The Heterogenous Impacts of Energy Price Changes on Household Expenditure from the Aspect of Different Types of Household in Japan

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Hoshino, Yuko, ENEOS Corporation
Ogawa, Junko, Institute of Energy Economics Japan

ENEOS株式会社

Outline

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4. Results
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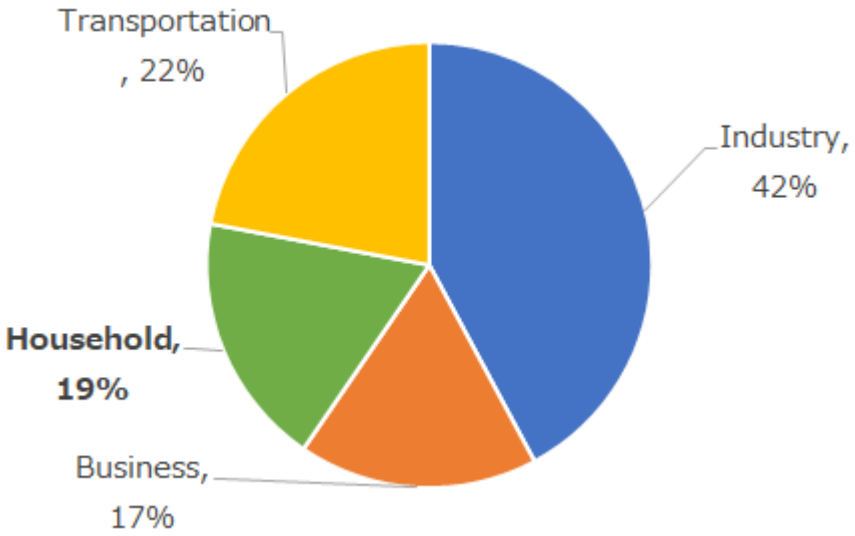
Introduction: Japan's household CO_2 Emissions

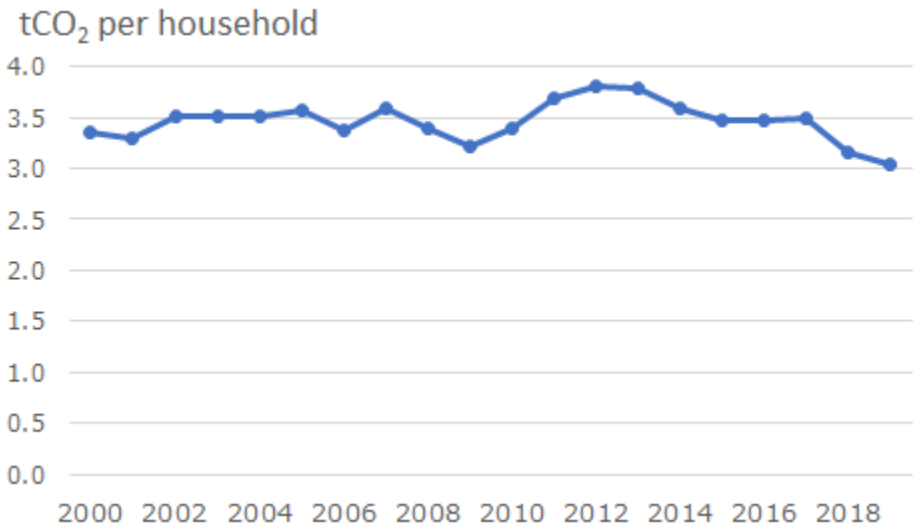
- In 2019, the household sector accounts for 19% of Japan's total CO_2 emissions.
- Japan's CO_2 emissions per household are not yet on the track of decreasing trend.

CO_2 emissions by sector in 2019 (including emissions from power sector)



Data Source: EDMC/IEEJ

CO_2 emissions per household (including emissions from power sector)



Data Source: EDMC/IEEJ

・Carbon pricing is expected to be effective as a CO_2 reduction measure in the household sector

. The effectiveness of carbon pricing depends on the price elasticity of energy demand

Introduction: The focus points of this Study

● When the oil price rise, the increase of the share of energy and transportation expenditure of low-income families is bigger than that of high-income families.

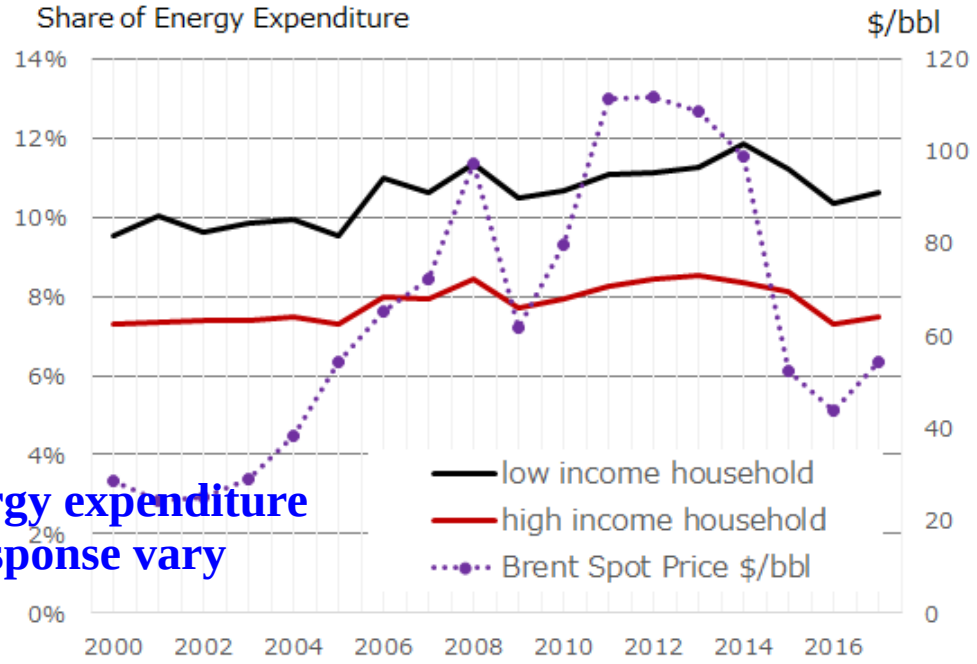
⇒ **Is price elasticity of energy demand in low-income household lower than in high-income household? If so, the price rise affects more on low-income household.**

In the following study,

● **We estimate the price elasticity of household energy demand**

- We focus on the household heterogeneities concerning the price elasticity
- As for the heterogeneities, we focus on income and city size differences

Share of energy and transportation expenditure in the total expenditure in low- and high-income household



share of energy expenditure and price response vary

Data Source: the family income and expenditure survey data, EDMC/IEEJ

Data used in the analysis

As for the expenditure data,

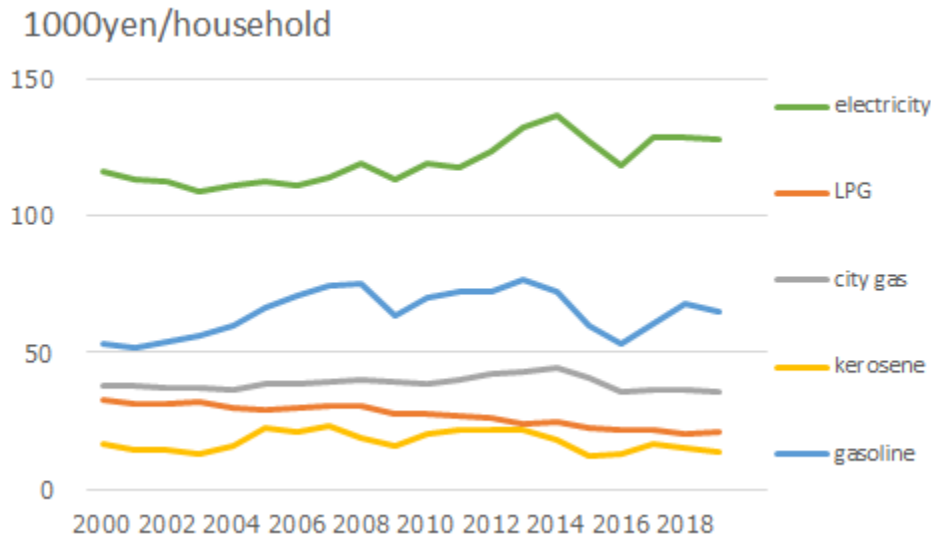
・The annual time series data aggregating “the Family Income and Expenditure Survey” conducted by the Statistics Bureau from 2001 to 2017

・The total consumption expenditure of households is divided into six expenditures of electricity, gas, kerosene, gasoline, transportation expenses, and other expenditures (sum of food and beverage, clothing, housing, education and entertainment, etc.)

As for the price data,

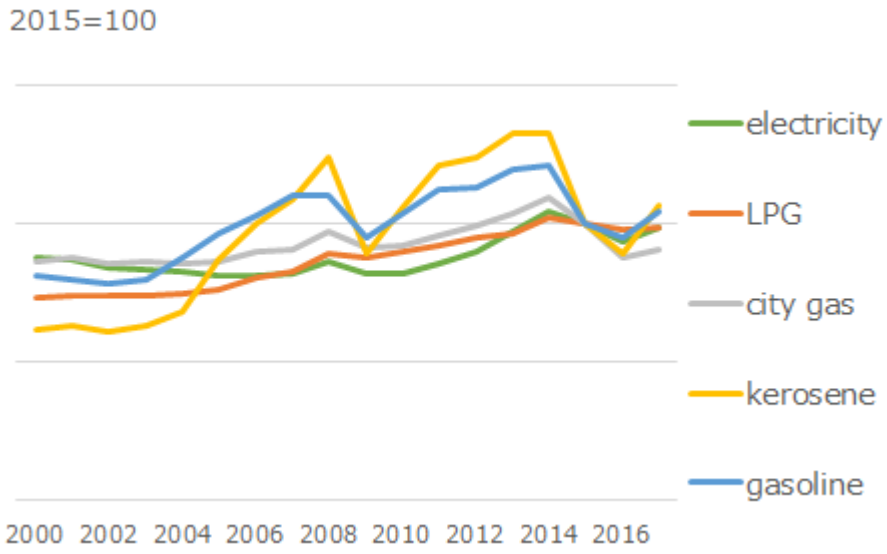
・The national average of Consumer Price Index for each item.

Energy Expenditure per Household



Data Source: the family income and expenditure survey data

Residential Energy Price

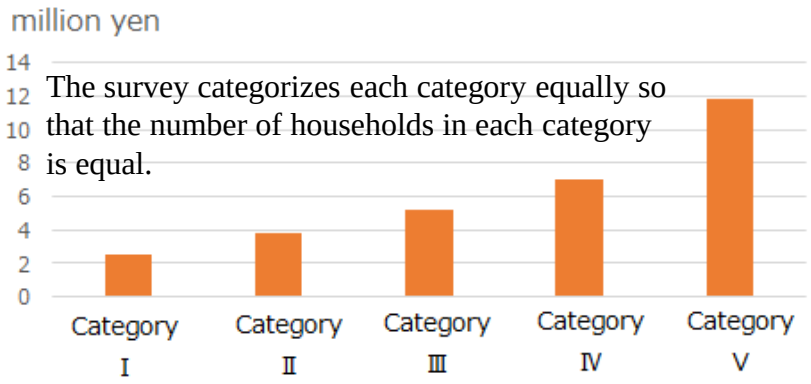


Data Source Consumer Price Index Statistics bureau

The Family Income and Expenditure Survey data

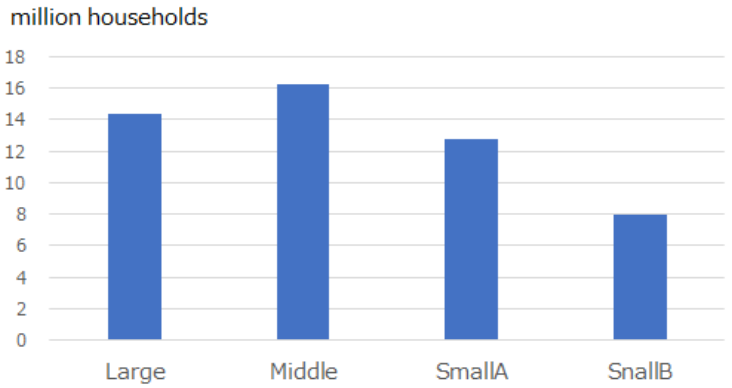
Income and City size distribution in Japan

Average household income by category

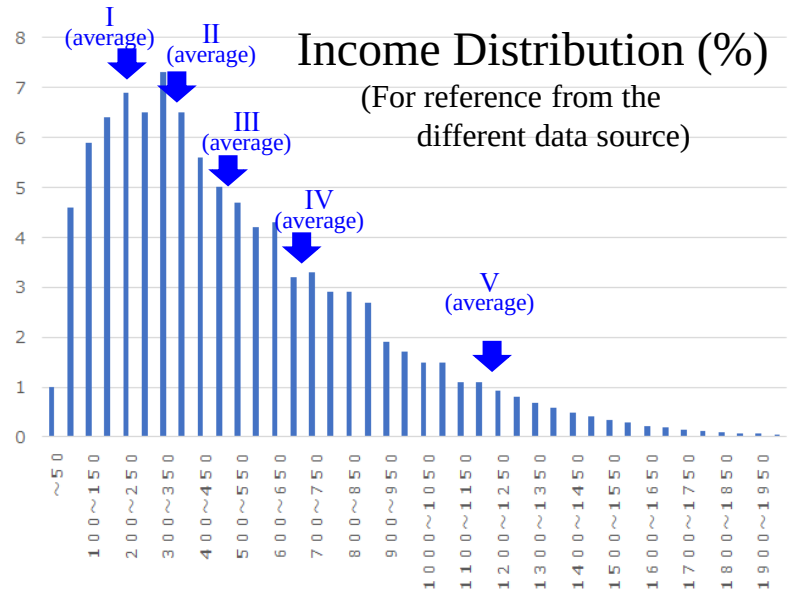


Data Source: the family income and expenditure survey data

Number of household by city size

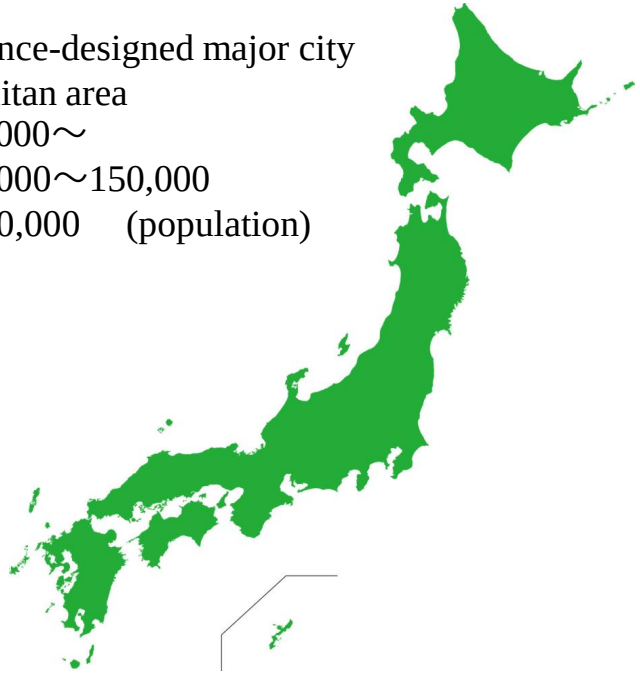


Data Source: the family income and expenditure survey data



Data Source: Comprehensive survey of living conditions, 2017

Large City: Ordinance-designed major city and Tokyo metropolitan area
Middle City：150,000～
Small City A： 50,000～150,000
Small City B：～50,000 (population)



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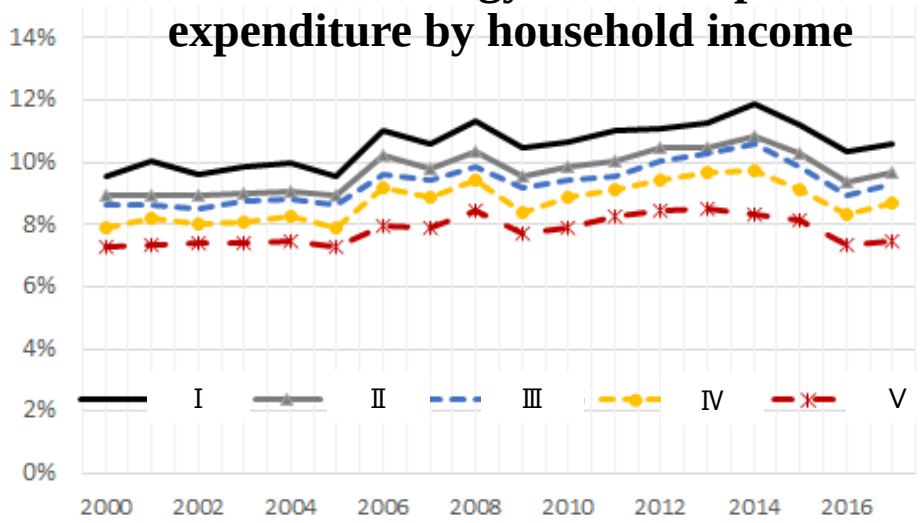
The Family Income and Expenditure Survey data

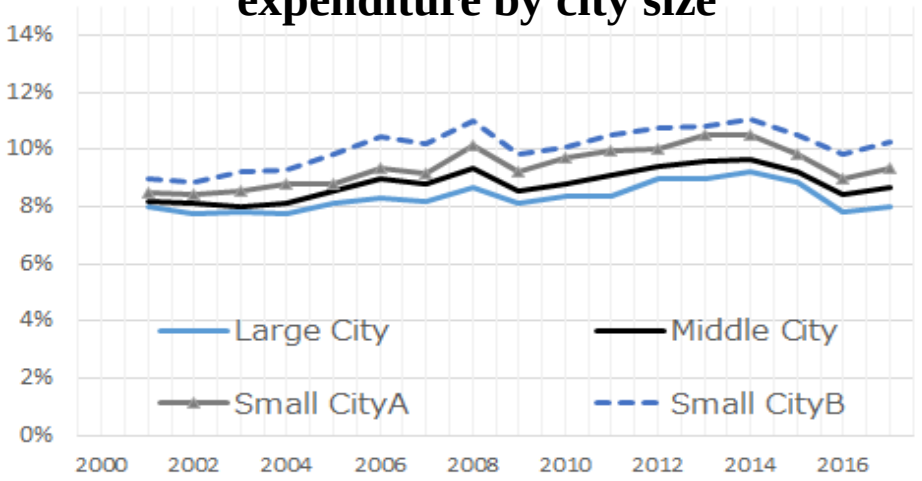
The share of energy expenditure in the total household expenditure by household income and city size

Total share of energy and transportation expenditure by household income



Data Source: the family income and expenditure survey data

Total share of energy and transportation expenditure by city size



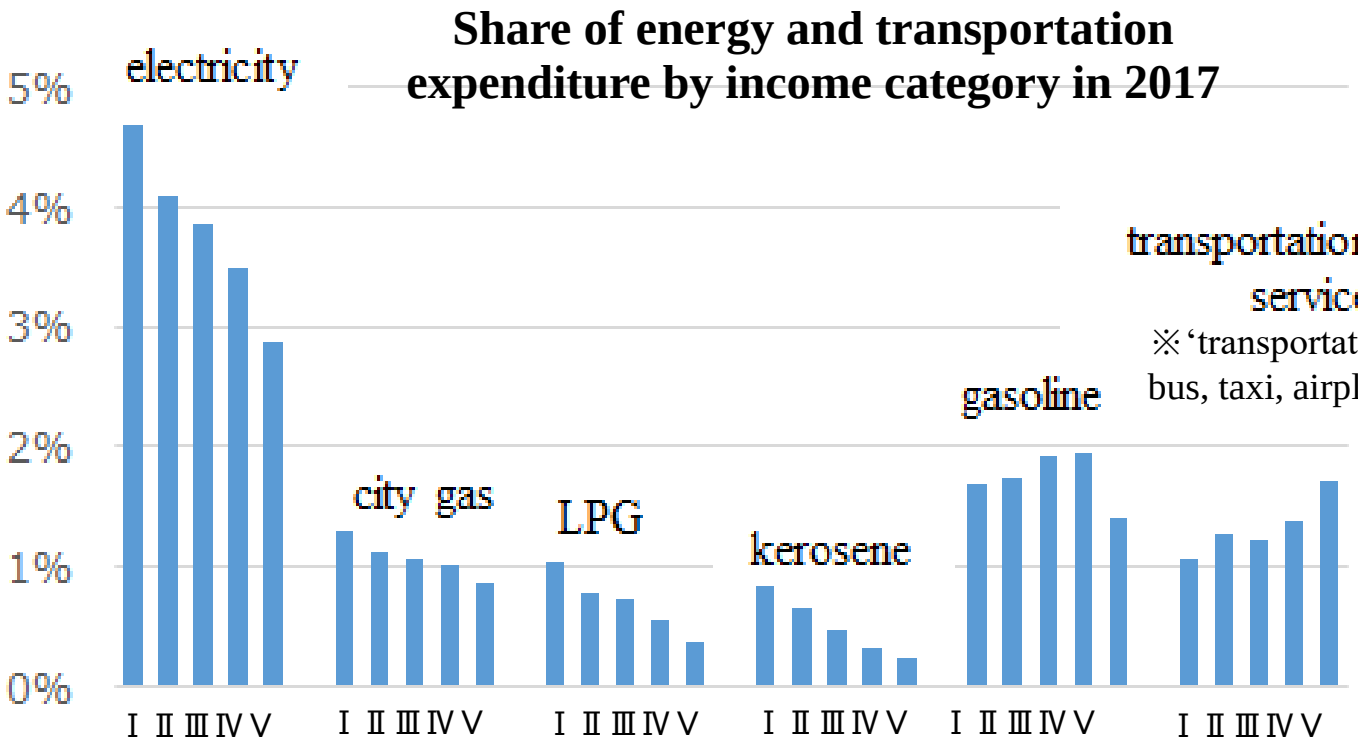
Data Source: the family income and expenditure survey data

●The share of energy and transportation expenses such as electricity, LPG, city gas, kerosene, gasoline and transportation service expenses is **increasing in low-income households and also in small city**, whereas it is relatively **stable at around 8% in high-income households and also in large city**.

The Family Income and Expenditure Survey data

The expenditure share of each energy source and service by household income

● As for the utility costs, the lower the household income, the higher the share of expenditure



※‘transportation expenses’: railroad, bus, taxi, airplane and toll roads.

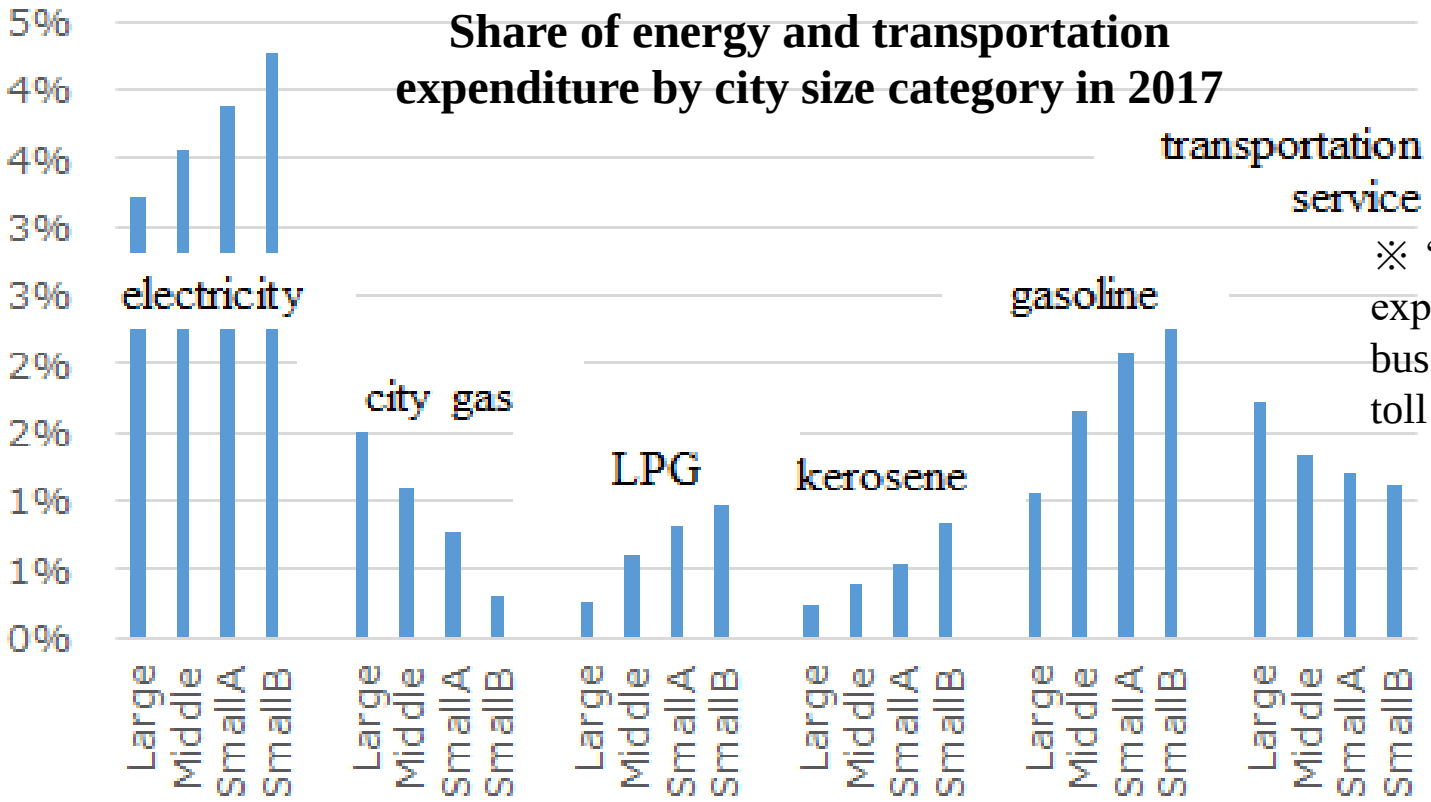
Data Source: the family income and expenditure survey data

It is expected that the impacts of rising energy costs on the household energy consumption and how each fuel is substituted by other energy is differed by the income category

The Family Income and Expenditure Survey data

The expenditure share of each energy source and service by city size

●The share of expenditure of electricity, LPG, kerosene and gasoline is higher in the small city compared to the larger city.



※ 'transportation expenses': railroad, bus, taxi, airplane and toll roads.

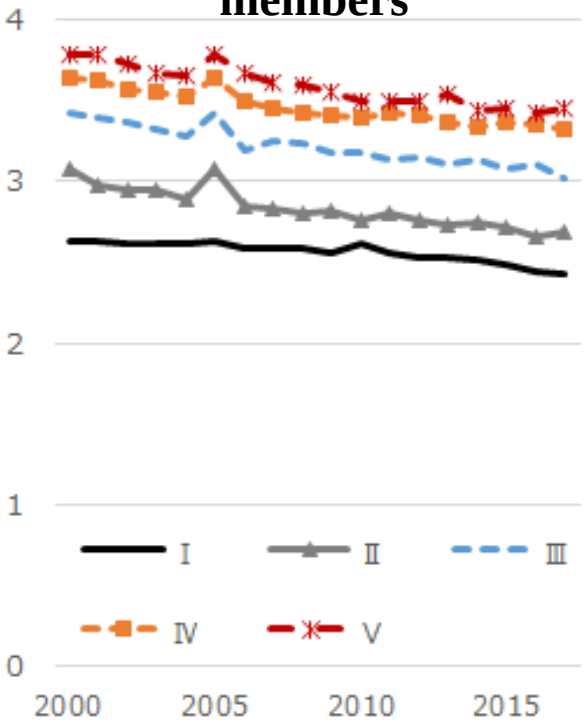
Data Source: the family income and expenditure survey data

It is expected that the impacts of rising energy costs on the household energy consumption and how each fuel is substituted by other energy is differed by city size.

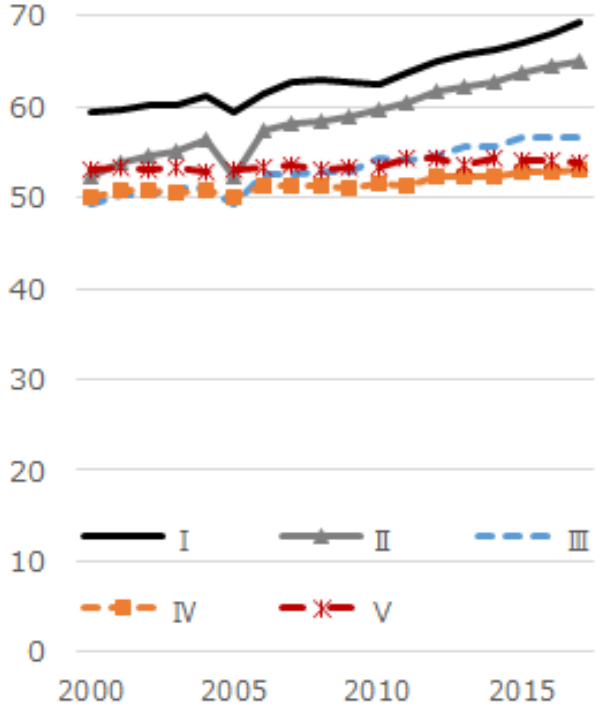
The Family Income and Expenditure Survey data

Household characteristics by income category

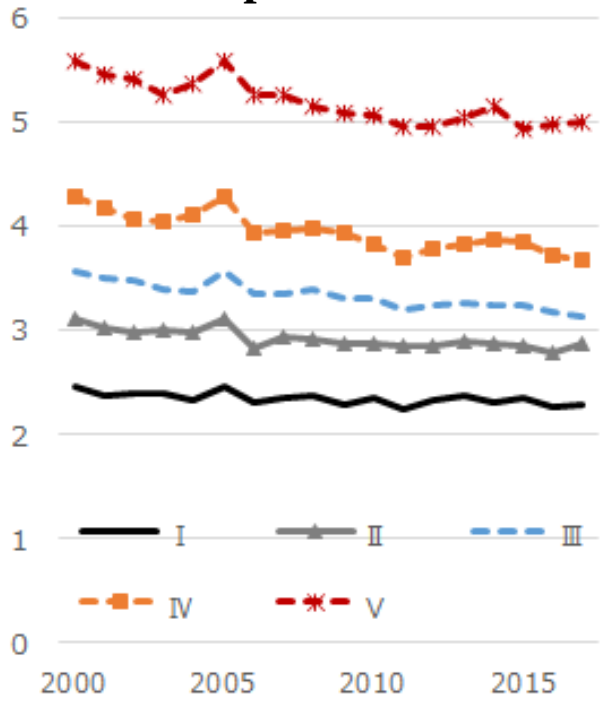
Number of household members



Age of householder



Household consumption expenditure



Data Source: the family income and expenditure survey data

- The number of household members gradually decreases
- The lower the household income, the smaller the household size.

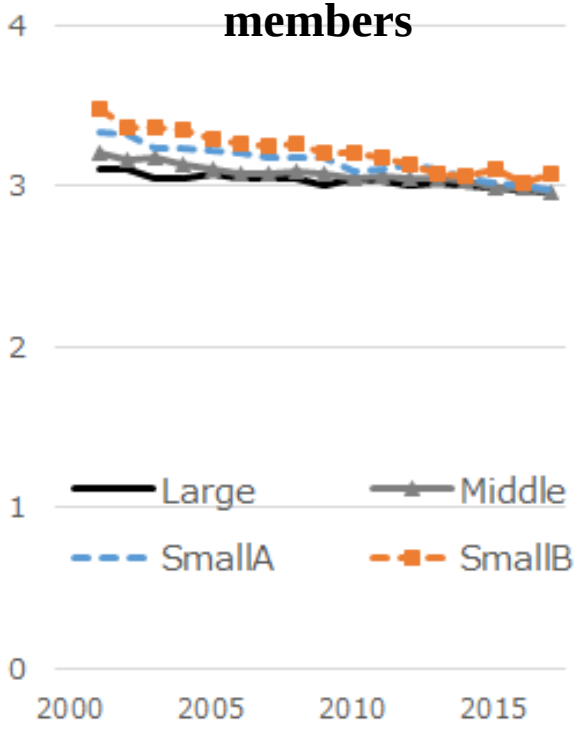
- The age of householder increases in Category Ⅰ & Ⅱ
- The lower the household income, the older the age of householder.

- Consumption expenditure of high-income household gradually decreases, while that of low-income household does not change.

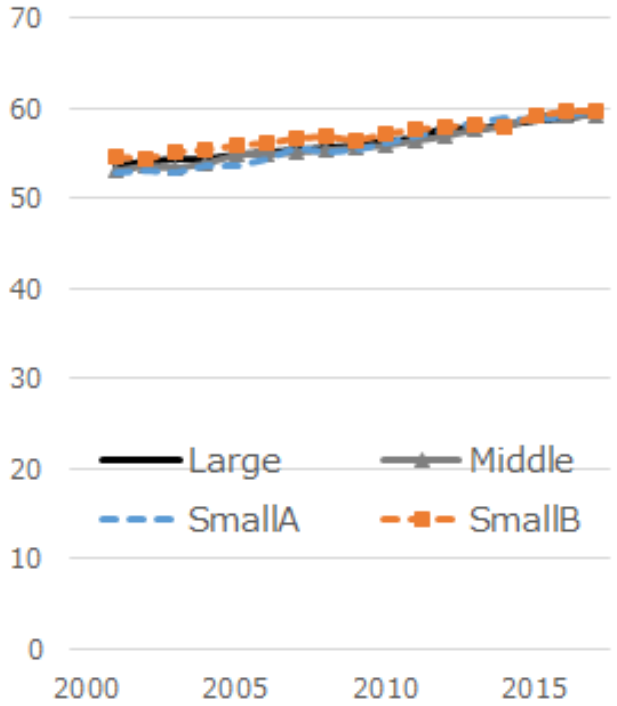
The Family Income and Expenditure Survey data

Household characteristics by city size

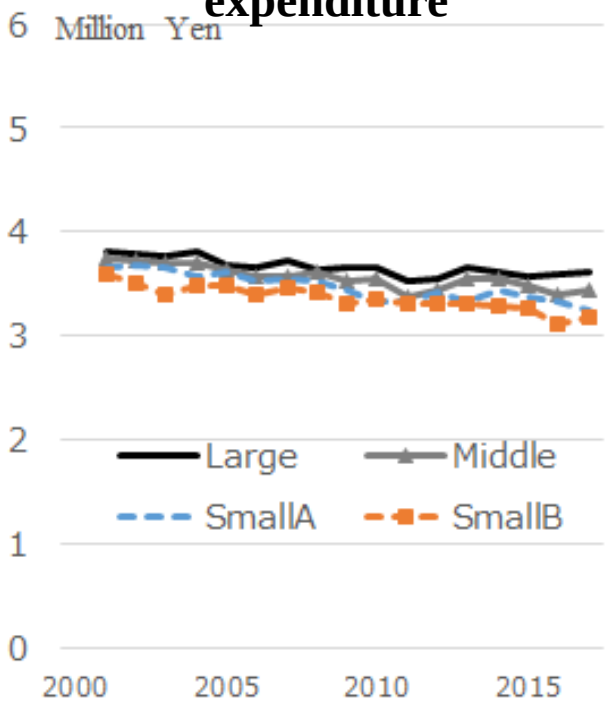
Number of household members



Age of householder



Household consumption expenditure



Data Source: the family income and expenditure survey data

- The smaller the city size, the larger the household size
- But the gap is narrowing

- The age of householder increases in all city size
- The age of householder is almost same among the cities in different sizes.

- The smaller the city size, the smaller the household consumption expenditure

Methodology: Analysis model

In order to estimate the price elasticity of household energy demand, we develop an translogarithmic model as follows.

The indirect utility function of representing household consumer takes the form:

$$V = (p, Y) \qquad (1)$$

We get the following quadratic, logarithmic indirect utility function:

$$lnV = \alpha_0 + \sum_i \alpha_i \ln(p_i/Y) + (1/2) \sum_i \sum_j \beta_{ij} \ln(p_i/Y)\ln(p_j/Y), \qquad Y = \sum_i p_i x_i \qquad (2)$$

Where p_i, p_j are the i-th, j-th prices, Y is total expenditure, x_i is the i-th consumption volume.
i,j = electricity, LPG, city gas, kerosene, gas oil, transportation service and other consumption

Applying Roy's identity to the indirect utility function in (2) , the i-th value share w_i can be written as :

$$w_i = [\ \alpha_i + \sum_j \beta_{ij}\ ln(p_j/Y)\ ] / [\ \sum_i \alpha_i + \sum_j \sum_k \beta_{kj}\ ln(p_j/Y)\ ] \qquad (3)$$

The own-price elasticity and the cross-price elasticity are calculated as follows

$$\eta_{pii} = -1 + [\ \beta_{ii}/w_i - \sum_j \beta_{ij}\ ] / [\ \sum_j \alpha_j + \sum_j \sum_k \beta_{jk}\ ln(p_k/Y)\ ] \qquad (4)$$

$$\eta_{pij} = [\ \beta_{ij}/w_i - \sum_j \beta_{ij}\ ] / [\ \sum_k \alpha_k + \sum_k \sum_l \beta_{kl}\ ln(p_l/Y)\ ], \quad (i \neq j) \qquad (5)$$

where $\sum_i w_i = 1$, $\sum_i \alpha_i = -1$, $\sum_j \beta_{ij} = 0$, $\beta_{ij} = \beta_{ji}$

As the sum of expenditure shares is $\sum wi = 1$, we estimate simultaneously the six share functions excluding one (other consumption) of each income category or city size using the method of Zellner's Seemingly Unrelated Regressions (SUR)

Results: The estimated parameters of share functions

Share functions by household income

		Category1	Category2	Category3	Category4	Category5
Estimated Parameter	α1	-0.048**	-0.042**	-0.040**	-0.036**	-0.031**
	α2	-0.011**	-0.009**	-0.008**	-0.006**	-0.004**
	α3	-0.015**	-0.014**	-0.013**	-0.012**	-0.011**
	α4	-0.009**	-0.007**	-0.006**	-0.005**	-0.004**
	α5	-0.019**	-0.019**	-0.021**	-0.021**	-0.017**
	α6	-0.012**	-0.013**	-0.013**	-0.014**	-0.016**
	β11	-0.031**	-0.030**	-0.026**	-0.023**	-0.011**
	β12	-0.015**	-0.008**	-0.008**	-0.003**	0.000
	β13	0.004*	0.001	0.000	0.000	-0.007**
	β14	-0.002	-0.005**	-0.004**	-0.003	-0.004**
	β15	0.003	0.004	0.004	0.001	0.006**
	β16	-0.010**	-0.010**	-0.009*	-0.011**	-0.012**
	β22	0.015**	0.014**	0.009**	0.005**	0.006**
	β23	-0.005**	-0.005**	-0.001	-0.003**	-0.003**
	β24	0.001	-0.004**	0.002	0.002	0.001
	β25	-0.004	0.005	-0.005*	-0.003	-0.002
	β26	0.029**	0.011**	0.017**	0.022**	0.007*
	β33	-0.014**	-0.013**	-0.011**	-0.008**	-0.006**
	β34	0.001	0.006**	0.001	0.001	0.003**
	β35	0.001	-0.008**	-0.001	-0.001	-0.004
	β36	-0.004	0.002	-0.007*	0.001	0.009**
	β44	-0.004	0.000	-0.004*	0.001	0.001
	β45	-0.004	-0.008*	0.001	-0.008**	-0.006*
	β46	-0.005	0.003	0.001	-0.002	0.001
	β55	0.029	-0.002	-0.018**	-0.005	-0.002
	β56	-0.014	-0.006	-0.001	-0.002	-0.005
	β66	0.001	0.017	-0.005	-0.026	-0.008
R^2	electricity	0.96	0.94	0.97	0.95	0.91
	LPG	0.39	0.58	0.58	0.75	0.79
	City Gas	0.85	0.78	0.85	0.87	0.67
	kerosene	0.84	0.60	0.64	0.46	0.20
	gasoline	0.78	0.88	0.86	0.86	0.75
	transport	0.88	0.87	0.84	0.82	0.57

Share functions by city size

		Large City	Middle City	Small CityA	Small CityB
Estimated Parameter	α1	-0.036**	-0.037**	-0.041**	-0.043**
	α2	-0.003**	-0.006**	-0.009**	-0.013**
	α3	-0.019**	-0.013**	-0.009**	-0.004**
	α4	-0.003**	-0.004**	-0.006**	-0.010**
	α5	-0.011**	-0.018**	-0.022**	-0.027**
	α6	-0.017**	-0.013**	-0.013**	-0.011**
	β11	-0.023**	-0.021**	-0.020**	-0.023**
	β12	0.000	0.005**	0.003	0.003
	β13	-0.002	-0.006	-0.02**	-0.010**
	β14	-0.005**	-0.008**	-0.01**	-0.01**
	β15	0.005	0.016**	0.02**	0.02**
	β16	-0.021**	-0.034**	-0.04**	-0.02**
	β22	-0.002	-0.004**	0.003	-0.003
	β23	-0.004**	-0.002	0.005**	-0.002
	β24	0.001	-0.002*	0.002	0.002
	β25	-0.001	0.003	-0.010**	-0.002
	β26	0.000	-0.001	0.010**	-0.003
	β33	-0.015**	-0.008**	-0.001	0.001
	β34	0.004**	0.007**	0.01**	0.001
	β35	-0.004	-0.009**	-0.01**	-0.002
	β36	0.014**	0.017**	0.01**	0.012**
	β44	-0.002*	-0.002	-0.005	0.001
	β45	-0.002	-0.004	-0.005	-0.015**
	β46	0.016**	0.013**	0.007*	0.009**
	β55	0.000*	-0.013**	-0.013	0.000
	β56	-0.015**	-0.023**	-0.014**	-0.018**
	β66	0.004**	0.078**	0.041**	0.034**
R^2	electricity	0.88	0.91	0.82	0.84
	LPG	0.29	0.82	0.63	0.27
	City Gas	0.78	0.56	0.71	0.12
	kerosene	0.74	0.71	0.68	0.60
	gasoline	0.87	0.95	0.87	0.86
	transport	0.75	0.80	0.78	0.42

Results: price elasticities by household income category, 2000-2017

Category1									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.32**	0.32	-0.09	0.04	Gasoline	**-0.54**	-0.24	other	**-0.92**
LPG	1.31	**-2.32**	0.46	-0.09	transport	-0.40	**0.89**		
City Gas	-0.29	0.36	**-0.05**	-0.06					
kerosene	0.23	-0.12	-0.10	**-0.50**					

Own Price Elasticities are shown in bold

Category2									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.26**	0.20	-0.03	0.12	gasoline	**-0.90**	0.29	other	**-0.94**
LPG	0.93	**-2.60**	0.59	0.48	transport	0.44	**-2.34**		
City Gas	-0.09	0.40	**-0.03**	-0.46					
kerosene	0.72	0.64	-0.89	**-1.06**					

Category3									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.32**	0.21	-0.01	0.11	gasoline	**-0.14**	0.07	other	**-0.91**
LPG	1.00	**-2.14**	0.09	-0.21	transport	0.12	**-0.63**		
City Gas	-0.03	0.06	**-0.04**	-0.13					
kerosene	0.78	-0.33	-0.29	**-0.18**					

Category4									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.34**	0.10	-0.01	0.08	gasoline	**-0.78**	0.09	other	**-0.92**
LPG	0.53	**-1.76**	0.45	-0.25	transport	0.14	**0.96**		
City Gas	-0.02	0.25	**-0.31**	-0.08					
kerosene	0.62	-0.38	-0.21	**-1.27**					

Category5									
	electricity	LPG	City Gas	kerosene		gasoline	transport		Other
electricity	**-0.62**	-0.01	0.23	0.15	gasoline	**-0.90**	0.32	Other	**-0.94**
LPG	-0.05	**-2.39**	0.75	-0.20	transport	0.32	**-0.51**		
City Gas	0.68	0.33	**-0.43**	-0.33					
kerosene	1.44	-0.28	-1.05	**-1.37**					

Results: price elasticities by city size category, 2000-2017

Large City									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.31**	0.01	0.05	0.16	gasoline	**-0.46**	2.62	other	**-0.96**
LPG	0.11	**-0.30**	1.48	-0.48	transport	1.72	**-5.23**		
City Gas	0.09	0.23	**-0.15**	-0.22					
kerosene	1.89	-0.48	-1.44	**-0.16**					

Own Price Elasticities are shown in bold

Middle City									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.29**	-0.08	-0.02	0.23	gasoline	**-0.38**	1.18	other	**-0.97**
LPG	-0.44	**-0.20**	0.05	0.21	transport	1.66	**-5.45**		
City Gas	-0.06	0.02	**-0.08**	-0.35					
kerosene	1.88	0.32	-1.05	**-0.73**					

Small CityA									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.47**	-0.09	0.46	0.22	gasoline	**-0.46**	0.59	other	**-0.92**
LPG	-0.36	**-1.31**	-0.56	-0.18	transport	1.15	**-4.38**		
City Gas	2.10	-0.66	**-0.89**	-0.66					
kerosene	1.42	-0.29	-0.93	**-0.19**					

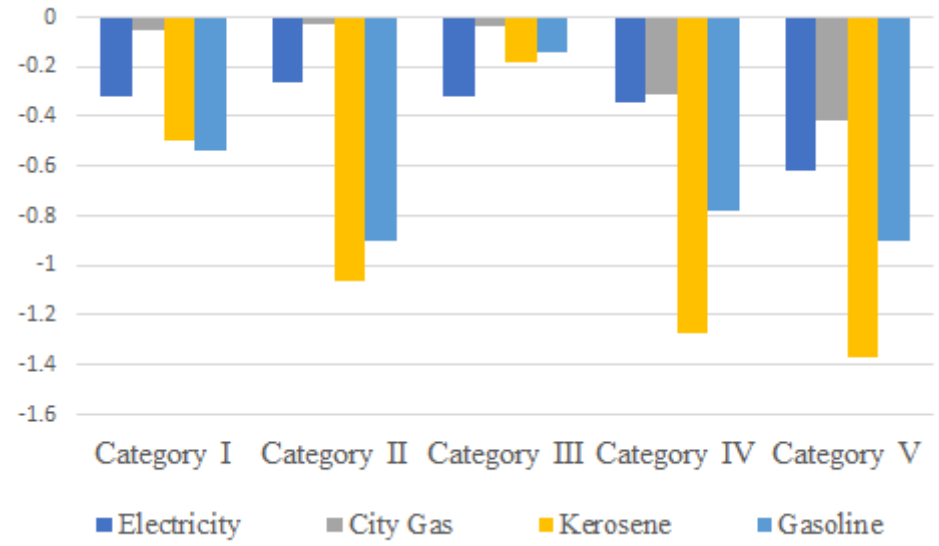
Small CityB									
	electricity	LPG	City Gas	kerosene		gasoline	transport		other
electricity	**-0.44**	-0.07	0.25	0.16	gasoline	**-1.01**	0.65	other	**-0.92**
LPG	-0.22	**-0.75**	0.15	-0.15	transport	1.82	**-4.35**		
City Gas	3.51	0.68	**-1.45**	-0.49					
kerosene	0.66	-0.19	-0.15	**-1.13**					

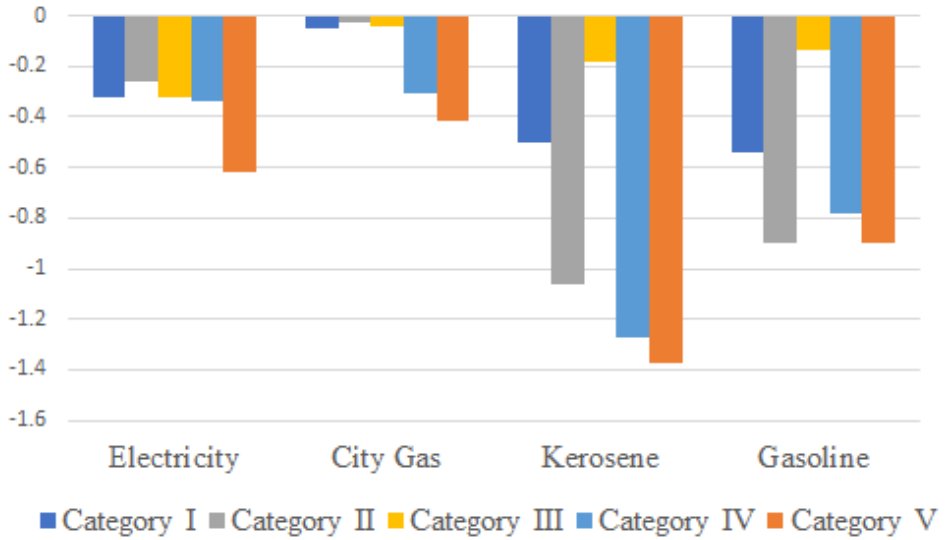
Results: The estimated own price elasticities by household income

●The own price elasticities of electricity, city gas, kerosene and gasoline are larger in the category 5 households than in the category 1 households.

⇒ The higher the household income, the more elastic the demand is. The energy conservation is easier in high income households because they can afford to invest in energy efficient appliances.

⇒ On the other hand, in the low-income households, the rise of energy prices increases household energy expenditure burdens more severely.

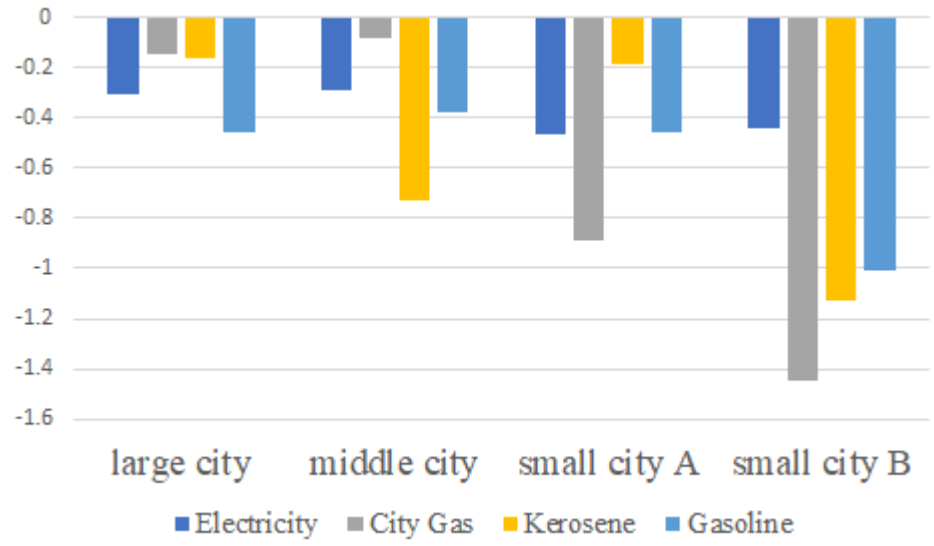


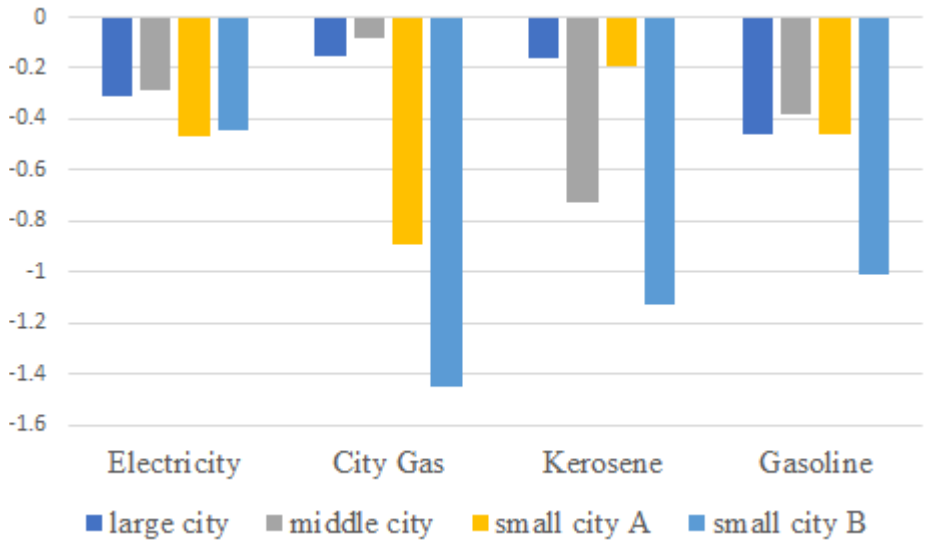


Results: The estimated own price elasticities by city size

●The own-price elasticities of small cities are larger than those of large cities. Because in a small city, average house size is larger and transportation tends to depend more on automobiles.

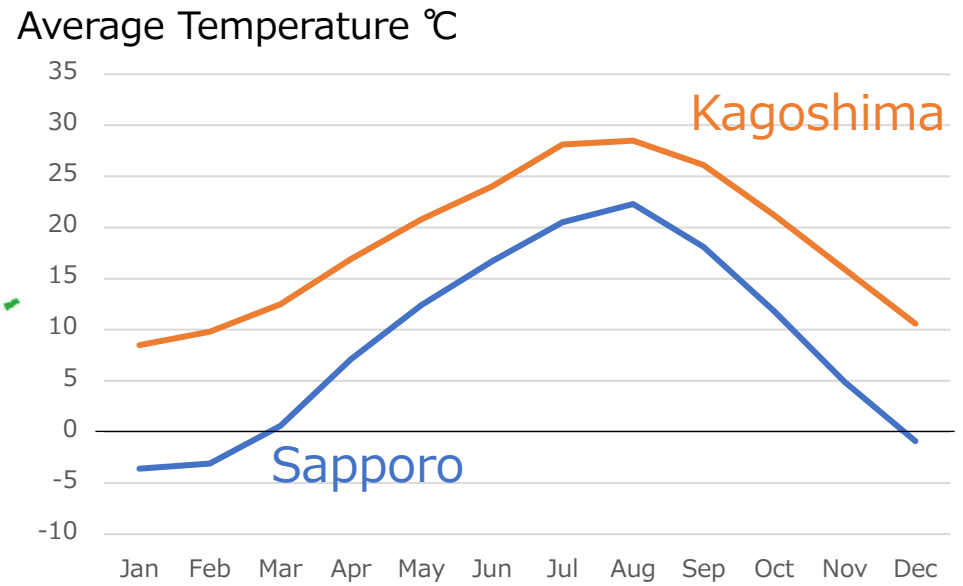
⇒ The households in a small city have more energy appliances and automobiles. Therefore, they have more chances to buy new appliances and cars ,which are more energy efficient.



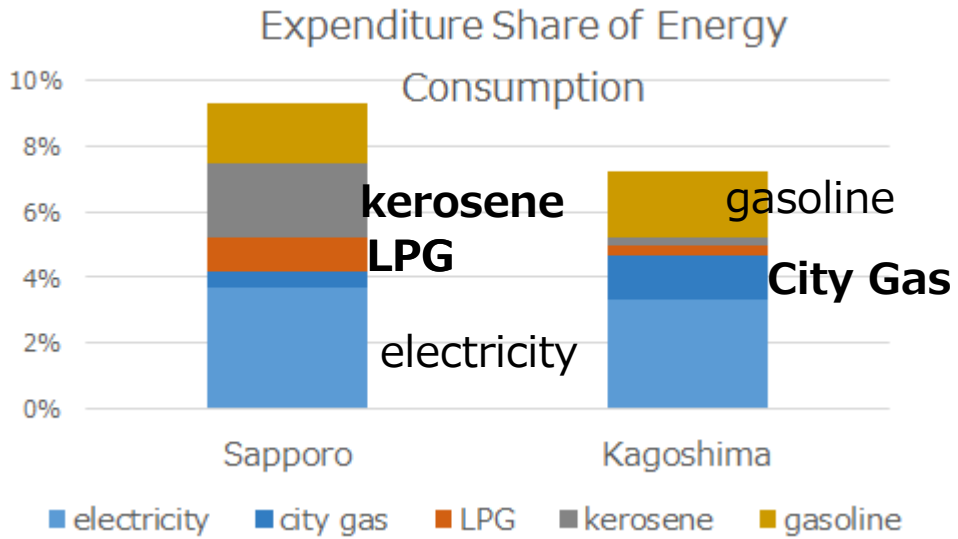


Household heterogeneities not included in this study

Demand for kerosene for heating is large



Data Source: Japan Meteorological Agency



Data Source: the family income and expenditure survey data, 2017

Conclusion

● The price elasticities vary according to the household income level and the size of the city where households are located. Our results suggest that energy pricing policy should be carefully designed considering the heterogeneous response of different types of household. This suggests that rise of energy price is quite regressive in the household sector.

● The higher own-price elasticities in the high-income households mean that energy conservation is easier in high-income households because they are affordable to invest in energy efficient appliances. On the other hand, lower own-price elasticities in the low-income households mean that the rise of energy price increases household's energy expenditure burden more severely.

● The price elasticities of households in a small city are bigger than those of households in a large city. Because in a small city where is generally located in a suburban area, average house size is larger and transportation tends to depend more on automobile rather than public transportation. This implies that the households in a small city use more energy appliances and automobiles. This also suggests rising price stimulates such household to replace less energy efficient appliances with energy efficient ones.

● Furthermore, the impact of differences in the regional climate on the price elasticity is one of our future research topics.