Diffusion of Household Gas Cogeneration Systems and the Role of Inter-energy Competition

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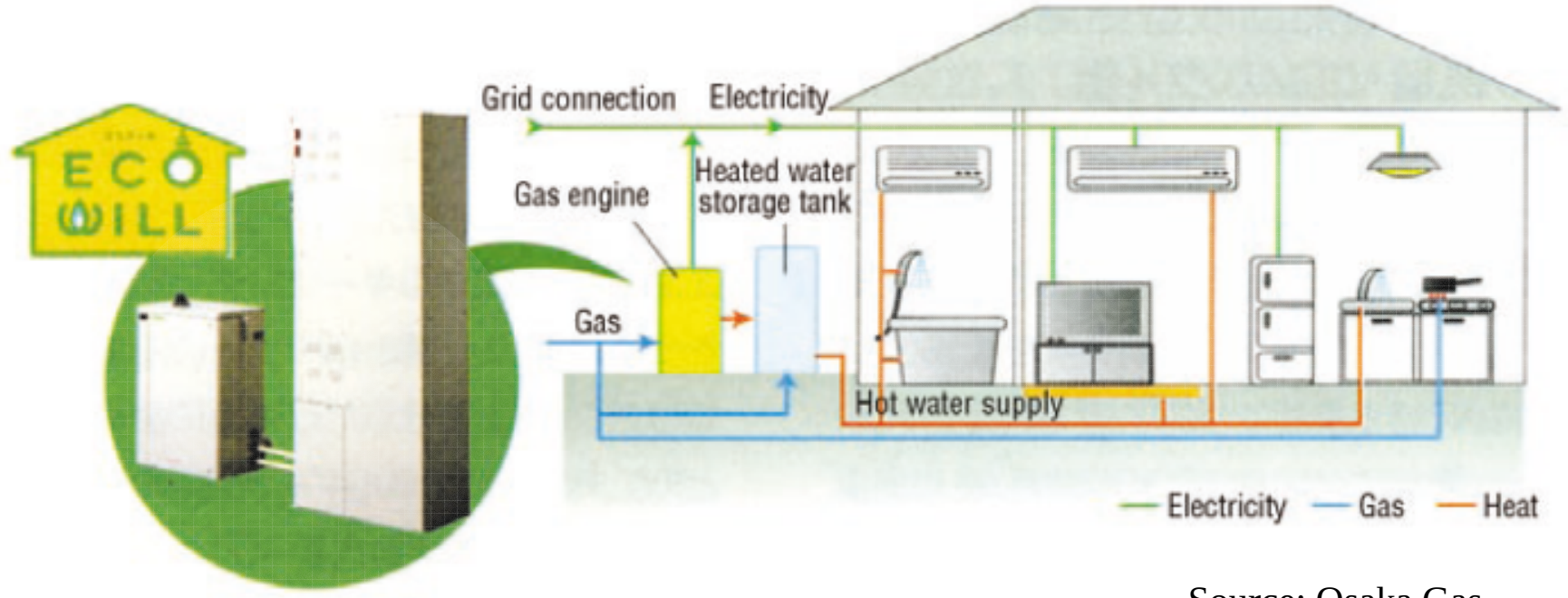
Household Gas Cogeneration System

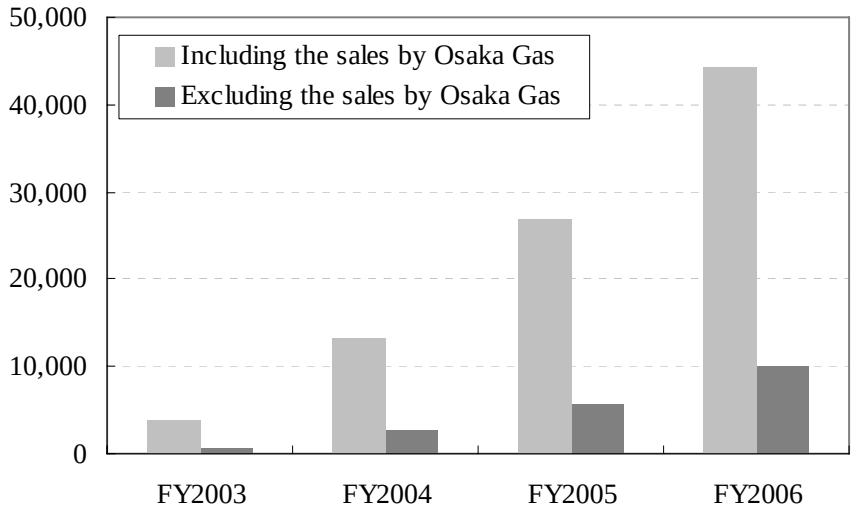
■ Household Gas Cogeneration System (ECOWILL)



Source: Osaka Gas

This cogeneration system generates 1 kW of electricity with a small gas engine. In this system, water is heated by exhaust heat recovered from the engine and stored in a water tank. The stored hot water is used not only for hot water supply but also for space heating.

Diffusion of Household GCS

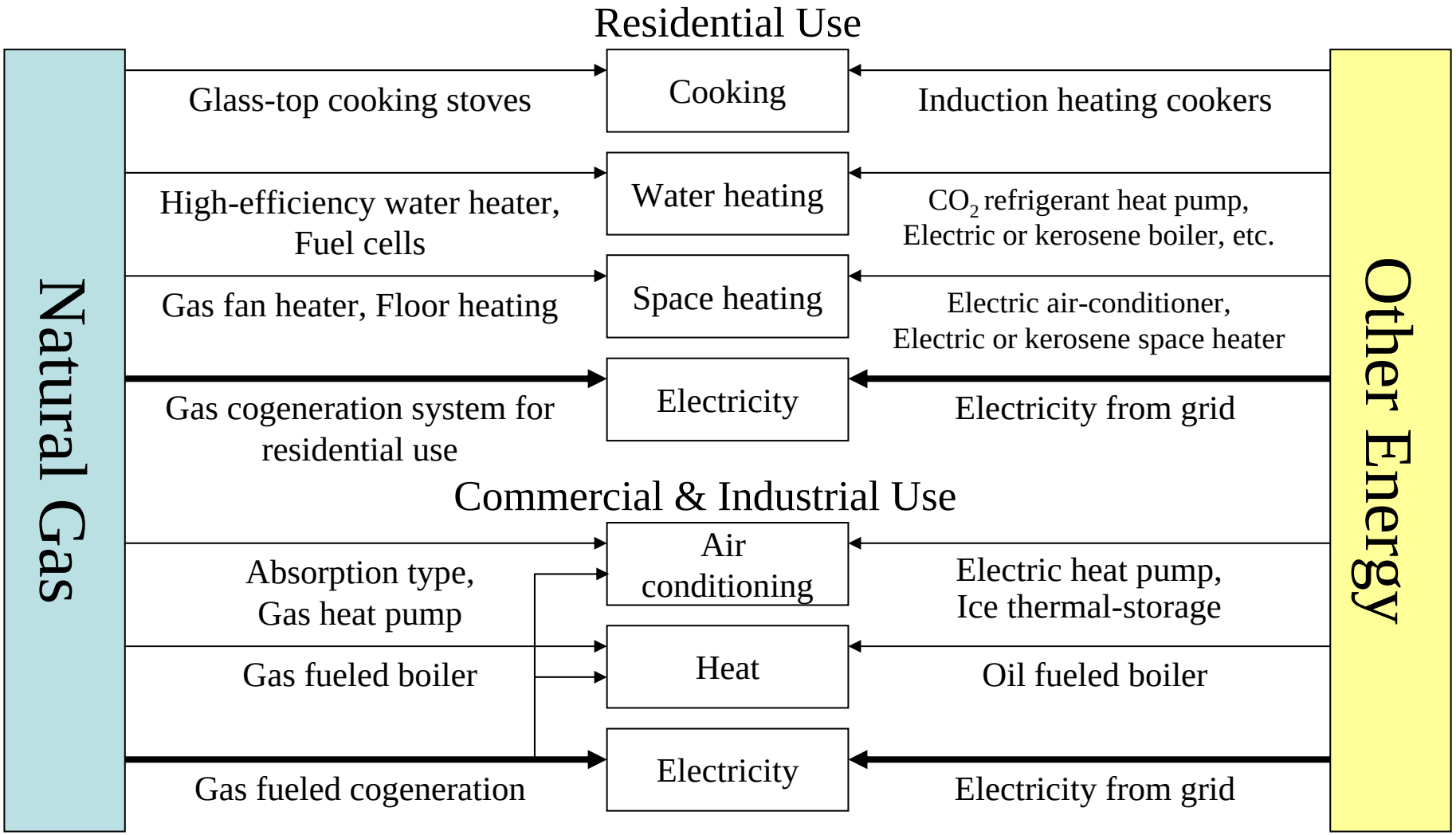


The Number of Installed GCS for Households

The Number of Gas Utilities whose Residential Customers Installed GCS

The number of households using this gas cogeneration system has increased in recent years.

Status of Inter-energy Competition



Source: Japan Gas Association

Purpose of This Study

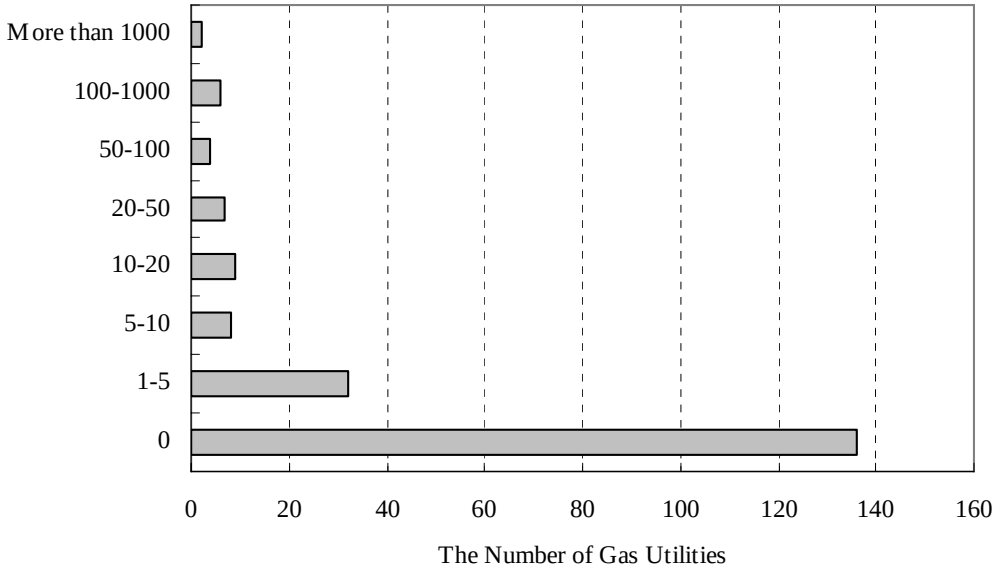
- In order to identify the major economic factors of the diffusion and to shed some light on the role of inter-energy competition, we apply a count data regression model for the total number of household gas cogeneration systems (GCS) installed from 2003–2006 in each service area of about two hundred gas utilities.
- Of particular interest to us is whether the gas price relative to electricity price has a negative impact on the number of cogeneration systems per customer; in other words, we attempt to determine whether the substitution effect between electricity and gas is observed.

Literature

- While it is evident that the substitution effect is observed among industrial customers, it is less clear whether a similar effect is observed among household customers, especially in the early days of its commercialization.
  - Earlier studies that analyzed the adoption of industrial cogeneration suggest that industrial customers are responsive to the price of fuel relative to that of electricity in their decision to adopt cogeneration.
  - Joskow and Jones (1983), Dismukes and Kleit (1995), Bonilla, et al. (2003) and Bonilla (2007)

Model

- Dependent Variable
  - The total number of household GCS installed by supply area of gas utilities from 2003 through 2006



The Distribution of the Dependent Variable

Model

- Independent Variable
  - The Number of Customers
  - Relative Price of Gas to Electricity for Residential Customers
  - Average Household Income
  - The Share of Household Gas Consumption
  - Dummy Variable for Municipally Owned Utilities
  - Dummy Variable for the Western Region
  - Dummy Variable for the Industrial/Commercial Customers with GCS
  - The Share of Newly Built Houses
  - The Share of Single-family Homes

Data and Estimation

- The data are all collected from publicly available sources

Descriptive Statistics

	Mean	Standard Deviation
ln *NCUST* (the Number of Customers)	9.374	1.485
ln *RPRICE* (Relative Price)	2.043	0.251
ln *AHINC* (Average Household Income)	1.154	0.211
PCTRSD (Share of Residential Demand)	0.566	0.212
PUBLIC (Dummy for the Publicly Owned)	0.165	0.372
WEST (Dummy for the Western Region)	0.388	0.489
CIGCS (Dummy for the C&I Cogeneration)	0.316	0.466
PCTNEW (Share of Newly-built House)	0.021	0.011
PCTSGL (Share of Single-family House)	0.582	0.116

Count Data Model

- Poisson Regression Model
  - The model assumes that the dependent variable follows a Poisson distribution with the conditional mean $\mu_i = \exp(x_i'\beta)$
  - It means that the variance equals the mean, but in many cases, this does not hold (over-dispersion).
- Negative Binomial Model
  - The model assumes that the dependent variable follows a Negative binomial distribution with the mean $\mu_i = \exp(x_i'\beta)$
  - The conditional variance is given by $Var(Y_i \mid X_i) = \mu_i(1 + \alpha\mu_i)$
  - When the dispersion parameter (alpha) is zero, it collapses to Poisson regression model

Estimated Parameters

	A	B
Constant	–12.903***	–8.828***
	(4.019)	(2.741)
ln *NCUST* (the Number of Customers)	1.260***	1.077***
	(0.175)	(0.138)
ln *RPRICE* (Relative Price)	–2.038**	–2.332**
	(1.032)	(0.964)
ln *AHINC* (Average Household Income)	1.868	1.614
	(1.198)	(0.989)
PCTRSD (Share of Residential Demand)	1.783**	2.097**
	(0.907)	(0.852)
PUBLIC (Dummy for the Publicly Owned)	–2.348***	–2.425***
	(0.561)	(0.524)
WEST (Dummy for the Western Region)	2.176	2.327***
	(0.378)	(0.366)
CIGCS (Dummy for the C&I Cogeneration)	1.342***	1.420***
	(0.508)	(0.475)
PCTNEW (Share of Newly-built House)	–12.801	
	(29.623)	
PCTSGL (Share of Single-Family House)	3.424	
	(2.420)	
(Dispersion Parameter)	3.371***	3.535***
	(0.522)	(0.538)
Log-likelihood	–392.5	–409.0
# of observation	182	206

Standard errors in parentheses.

***, **, and * are significant at the greater than 1%, 5%, and 10% levels of significance, respectively.

- The parameters of the two variables associated with residential characteristics (*PCTNEW*, *PCTSGL*) are not statistically significant (A) and we estimate the model without these variables (B).
- The dispersion parameter is statistically significant, favoring the negative binomial model over the Poisson regression model.
- The parameter on the total number of customers is very close to unity; the number of installed household GCS increases in proportion to the number of customers, holding other things constant.

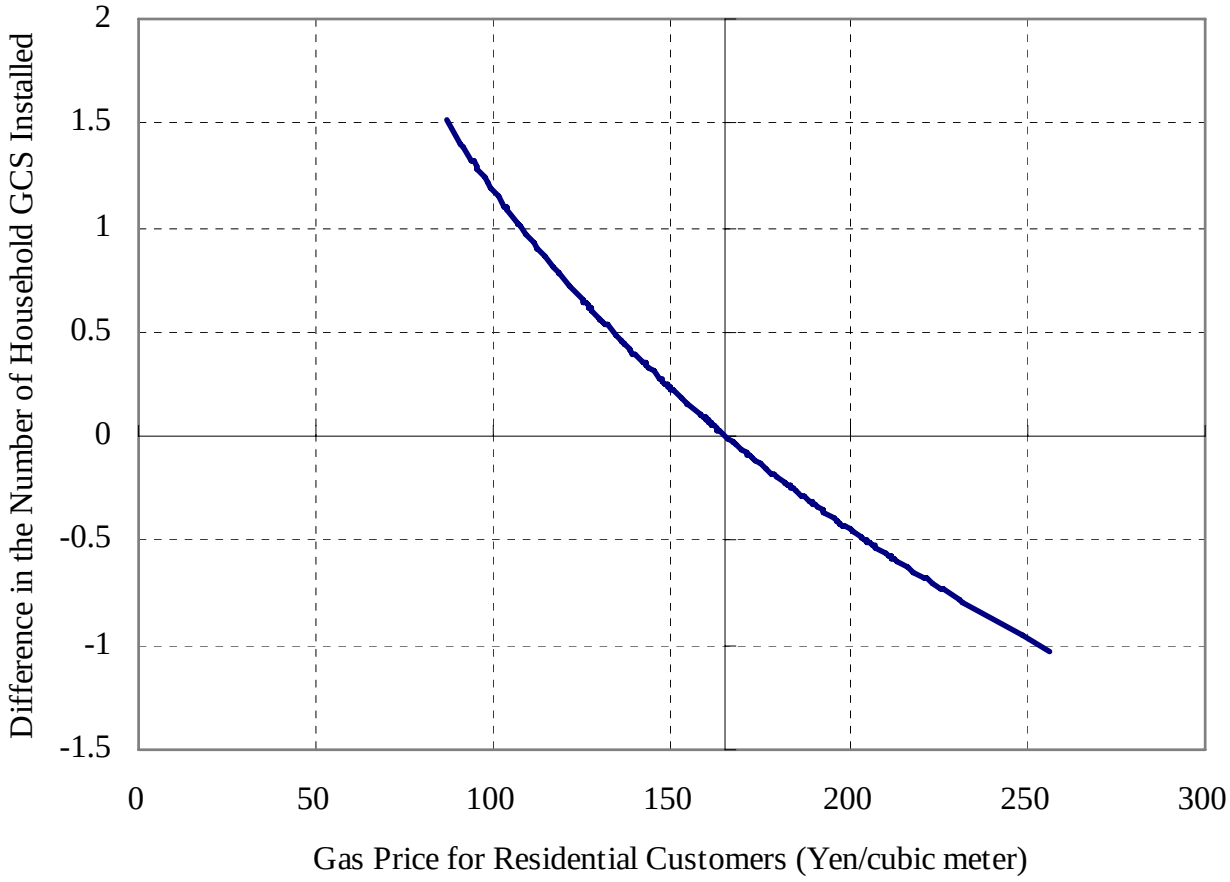
Results

- The average household income is positive as expected, but statistically insignificant.
- The share of household customers' demand is statistically significantly positive as expected.
- The municipal ownership is statistically significantly negative, suggesting a weaker incentive to promote GCS among municipally owned utilities.
- The dummy variable for the western region is statistically significantly positive, consistent with the result of an earlier study.
- The past experience with commercial and industrial cogeneration is statistically positive as expected.

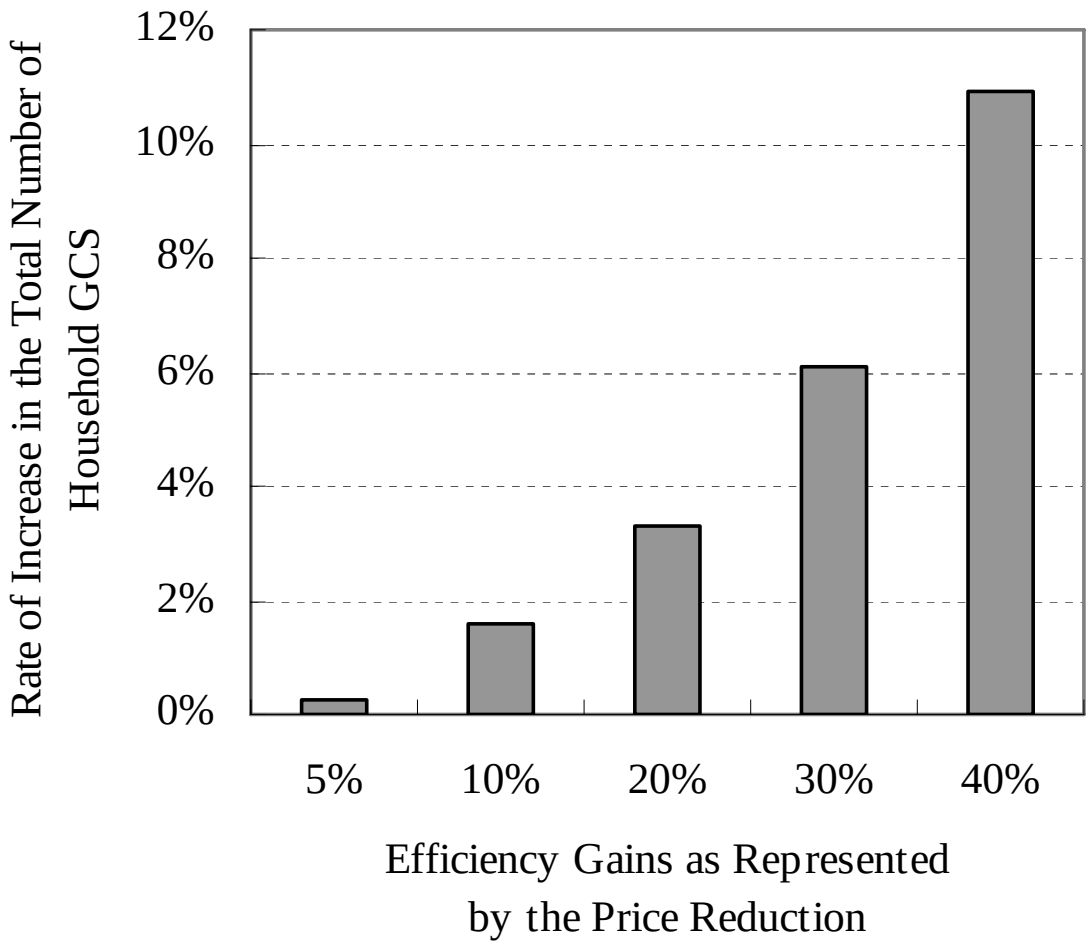
Results

- The parameter on the relative price of gas to electricity is statistically significantly negative (at the 5% level of significance), indicating that the substitution effect explains a part of the diffusion of household GCS.
- The actual price differential alone leads to a difference of 2.5 units of household GCS (at the mean).
- The efficiency gains in the industry would help accelerate the diffusion.
  - There exists a large price differential among the gas utilities; improving the efficiency in the future would be plausible.

The Simulated Impact of Gas Prices



The Simulated Impact of Efficiency Gains



Conclusion

- Our results based on the negative binomial regression model revealed that a lower price of gas relative to electricity facilitates the diffusion of household gas cogeneration systems, indicating the substitution effect between gas and electricity and the potential for inter-energy competition for household customers under regulation.
  - Since there exists a large price differential among the city gas companies, improving the efficiency of the industry would help accelerate the diffusion.
- As a future research, an econometric analysis utilizing the feature of panel data would be useful for investigating the changes over time.