CONSUMER'S ATTITUDE TOWARDS INVESTMENTS IN RESIDENTIAL ENERGY EFFICIENT APPLIANCES: HOW END-USER CHOICES CONTRIBUTE TO CHANGE FUTURE ENERGY SYSTEMS

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Overview

The proliferation of increasingly energy efficient appliances is a key strategy to address the impacts of rising residential electricity demand. To this end, governments and institutions are interested in understanding the drivers of consumer choice between conventional and environmentally friendly alternatives when purchasing new household electric appliances. This study employs empirical data from a survey conducted by the Danish Energy Agency to model the decision criteria behind Danish consumer investment in energy efficient labelled appliances. This analysis uses logistic regression over a set of socioeconomic, demographic, and behavioural variables to predict purchase propensities. Results demonstrate that housing type, quantity of inhabitants, income, age, and end-use behaviour are strong predictors for investment in energy efficient appliances. These findings are relevant for energy-related actors interested in targeting consumers in the appliance market, particularly for a relatively wealthy national context. The study concludes by integrating the predicted propensities with an energy-systems model (Balmorel) to assess the nation-wide impact in terms of electricity, emissions and economic savings.

Methods

The primary dataset analysed is the Danish Energy Agency (DEA)'s bi-annual survey, "El-model Bolig" for the year 2012. After removing the oservations with missing values, the size of the sample survey is n=1716. The primary variables of interest are of socioeconomic and demographic, chosen with the intention of predicting investment in the highest EE labelling: age, quantity of inhabitants, housing type, house size, year built, income, investments in EE appliances and other additional questions regarding profession and end-use behaviour for appliances.
All pertinent behavioural characteristics towards energy savings have been combine in a singular variable: EE index.
To prove the accuracy of our dataset with the reality, a comparison was made with the real-data reported by Statistic Denmark (DS), taken from national registries and without sampling errors. The analysis showed that the 2012 survey sampling is generally representative of Denmark.

The investigation on the consumer's behaviour towards investments in household energy efficient appliances is evaluated with a discrete choice model. If the investment is considered as a binary outcome *y*, the logistic regression model selected assumes that:

$$logit\left(P(y=1|x_{1,},\dots,x_n)\right) = \; log\frac{P(y=1|x_{1,},\dots,x_n)}{1-P(y=1|x_{1,},\dots,x_n)} = \beta_0+\beta_1X_1+\dots+\beta_nX_n$$

where *y* represents the investment binary outcome (1 = investment, 0 = no investment), X_n represents the vector of explanatory variables (e.g. age, job, income, type of house, …) and β_n the vector of unknown parameters to be estimated. The unknown parameters β_n are estimated by the logit maximum likelihood function *logit*.
Based on the model parameters $\widehat{\beta_n}$, the resulting predicted probability of investments (i.e. the probability that *y=1)*, given the characteristics of the respondent, is computed as:

$$\hat{\pi} = P(y=1|x_{1,},\dots,x_n) = \frac{\exp(\widehat{\beta_0}+\widehat{\beta_1}X_1+\dots+\widehat{\beta_n}X_n)}{1+\exp(\widehat{\beta_0}+\widehat{\beta_1}X_1+\dots+\widehat{\beta_n}X_n)}$$

The predicted joint-probability thus considers all the explanatory variables included in the model for each observation in the sample.

To complete the analysis, the predicted consumer investments are embedded into the well-known energy system model Balmorel to assess the system-wise socioeconomic impacts. The standard Balmorel model used for power generation dispatch has been extended to handle investments in EE appliances. Investing in EE appliances in a given region *r* reduces the electricity consumption for that region and in turn informs the optimal configuration of generation technologies lowering system costs.

Results

Table 1 reports the results of the multivariate regression consumer investments model. All the variables considered are statistically significant predictors after controlling for the other variables and they all positively affect the total probability of investment. For example, assuming all other variables fixed (Age = 40-49 years, housing = apartment, mean EE index, inhabitants = 2, Odds ratio of 100,000 DKK/yr vs. 200,000 DKK/yr), by increasing income 100,000 DKK, the expected odds will be 1.079 times greater (i.e.exp(0.07614)).

Table 1: Estimates of the consumer investment model

Explanatory variables	Estimate	Std. Error	z-value	p-value	Significance level
Intercept	-1.74637	0.28034	-6.229	4.68E-10	***
Income	0.07614	0.02995	2.542	0.011014	*
Farmhouse	0.69262	0.22896	3.025	0.002486	**
Single-family house	0.55598	0.14148	3.93	8.50E-05	***
Town-SD-row	0.29058	0.17268	1.683	0.092416	.
Age: 30-39 years	0.7461	0.26379	2.828	0.004679	**
Age: 40-49 years3	0.75854	0.24018	3.158	0.001587	**
Age: 50-59 years	0.7891	0.23709	3.328	0.000874	***
Age: > 60 years	0.91931	0.23722	3.875	0.000106	***
Qty-inhabitants	0.21536	0.0653	3.298	0.000974	***
EE-index	1.02148	0.31335	3.26	0.001114	**

Significance codes: 0.001 '***', 0.01 '**', 0.05 '*', 0.1 '.'

Figure 1 (left) shows the development of the expected probabilities for different levels of income. The exponential trends suggest that the higher is the income of the respondent, the higher is the probability that the same respondent will invest in more efficient household appliances. The differing levels (intercepts) of the curves illustrates the relatively much more important factor house type. Figure 1 (right) shows the electricity consumption reduction resulting from the EE investments in four representative days (one for every season) used in the simulations. The reduction profile is linked to the electricity consumption profiles of the examined home appliances and, as expected, is larger for load peak hours (morning 7:00-10:00 and evening 17:00-20:00) as well for winter weeks

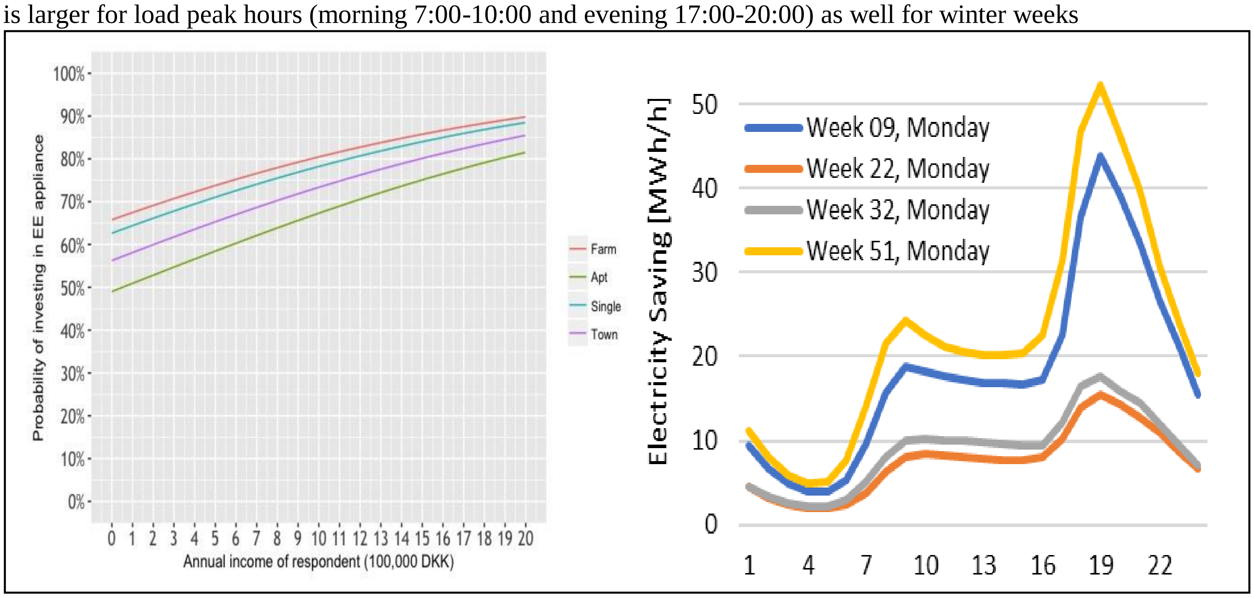

Figure 1: Predicted probability of investing in EE appliance vs. income (left) and electricity savings achieved at system level (right).

Conclusions

The reported study focused on the drivers for investments in energy efficient appliances and the estimated systems-wide consequences of this uptake. Using a logistic regression model, socioeconomic and housing characteristics were found to be highly significant when explaining investment in efficient appliances (*p-value <0.05*), with housing type the stronger of these predictors. Income was a positive predictor for EE investment although with much less influence on the total probability than other variables. The further implementation of the investment probabilities in Balmorel, provided an idea of the impact of consumer's choices in the energy system. The results lead to the conclusion that consumers' attitude towards energy savings does have an impact on the whole energy system. Energy and environmental savings corresponded to approximately 125 GWh/year and 75 Kton CO2.