Consumer Trade-off and the Diffusion of Energy Efficient Home Appliances
-The Case of Brazilian Household Refrigeration Market-

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1. Background

Concerns about threats to energy supply and global climate change have raised the importance given to energy efficiency. However, a substantial amount of literature suggests that while there are significant opportunities to reduce energy consumption cost-effectively, they are not fully put into practice (Golove and Eto, 1996). This is because energy efficiency investment is primarily a matter of individual decision making, and reflects the rationale of the decision maker. Therefore, uncovering consumers' preference towards energy efficiency is crucial in forming policies that aim to promote the efficient use of energy.

2. Objective

The objective of this study is as follows. This study attempts to estimate a multinomial logit model for the selection of household refrigerators in Brazil, using a unique set of refrigerator sales data in 2006. It assumes that consumers consider the following product attributes when making purchasing decisions: initial cost (Brazilian Reais (R$)), running cost (electricity bill, in R$/year), and internal volume (size, in liters), and selects the alternative that maximizes their utility. Scenario analysis is performed which examines the effects of potential financial incentive programs in influencing consumer choice behavior.

3. Methodology

(i) Statistical analysis

The amount of time taken for net cost (initial cost plus net running cost) of most energy efficient refrigerators (Label A) to breakeven with less efficient refrigerators are calculated by deriving a representative refrigerator of each energy efficiency class. The resulting breakeven time is calculated as follows:

$$Breakeven\ \ time = \frac{Incost_i - Incost_A}{Runcost_A - Runcost_i} \tag{1}$$

where, *Incost* denotes "initial cost", *Runcost* denotes "running cost", *A* denotes representative refrigerator of Label A, and *i* denotes representative refrigerators with Labels B, C, or D.

(ii) Consumer choice model

Given that each individual has a feasible choice set denoted by C_n, the utility function for the multinomial logit model when a consumer *n* selects an alternative *j* with an energy efficiency label *i* is:

$$U_{nij} = \beta_1 Vol_{ij} + \beta_2 Incost_{ij} + \beta_3 Runcost_{ij} + \varepsilon_{nij} \tag{2}$$

where, *Vol* indicates "internal volume", *Incost* indicates "initial cost", and *Runcost* indicates "running cost". β_1, β_2, and β_3 each indicates the coefficients.

Assuming that Eq. (2), for all $ij \in C_n$, and that all the disturbances ε_{nij} are (i) independently distributed, (ii) identically distributed, and (iii) Gumbel-distributed with a scale parameter $\beta > 0$, then the probability can be expressed as:

$$P_n(ij) = \frac{\exp(U_{nij})}{\sum_{k \in C_n} \exp(U_{nkj})} \tag{3}$$

The maximum likelihood simulation is performed to find estimators:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni} \ln P_{ni} \tag{4}$$

and the estimator is the value of β that maximizes this function.

(iii) Scenario analysis

Scenario analysis is performed to examine the effects of financial incentive programs on choice probabilities of refrigerators of each efficiency class. Two scenarios were set; one with direct subsidy given to most efficient refrigerator models (Label A) which lowers its initial cost, and the other with tax levied on least efficient refrigerator models (Label D) which raises its initial cost. Both subsidy and tax levels are analyzed at 5%, 10%, 15%, and 20%. The subsequent market shares (logit probabilities) are calculated using Eq. (2) and Eq. (3). Electricity end-use savings (GWh), CO_2 emissions reduction ($MtCO_2$), and budgetary spending needed for policy implementation is calculated to determine the magnitude of policy effects.

(iv) Data source

- For the historical series of refrigerator sales, data from Euromonitor International (2011) was used.
- The market share of refrigerators by volume and energy efficiency label, data from AC Nielsen (2006) and Vendrusculo (2009) were used.

- The specifications of each product model (volume and electricity consumption level) were derived by using data provided by INMETRO (2011).
- The respective energy efficiency class was calculated using the official equations published by the Ministry of Mines and Energy (MME).
- The price data of each product model is derived through press releases, news articles and online retailing websites.

4. Results

(i) Statistical analysis

The results show that it takes 7.3 years, 9.5 years, and 9.8 years for Label A to break-even with Label D, C, and B respectively. This is well below the average lifetime of refrigerators, which is often claimed to be 16 years (Vendrusculo, 2009). This shows that refrigerators with Label A are a cost-effective alternative in the long-run, if assuming that electricity tariff remains at the same level at the time of purchase, and that consumers use the refrigerator until the end of its product lifetime.

(ii) Consumer choice model

The derived parameter estimates show that consumers consider internal volume as the most important product attribute that influences their choice behavior. The coefficient of running cost is a positive value, which indicates that the utility derived from the product increases as running cost increases.

Table 1. Parameter estimates of MNL

Variables	Estimates (β_i)	Std.err.	P-value
Volume (β_1)	0.0033*	0.0009	0.000
Initial cost (β_2)	-0.0009*	0.0008	0.019
Running cost (β_3)	0.0019*	0.0001	0.000
Constant	0.830*	0.0983	0.000
R squared	0.389		

Figure 1 compares the actual market share and modeled estimates of refrigerators by energy efficiency label. The results show that the model predicts the actual market share fairly well, with an overall predictive quality of 78.7 percent.

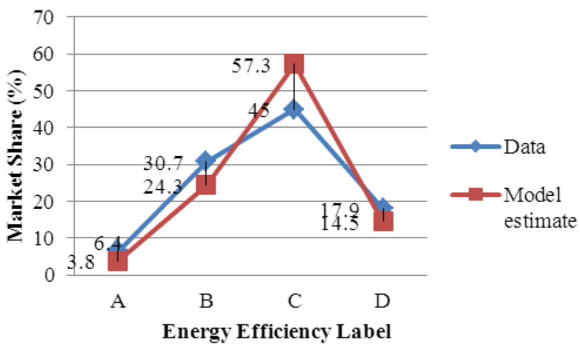

Figure 1. Model estimates of market share by label

(iii) Scenario analysis

Scenario analysis showed that financial incentive programs only have slight effects in influencing consumer choice behavior, as consumers generally place relatively little importance on initial cost, as suggested by the derived parameter estimates of consumer choice model. Tax levied on least efficient refrigerators is more effective than direct subsidies given to most efficient refrigerators, in achieving electricity end-use savings and CO_2 emissions reductions. Furthermore, as illustrated by the high welfare costs associated with direct subsidies, whether it is in the public interest to spend a significant amount of tax revenue to promote energy efficient investments is debatable.

5. Conclusions

On the basis of the results obtained, following conclusions could be drawn:

- Despite cost-effectiveness of energy efficient refrigerators, consumers prefer inefficient products, which exhibit consumers' indifference towards energy efficiency. Insufficient information and other cognitive limitations may be thought as potential explanations to this behavior.
- Therefore, further efforts in disseminating energy efficiency principles and practices through information programs seem to be a first and foremost priority, as it is unlikely that further policy instruments such as financial incentives would succeed without favorable market environment characterized by public support and understanding towards energy efficiency.

A key area of enhancements to the consumer selection model would be to introduce socio-economic and demographic characteristics in the systematic portion of the utility function. The effects of current information programs can also be assessed further by examining the changes in consumer behavior before and after policy implementation, by using data from multiple years. However, these directions for further research depend crucially on the availability of data.

6. References

[i] Euromonitor International (2011). "Refrigeration Appliance Market- Brazil"

[ii] Golove, W.H., and J.H. Eto (1996). "Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency", Berkeley, CA: Lawrence Berkeley National Laboratory, LBL-38059.

[iii] INMETRO <www.inmetro.gov.br/>

[iv] Vendrusculo, E.A., G. de Castilho Quieroz, G. de Martino Jannuzzi, and J. A. Pomilio (2009). "Life cycle cost analysis of energy efficiency design options for refrigerators in Brazil", *Energy Efficiency*. 2(3): 271-286.