of the curve implies that the ownership ratio of energy-consuming durables remains low until the per capita income reaches a certain "acquisition" threshold, but takes off very rapidly thereafter. As a case study, he analyzes the diffusion process of motor vehicles in the US. Similarly, Bain (1962) and Williams (1972) analyze the diffusion process of televisions (TVs) in the UK, while McCarthy and Ryan (1976) analyze that in Ireland¹. More recently, scholars examine appliance ownership in developing countries to predict appliance diffusion through economic development (World Bank, 2008; Gertler and Wolfram, 2011; Wolfram et al., 2012; Deutsche Gesellschaft für Internationale Zusammenarbeit, 2013; Auffhammer and Wolfram, 2014).

Although these studies have used macro data for empirical analyses, some scholars have recently used micro data at the

¹ Williams (1972) also analyzed the diffusion process for refrigerators.

household level. For example, O'Doherty et al. (2008), Leahy and Lyons (2010), and Leahy et al. (2012) study appliance ownership in Ireland, and Mate (2012) studies that in the US. All studies report that socioeconomic characteristics of households have a large impact on their appliance ownership.

The majority of households in developed countries own one refrigerator and one washing machine, and tend not to purchase a second. Therefore, these appliances' electricity consumption is expected to decrease through technological improvements. In contrast, households install more than one air conditioner (ACs), TVs, and personal computer (PCs).

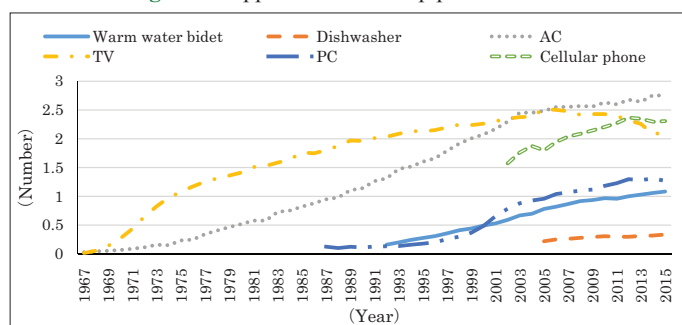
Figure 1 presents the historical change in the number of appliances owned by the average Japanese household. The number of TVs already exceeded one in the 1970s. The average Japanese household now owns more than two TVs. The number of ACs has steadily increased over the last 50 years, and approaches three. Similarly, cellular phones are not only owned by parents but also children.

Households in developed countries purchase second and third appliances to make their life easier and more convenient. Households simultaneously demand more functionality from their appliances. Despite the penetration of energy efficient appliances, the monthly energy consumption of the average Japanese household has remained at 300 kw from 1995 to 2010 (Federation of Electric Power Companies of Japan, 2015)². Nevertheless, previous studies have examined whether households own a specific appliance or the variety of appliances they own (O'Doherty et al., 2008). This study first aims to identify the type of households owning multiple appliances.

Recent studies demonstrate that appliance ownership is correlated with family structure. For instance, Lovingood and McCullough (1986) analyze the relationships of demographic variables, ownership of 11 appliances, and time spent in four categories of household tasks in the US. Then they find that appliance ownership is related to the time spent for household tasks. Brenčič and Young (2009) analyze the Canadian Survey of Household Energy Use data. They find that households owning time-saving appliances allocate more time to household production activities but do not necessarily

2 It decreased by about 10% after the Great East Japan Earthquake in 2011 (Federation of Electric Power Companies of Japan, 2015).

Figure 1: Appliance ownership per household



Cabinet Office, Government of Japan, 2015

consume more electricity. Greenwood et al., (2005) propose that the diffusion of appliances freed women from housework and enabled them to engage in market-related work. Coen-Pirani et al. (2010) compare the US Census data between 1960 and 1970 and provide empirical evidence to support this hypothesis.

We expect that household income structure will also affect appliance ownership. For instance, in double-income households, a woman's labor income may have a different effect on the likelihood of purchasing a dishwasher than a man's labor income. Similarly, labor income may affect the likelihood of purchasing a second TV differently from non-labor income, such as pension income. Nevertheless, previous studies examine only the impact of total household income on appliance ownership. Thus, this study's second purpose is to examine whether household income structure affects appliance ownership.

The empirical analysis of this study uses the Japanese National Survey of Family Income and Expenditure (NSFE) data. Although many countries have conducted a survey of appliance ownership, household income structure has not been surveyed in detail. For instance, the Residential Energy Conservation Survey by the US Energy Information Administration (2009) does not distinguish between a husband's or wife's income. In contrast, the NSFE includes information about household income structure. Although the Energy Follow-Up Survey by the UK Department of Energy and Climate Change (2011) includes information about household income structure, it does not report household wealth. Since the NSFE includes information about each household's deposits and loans, it is possible to estimate the impact of wealth on appliance ownership.

The rest of the paper is organized as follows. Section 2 explains the data used in this study. Section 3 presents the empirical models and Section 4 reports the estimation results. Section 5 concludes the paper.

2. METHODOLOGY

2.1. Data

The NSFE is a Nationwide Survey started in 1959, and is conducted every 5 years. Though the latest survey was completed in 2014, neither the 2009 nor 2014 data are publicly available at present. Therefore, this study uses data from 2004.

The NSFE includes detailed information about household revenue, expenditures, deposits, loans, and ownership of durables. The 2004 NSFE survey was conducted in 168 municipalities selected as a research area from September to November. Although the survey included about 59,374 households, only those with less than seven members were included in the dataset. Since this study examines how household income structure affects appliance ownership, we excluded single-person households. We further removed households lacking income and wealth information, resulting in a final dataset of 39,136 households.

The NSFE surveys the ownerships of 42 varieties of durables—from furniture to vehicles. This study focuses on seven appliances:

AC, TV, PC, cellular phones, dishwashers, solar water heaters, and warm water bidets.

Table 1 summarizes the ownership of these appliances. The ownership rate of AC is 86%, with an average of 2.35 owned. On the other hand, TVs have an ownership rate of 98%, with an average of 2.29 owned. Although the ownership rate for PCs is only 69%, the average is 1.00, indicating that some households have multiple PCs while others own none. The ownership rates for dishwashers, solar water heaters, and warm water bidets are low.

Considering these statistics, we examine whether a household owns a dishwasher, a solar water heater, and a warm water bidet. However, we analyze ownership rates for ACs, TVs, PCs and cellular phones.

Previous studies such as Leahy et al. (2012), Mate (2012), and Wolfram et al. (2012) find that the likelihood of appliance ownership increases as a household income increases. In this study, we decompose household income into labor income for husbands and wives, and non-labor income to evaluate their individual impact on appliance ownership. This study defines non-labor income as the money remaining after subtracting family members' earned incomes from the household's regular monthly income. We further calculate the value of financial assets held by each household by subtracting loans from deposits reported in the survey and then estimate the impact of financial assets (wealth) on appliance ownership.

Table 2 summarizes the sample households' socioeconomic statistics. The average age of household heads is 54.21%, and 77.67% of household heads are employed. The mean household annual income is 6.89 million yen (57,400 USD)³, with a mean monthly income for husbands of 213.8 thousand yen (1780 USD) while that for wives is 40.4 thousand yen (336 USD). Additionally, 25,188 households (64.36%) have some labor income while 13,948 households (36%) have no labor income. If the data only for persons with positive labor income are used, the mean income for husbands becomes 396.1 thousand yen (3300 USD) while that for wives becomes 148.0 thousand yen (1230 USD). The average household's financial assets are 10.0 million yen (83,370 USD), with only a slight difference between employed and unemployed households.

This study also examines sociodemographic variables commonly used in earlier studies. Specifically, we include age, the household head's profession, and the number of children under 15 years old in the home. We also include variables related to housing conditions: Location, floor space, type, and tenure.

3 When 1 USD = 120 JPY, the exchange used throughout this study.

Table 1: Appliance ownership in households with more than two persons (N=39,136)

Statistics	AC	TV ^a	Cellular phone ^b	PC	Warm water bidet	Dishwasher	Solar water heater
Ownership rate	0.86	0.98	0.84	0.69	0.59	0.19	0.10
Average number of appliance owned	2.35	2.29	1.82	1.00	0.73	0.20	0.11
Minimum	0	0	0	0	0	0	0
Maximum	9	12	7	9	7	4	6

^aAggregated cathode-ray tube, plasma, and liquid crystal televisions, ^bIncludes personal hand-phone system. Source: Japanese National Survey of Family Income and Expenditure (2004). AC: Air conditioner, TV: Television, PC: Personal computer

2.2. Empirical Model

The impact of socioeconomic variables on dishwasher, solar water heater, and warm water bidet ownerships are analyzed with logistic models, assuming that the probability that household i owns an appliance is given by the logistic function:

$$\text{Prob}(Y = 1|X_i) = \frac{\exp(\lambda_i)}{1 + \exp(\lambda_i)}$$

Where, $\lambda_i = X_i' B$. Here, X_i is the vector of the socioeconomic variables and B is the vector of the associated coefficients to be estimated.

We evaluate the impact on ownership of AC, TV, PC, and cellular phones with count data models, assuming that the probability that the number of appliances owned by household i becomes y_i is given by the Poisson function:

$$\text{Prob}(Y = y_i|X_i) = \frac{(\lambda_i)^{y_i} \exp(-\lambda_i)}{y_i!}$$

Though negative binomial models were estimated, none of the overdispersion parameters became statistically significant. Thus, this study reports only the estimation results of the Poisson models.

3. RESULTS

Table 3 reports the estimation results for dishwasher, solar water heater, and warm water bidet ownership based on the logit models. Since the logit models are non-linear, the report is limited to the marginal effects evaluated at the average of the explanatory variables. The value in the Table 3 is the change in the probability of ownership when the variable increases by one unit. For dummy variables, the value is the change in the probability when the dummy variable changes from zero to one.

Table 3 demonstrates that the marginal effect varies across income types. For instance, although the increase in labor income by 10 thousand yen (83.3 USD) raises the ownership probability of a dishwasher by 0.12%, the increase in non-labor income by the same amount lowers it by 0.07%. When labor income increased, people purchased a dishwasher as a way to save time. However, an increase in non-labor income leads to a lesser likelihood of owning a dishwasher. Table 3 also shows that each partner's labor incomes have different effects on appliance ownership. Although an increase in a wife's labor income raises the ownership probability of solar water heater, an increase in a husband's labor income lowers it. Table 3 further shows that the marginal effect of

Table 2: Descriptive statistics: Explanatory variables (N=39,136)

Variables	Unit	Average or share	Standard deviation	Minimum	Maximum
Income and wealth					
Total household annual income ^a	10,000 yen	686.09	397.75	1	2500
All persons					
Husband's monthly income	10,000 yen	21.38	23.29	0	250
Wife's monthly income	10,000 yen	4.04	9.18	0	71.13
Employed persons only ^b					
Husband's monthly income	10,000 yen	39.61	16.83	014	250
Wife's monthly income	10,000 yen	14.80	12.22	010	71.13
Household non-labor income	10,000 yen	4.93	8.69	0	149.75
Household wealth ^c	10,000 yen	1000.46	2079.70	-4496	9500
Employed households ^d	10,000 yen	997.43	2077.49	-4389	9500
Unemployed persons ^d	10,000 yen	1010.13	2087.39	-4496	9500
Household head					
Age ^e	Year	54.21	13.84	17.5	87.5
Unemployed ^d	Dummy	0.22		0	1
Female	Dummy	0.08		0	1
Agricultural, forestry, and fishery sector	Dummy	0.04		0	1
Self-employed	Dummy	0.01		0	1
Manager	Dummy	0.04		0	1
Household information					
Number of household members	Person	3.26	1.22	2	7
Number of children under 15	Person	0.87	0.88	0	5
Housing conditions					
Three major metropolitan areas	Dummy	0.40		0	1
Homeowner	Dummy	0.80		0	1
Detached house	Dummy	0.79		0	1
Floor area	m ²	1193.13	484.32	300	2000

^aThe minimum and maximum household annual income are recoded 1 and 2500 thousand yen, ^bIncludes only the persons earning positive salary, ^cFinancial assets estimated by subtracting loans from deposits for each household, ^dHouseholds whose head is employed are 30,937 (77.67%), ^eThe mean age for each age category is used for the analysis

Table 3: Logit model estimation (marginal effect, change in the probability of ownership)

Variables	Dishwasher (%)	Solar water heater (%)	Warm water bidet (%)
Income and wealth			
Husband's income	0.12	-0.04	0.17***
Wife's income	0.12***	0.03*	0.01
Household non-labor income	-0.07**	-0.06***	0.41***
Household wealth	-0.00076***	0.00058***	0.00004
Household head			
Age	0.65***	0.63***	-0.82***
Unemployed	0.27	-0.18	-0.64
Female	-1.29*	0.66	1.03
Agricultural etc., sector	-2.29**	0.58	-2.20*
Self-employed	1.83	-2.23*	0.45
Manager	1.32	-0.30	-0.20
Household information			
Household members	0.65***	0.63***	-0.82
Children under 15	-0.40	0.13	-0.19
Housing conditions			
Metropolitan areas	5.19***	-4.60***	10.71***
Homeowner	7.68***	5.54***	31.89***
Detached house	1.06	10.23***	4.57***
Floor area	0.012***	0.003***	0.018***

***Indicate statistical significance at the 10%, 5%, and 1% levels, respectively

income and wealth on the ownership vary across appliances. While an increase in financial assets raises the ownership probability of solar water heater, it lowers that of dishwasher.

As the age of the household head increases, both the ownership probabilities of dishwashers and solar water heaters increase. In

contrast, the ownership probability of warm water bidet decreases. When the household head engages in agriculture, forestry, and fishery, the ownership probabilities of dishwashers and warm water bidets decrease by 2%. In addition, as the number of household members increases, the ownership probabilities of dishwashers and solar water heaters increase, though it decreases for warm water bidets. Perhaps goods and services besides warm water bidets are more important for large families.

As in previous studies, housing conditions are important determinants of appliance ownership. For instance, the ownership probability for dishwashers among homeowners is 7.68% higher than for renters; that for warm water bidets among homeowners is higher by 31.89% compared to renters. Detached houses have a 10.23% higher ownership probability of solar hot water heaters.

Table 4 shows the estimation results for AC, TV, PC, and cellular phone ownership based on the Poisson models. Since the Poisson models are also non-linear, only the marginal effects evaluated at the average of the explanatory variables are reported. However, the value in the Table 4 reports the change in the expected number of appliances owned when the variable increases by one unit.

Table 4 shows that the effect of income on the number of the appliances owned varies across income types. For instance, a wife's labor income increases the number of TVs at home, while the husband's labor income decreases it. Although labor income increases the numbers of PCs and cellular phones, non-labor income decrease them. The Table 4 shows that the marginal effect

Table 4: Poisson model estimation (marginal effect, change in the number of appliances owned)

Variables	AC	TV	PC	Cellular phone
Income and wealth				
Husband's income	0.005***	-0.001***	0.008***	0.008***
Wife's income	0.004***	0.004***	0.008***	0.013***
Non-labor income	0.004***	0.005***	-0.007***	-0.028***
Household wealth	0.00005***	0.00006***	0.00003***	-0.00002***
Household head				
Age	-0.0003	-0.0004	-0.0006	0.0002
Unemployed	-0.028	0.001	0.009	-0.024
Female	-0.003	0.014	0.002	-0.028
Agricultural etc., sector	0.013	-0.010	0.020	-0.039
Self-employed	-0.043	0.005	-0.048	-0.008
Manager	-0.044	-0.027	-0.007	-0.014
Household information				
Household members	0.085***	0.178***	0.087***	0.307***
Children under 15	-0.012	-0.012	-0.006	-0.012
Housing conditions				
Metropolitan areas	0.877***	0.111***	0.180***	0.153***
Homeowner	0.694***	0.361***	0.106***	0.026
Detached house	0.413***	0.270***	-0.080***	-0.059**
Floor area	0.0009***	0.0007***	0.0002***	0.0002***

*****Indicate statistical significance at the 10%, 5%, and 1% levels, respectively. AC: Air conditioner, TV: Television, PC: Personal computer

of a wife's labor income on the number of cellular phones is larger than that for husbands.

Table 4 confirms that housing conditions substantially affect the number of appliances in the home. In particular, housing conditions have a large impact on AC ownership. Those owning a detached house in the three major metropolitan areas are expected to have more than two ACs. Compared to the effects of housing conditions, those of income and wealth are relatively small.

Data for lot areas and house ages are available for owned houses, and this subsample is analyzed for their impact on appliance ownership. For brevity, this paper reports only the main results. Both factors have a positive impact on solar water heater ownership. On the other hand, they have a negative impact on the ownership of dishwashers, warm water bidets, ACs, and PCs. For cellular phones, only the age of the house has an impact, which is negative. Including the lot areas and the ages of the houses does not change the estimation results in Tables 3 and 4.

4. CONCLUSION AND POLICY IMPLICATIONS

Earlier research investigated the effects of total household income on appliance ownership. This study uses detailed data from the Japanese NSFES to examine how household income structure determines the number of appliances owned in a home. The empirical results demonstrate that income levels and types affect appliance ownership differently, and specific types have negative effects on appliance ownership.

Households purchase a wide variety of goods and services besides the appliances analyzed. As an income increases, households may start purchasing another good or service, and an appliance could be an inferior good. For example, as non-labor income increases,

people eat out more frequently and reduce cooking at home. If so, they will not purchase a dishwasher.

Another possibility is that household income structure is correlated with lifestyle or the intensity of appliance use. For example, those who spend much of their time at work may not have time for watching TV at home, and will not purchase a TV.

To that end, this study's results suggest that household income structure affects appliance ownership. Since it is expected that the demographic structure in developed countries changes rapidly through women's labor force participation and an aging population in the near future, it is important to assess how changes in household income structure affects household energy consumption.

Though this study finds that both income and wealth affects appliance ownership to some extent, housing conditions have a much larger impact. Home ownership has a positive impact on the ownership of all seven appliances. Thus, as O'Doherty et al. (2008) find, this study also finds that homeowners are more likely to install an energy saving feature (a solar water heater), but are also more likely to have more appliances. Additionally, households living in a detached house tend to own more appliances, excluding PCs and cellular phones. Although many countries have promoted home ownership, policymakers should assess its impact on energy consumption.

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