10.4 Integrating Discrete Choice Experiments and Bottom-up Energy Demand Models to Investigate the Long-term Adoption of Electrical Appliances in Response to Energy Efficiency Policies

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1. Introduction

Energy-efficiency policies in the European Union (EU) are subject to ongoing critical assessments with regard to their energy-saving and distributional effects and cost-effectiveness. Ex-ante evaluations of such policies are typically performed through energy-economy models[1]. However, equally typically these modelling approaches fail to account for heterogeneity in consumer preferences across technological variants (e.g. energy label classes), socioeconomic characteristics (e.g. income levels), or countries. For example, the PRIMES model used for the EU's Reference Scenario 2016 applies a single implicit discount rate to simulate households' decisions to invest in electrical appliances across all member states and consumer types[2].

Addressing this research gap, this study integrates empirical findings on individual behaviour in adopting appliances into a bottom-up energy demand model to simulate the long-term effects of major EU energy-efficiency policies on the adoption of energy-efficient technologies. More specifically, by employing representative surveys across ca. 4,500 households in eight EU countries in combination with the bottom-up energy demand model FORECAST, we analyse the impact of minimum energy performance standards (MEPS), labelling and rebates on the diffusion of white appliances by class of energy label and on energy demand in the EU-28 until 2030. White appliances currently account for approximately 40 percent of the EU's residential electricity use[3].

2. Methodology

Our methodology has two major elements. First, demographically representative surveys were carried out in eight EU member states[1] to analyse empirically factors influencing individual decision-making and the response of households to different policy instruments. The survey included a stated-preference discrete choice experiment (DCE) on hypothetical technology adoption of refrigerators. In these DCEs, participants were asked to make a series of choices between different refrigerator-purchasing options differing by energy label, size (volume), length of warranty, ratings of customer reviews, purchase price and availability of rebates for top-rated refrigerators. In addition to the DCE, the survey included items on socio- economic characteristics, attitudes, and household characteristics, including income, family size and environmental preferences.

Second, the empirical findings from the DCE are implemented in the bottom-up vintage stock model FORECAST[4,5] to analyse the impact of households' decision-making criteria and of policy instruments on the long-term diffusion of white appliances and on energy demand. The results from estimating the DCE via mixed-logit models[6] are used to parameterise the utility functions in FORECAST. Since our specification of the mixed-logit models allowed respondent valuation of the technological attributes (e.g. energy labels) to vary by household characteristics (e.g. income levels) and countries, these utility functions account for substantial heterogeneity across consumers by household incomes, family size and environmental preferences. The logit specification of the latent utility function[7] is then used to calculate annual market shares (sales) per label class. To transfer the findings for refrigerators to other white appliances (e.g. washing machines), we assumed the implicit discount rates[8] to be the same across white appliances per country. Likewise, to transfer the findings to the twenty EU countries not included in our survey, we conducted a cluster analysis[9] based on countries' similarities in socio-economic terms.

Important exogenous factors affecting the outcomes of our policy simulations include techno-economic variables (e.g. characteristics of available technologies, electricity prices) and policy variables (e.g. design of minimum energy-performance standards). Our simulations compare a business-as-usual scenario (essentially comprising current Ecodesign and labelling legislation) with a new policies scenario (essentially, tightened MEPS combined with rebates for low-income households). In all scenarios, the framework conditions (population, electricity prices, etc.) are based on the EU Reference Scenario[2] and were kept the same.

3. Results and Findings

Findings from the DCE generally suggest that participants dislike higher purchase prices for refrigerators and like rebates, preferring appliances with better energy labels, larger volumes, longer warranties and higher customer ratings[10]. These evaluations are found to differ by household characteristics (income, household size, environmental preferences) and countries.

1 *The selected countries are France, Germany, Italy, Poland, Romania, Spain, Sweden and the United Kingdom, which together account for about 74% of the EU population[11]. In each country, participants were selected via quota sampling so as to be representative in terms of gender, age, income and regional population dispersal. The survey was administered in July and August 2018. The total sample size is n = 4557, with individual sample sizes ranging from 415 (Italy) to 599 (Sweden). Note that at the time the survey was implemented, the United Kingdom was still part of the European Union.*

Embedded in the FORECAST model, the DCE results provide an empirical basis for scenario-specific simulations of the diffusion of white appliances in the EU by 2030 in response to different policy instruments. Principal model outputs include yearly market share (sales) and stock dynamics disaggregated by appliance technology (refrigerators, freezers, washing machines, dryers, dishwashers), energy label (A+++, A++, etc., and consumer group (eight permutations of income level, family size and environmental preferences). Aggregated indicators include final energy demand and total cost of ownership (investment, maintenance, electricity costs). Figure 1 shows how different policies should affect the long-term stock development of all white appliances from 2015 to 2030. Compared with the business-as-usual scenario, stricter MEPS combined with rebates, disbursed to low-income households, can clearly boost the adoption of efficient household appliances. The former scenario is projected to entail a 20.4% (34.9 TWh) reduction in final energy demand by 2030 (compared to 2015 levels), while the latter scenario generates savings of 29.9% (51.0 TWh) in the same timeframe.

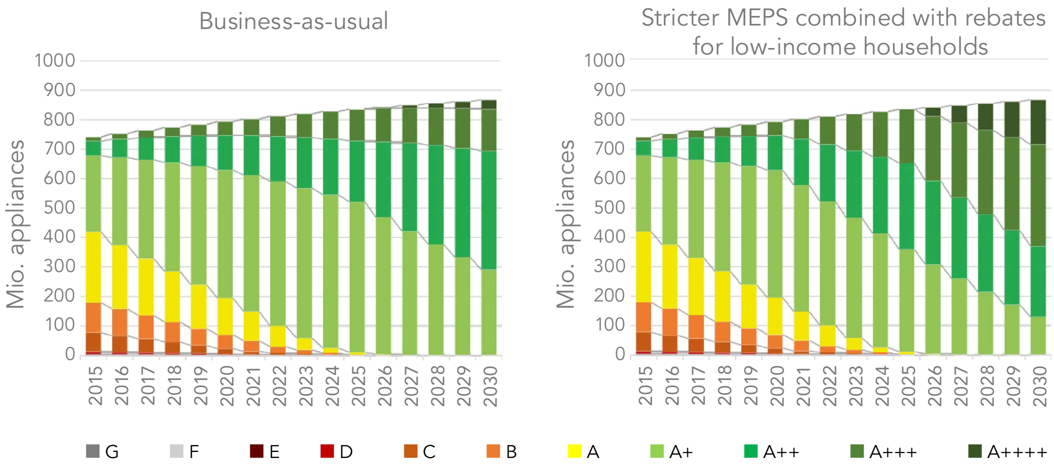

Figure 1.

Stock development of white appliances in the EU-28 by energy label, 2015–2030.

While our findings underscore the significance of the EU's Ecodesign and Labelling legislation, they also indicate unwanted distributional effects in some countries if there is stricter regulation, which should be considered when designing policy. We conclude that, by coupling empirical data on individual appliance adoption with a bottom-up energy model, our approach provides robust insights into households' responses to energy-efficiency policies and the long- term implications for energy demand.

Methodological limitations of the approach include the projection of cross-sectional survey data to future years (not accounting for prospective changes in consumer preferences), as well as the lack of consideration to direct rebound effects (i.e., consumers increasing appliance use in response to achieved cost savings). In turn, our approach illustrates the benefits of distinguishing household responses to policies (and technology features) by socio-economic group when assessing the effects of energy-efficiency policies in the residential sector. This paper can only provide a sketch of the potential applications. The empirical findings from the DCEs may also be integrated into other model types (e.g. agent-based models). Finally, future research could expand this approach to cover other end-use technologies.

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