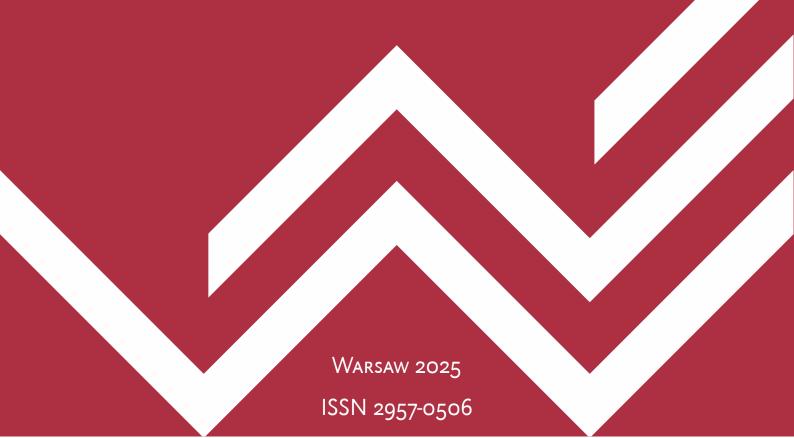


# WORKING PAPERS

No. 26/2025 (489)

# THE IMPACT OF THE NEW EU ENERGY LABEL 2021 ON ENERGY CONSUMPTION OF DOMESTIC APPLIANCE

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# The Impact of the New EU Energy Label 2021 on Energy Consumption of Domestic Appliances

Toker Doganoglu<sup>1</sup>, Lukasz Grzybowski<sup>2\*</sup>, Frank Verboven<sup>3</sup>

**Abstract:** This paper examines the impact of the 2021 revision of the EU energy labeling regulation on the energy efficiency of refrigerators sold in Belgium, France, Germany, and Poland between 2019 and 2022. We analyze detailed product-level sales data to assess whether the introduction of the new labeling system (the New EU Energy Label 2021) improved the energy performance of products available on the market. The results reveal substantial cross-country differences in sales-weighted energy consumption: Germany and Belgium exhibit significantly lower average energy use, reflecting differences in product portfolios and consumer preferences, while consumers in France and Poland tend to purchase less efficient models. After controlling for refrigerator characteristics, average energy consumption declined by 2.8% in France, 3.4% in Belgium, and 3.5% in both Germany and Poland between March 2021 and December 2022. We further estimate a nested logit demand model incorporating both energy labels and the discounted ten-year cost of electricity consumption. The results indicate that, except in Poland, consumers tend to undervalue future energy costs under both the old and new labeling regimes. The estimated willingness to pay (WTP) for labels varies across countries, with some evidence of overvaluation for specific efficiency classes. Using the model, we conduct counterfactual simulations to assess the effects of alternative policy scenarios. The simulations suggest that the 2021 reform led to measurable improvements in the average energy efficiency of refrigerators sold in the EU market.

Keywords: Energy Efficiency, EU Energy Label, Nested Logit

**JEL codes:** D12, L51, Q58

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# 1 Introduction

In response to accelerating climate change, the European Union (EU) has committed to achieving carbon neutrality by mid-century. This ambition is at the core of the European Green Deal, a acomprehensive framework of policy initiatives designed to promote cleaner energy, greater efficiency, and sustainable economic growth. A central element of this transition is improving the energy performance of products and buildings while addressing issues such as energy poverty.

Energy efficiency plays a central role in the EU's decarbonization agenda. Global estimates suggest that end-use energy efficiency alone could cut  $CO_2$  emissions by up to 35% by 2050, even amid rising global GDP. Within the EU, households accounted for approximately 26% of total final energy consumption in 2022, with 13.9% attributed to lighting and appliances, and 78.4% to space and water heating.<sup>1</sup> These figures highlight the importance of stimulating the adoption of energy-efficient technologies in the residential sector.

Two cornerstone instruments underpin the EU's approach to energy efficiency in consumer goods and industrial equipment: the Energy Labeling Regulation and the Ecodesign Directive. The former informs consumers through standardized efficiency labels, while the latter removes the least efficient products from the market by imposing minimum performance st andards. To gether, they complement long-standing building efficiency policies that have shaped Europe's energy landscape for more than four decades.

The New EU Energy Labeling Regulation, implemented in March 2021, aims to impact energy consumption, consumer choice, and environmental sustainability by addressing both the demand and supply sides. On the demand side, it seeks to make it easier for consumers to understand and compare the energy efficiency of different products, thereby improving consumer awareness by providing clear and accessible information about energy consumption. On the supply side, the Regulation is designed to encourage manufacturers to innovate and develop more energy-efficient products. Furthermore, in conjunction with the Ecodesign Directive, which establishes mandatory ecological requirements for energy-using products, it should facilitate the removal of energy-inefficient products from the market.

In this paper, we address the following questions. Did the introduction of the New Energy Label in 2021 reduce the energy consumption of household appliances sold in the EU? Does the regulation lead to sales reallocation, whereby new energy-efficient products replace less efficient one? Do energy labels help consumers account for the cost of energy use in their purchase decisions? Are there differences across EU countries, and what explains them? Finally, what would be the impact of alternative policy measures, such as banning the sale of inefficient refrigerators or implementing a feebate policy which combines a subsidy ("rebate") for energy-efficient products, and a tax ("fee") for energy-intensive ones.

<sup>&</sup>lt;sup>1</sup>Source: Eurostat.

We address these questions by analyzing changes in the annual energy consumption of refrigerators sold in four European countries—Belgium, France, Germany, and Poland—between 2019 and 2022. This period covers the introduction of the new EU energy labeling framework, established by Regulation (EU) 2017/1369 of 4 July 2017, which came into force on 1 March 2021. From that date, several product groups, including refrigerators, dishwashers, washing machines, and electronic displays, had to be sold with the new rescaled energy labels.

Our raw data reveals significant variations in the average sales-weighted energy consumption of refrigerators across these four countries, with substantially lower levels in Germany and Belgium due to differences in product portfolios and consumer purchasing b ehavior. On the contrary, consumers in France and Poland tend to purchase less energy-efficient products. We generate an energy efficiency index for each country based on a regression that accounts for a broad range of refrigerator characteristics, as well as changes in the range and quantity of models purchased in each country over time. The differences in the average level of energy efficiency across countries per sist but become smaller, indicating substantial variations in the features of products purchased in these four countries that impact their energy efficiency. The energy efficiency indices for all countries show a steady decline after March 2021. Specifically, the average energy consumption of refrigerators between March 2021 and December 2022 decreased by 2.9% in France, 4.6% in Poland, 5.1% in Germany, and 7.3% in Belgium. After controlling for refrigerator characteristics that affect energy usage, the decline was 2.8% in France, 3.4% in Belgium, and 3.5% in both Germany and Poland.

We subsequently estimate two specifications of a nested logit demand model for refrigerator purchases. The first specification in corporates the discounted cost of electricity consumption over ten years. The results indicate that consumers in France and Belgium substantially undervalue future electricity costs when purchasing refrigerators under both the old and new labeling regimes. The degree of undervaluation is less pronounced in Germany. In contrast, Polish consumers appear to overvalue electricity costs, suggesting greater awareness or sensitivity to energy expenditures.

In the second demand specification, we estimate consumers' willingness to pay (WTP) for energy labels. Consistent with the first specification, we find that in Poland, consumers substantially overpay relative to the implied ten-year energy savings, particularly for the new C and D labels as well as the top old A+++ label. In France and Germany, consumers also tend to overpay for the top new C label, while displaying only modest over- or underpayment for other labels. In Belgium, consumers slightly overpay for the top C label but underpay for most others.

Using the estimated model, we conduct three counterfactual simulations to evaluate the impact of alternative policy interventions for the final period in our dataset, December 2 022. In the first scenario, we assume that the previous labeling regulation had remained in force, assigning predicted old labels to newly introduced products where necessary. Under this counterfactual, average energy consumption would be substantially higher in Belgium (18.8%) and Germany (10.6%), moderately higher in France (2.6%), and lower in Poland by 5.8%. These differences are primarily driven by

large increases in refrigerator sales in Belgium (13.6%) and Germany (6.7%) under the old scheme. In Poland, by contrast, the model predicts a slight decline in sales under the old scheme (-1.6%) and a shift in demand toward more energy-efficient refrigerators.

Second, we simulate a ban on the sale of refrigerators with the lowest energy efficiency ratings under the new labeling system (i.e., labels F and G). To preserve product variety, refrigerators in these categories are replaced by models with label E, with corresponding adjustments to marginal costs and electricity consumption. This intervention results in substantial efficiency gains: the energy usage declines by 8.1% in France, 6.0% in Germany, 2.7% in Poland, and 0.7% in Belgium. Overall, the average energy efficiency of purchased refrigerators improves notably, although this effect is partly offset by increased refrigerator sales in all countries except Germany.

Finally, we evaluate the impact of a *feebate* scheme that subsidizes refrigerators with below-average energy use and taxes those with above-average use. The resulting energy savings are modest in countries where consumers undervalue electricity costs—amounting to 1.9% in Belgium and France and 0.3% in Germany—while in Poland, where consumers tend to overvalue operating costs, energy consumption increases slightly by 1.1%. This is due to the average energy usage of purchased refrigerators, while sales remain relatively unchanged.

Overall, the simulations reveal substantial cross-country heterogeneity in the effects of energy-efficiency labeling and related policy measures. These findings suggest that uniform EU-wide interventions may have uneven impacts. In particular, the pronounced undervaluation of electricity costs in France and Belgium warrants further investigation to better understand its behavioral and structural drivers and to design more effective, country-specific policy responses.

The remainder of the paper is organized as follows. Section 1 reviews the relevant empirical literature. Section 2.1 describes the institutional background pertinent to energy-efficiency regulations. Section 4 introduces our empirical model. Section 5 presents our empirical findings, and finally Section 7 concludes.

Related literature Our paper contributes to the following streams of literature. First, several papers estimate structural demand models to understand the adoption of energy-efficient technologies. A series of studies by Houde and various co-authors employ structural models to evaluate the effectiveness of labeling programs, minimum efficiency standards, taxes, and subsidies (Houde 2018a, 2018b; Houde and Spurlock 2015, 2016; Houde and Aldy 2017; Houde and Myers 2019). These papers exploit various policy changes and primarily quantify their effects on refrigerator sales in the United States. They rely on a transaction-level dataset from a nationwide appliance retail chain, supplemented with information from other sources. In a related study, Cohen et al. (2017) estimate a structural model of demand and supply using sales data on refrigerators in the United Kingdom from 2002 to 2007. They find that the main factor limiting the full impact of rising electricity prices on reducing refrigerator energy consumption is not consumer myopia, but

rather shifts in relative prices that favor less efficient mo dels. They also find that manufacturers respond strongly to increases in electricity prices by adjusting their product portfolios. $^2$ 

Another stream of literature is focused on estimating willingness-to-pay (WTP) for energyefficient products, which, due to the scarcity of sales data, primarily utilizes stated preference methods. For instance, Sammer and Wüstenhagen (2010) conducted face-to-face interviews with Swiss consumers shopping for washing machines, using choice-based conjoint analysis to determine the value placed on eco-labels relative to other product attributes. Their findings indicated a willingness to pay a 30% premium for energy-efficient washing machines in Switzerland. Shen and Saijo (2009) employed a hypothetical choice experiment to estimate consumers' WTP for higher energy efficiency ratings on air conditioners and refrigerators in Shanghai. They find that the WTP for more energy-efficient refrigerators was higher than that for more energyefficient air conditioners, implying that consumers have a greater incentive to pay more for appliances they use more frequently. In a related paper, Zha et al. (2020) explored consumer attitudes toward energy-efficient refrigerators and washing machines using a discrete choice experiment conducted in China in 2017. They conclude that consumers are willing to pay a premium for an improved energy-grade label on refrigerators compared to washing machines. In another paper, Galarraga et al. (2011) used a revealed preference method in the Spanish dishwasher market. They estimate consumers' WTP for the attributes represented by energy efficiency labels and conclude that 15.6% of the final price is paid for the energy efficiency attribute, which represents approximately 80 Euros of the average market price. Finally, Panzone (2013) uses data on several million transactions in the UK over two years, 2009-2011, to estimate AIDS models for refrigerators, washing machines, TVs, and light bulbs. He concludes that consumers invest in energy efficiency when expecting electricity prices to rise in the future.

There is also a growing literature on consumer inattention and misperception regarding the true cost of purchasing and operating energy-consuming products. For instance, Allcott (2013) provides survey evidence suggesting that car buyers may misunderstand key information on fuel economy labels and cannot often accurately compute lifetime fuel costs. Several other studies examine whether consumers fully internalize future fuel costs when purchasing vehicles. Allcott and Wozny (2014) use transaction-level data to estimate how fuel prices are capitalized into used vehicle prices and find evidence of partial, but not full, capitalization. Busse, Knittel, and Zettelmeyer (2013) analyze market-level variation in gasoline prices and vehicle sales, concluding that consumers respond to fuel costs but may exhibit some degree of inattention or myopia. Grigolon, Reynaert, and Verboven (2018) estimate a structural model of car demand in Europe and find that consumers significantly undervalue future fuel expenses, especially in segments with lower-income buyers.

<sup>&</sup>lt;sup>2</sup>There is also a growing body of related literature examining the impact of food packaging regulation using structural models, for example, Allais, Etilé, and Lecocq (2015) Dubois, Griffith, and O'Connell (2018), Lin, Bronnenberg, and Herpen (2020), Araya, Elberg, Noton, and Schwartz (2022), Barahona et al. (2023), Alé-Chilet and Moshary (2025).

To the best of our knowledge, no other papers have assessed the effectiveness of the New EU Energy Label 2021. In particular, no prior studies have utilized sales data spanning the period before and after the regulation's implementation in March 2021 to measure the average energy consumption of purchased refrigerators and analyze consumer purchasing behavior.

# 2 Institutional background

#### 2.1 Energy efficiency label regulations in Europe

Labeling regulations The first E U-wide E nergy L abeling R egulation w as a dopted in 1992 through the EU Directive 92/75/EC. The labeling specifications are detailed in individual implementing directives for each product type. Specifically, the first implementing directive for refrigerators and freezers was issued in January 1994 (94/2/EC) and took effect in January 1995. Each Member State was responsible for translating the directives into law and ensuring that all suppliers and dealers within their territory fulfilled their obligations. Additionally, the labeling scheme was to be supported by educational and promotional information campaigns aimed at encouraging more responsible energy use by private customers. The energy efficiency of appliances was rated in terms of energy efficiency classes from A to G, with A being the most energy-efficient and G the least. This information was also required to be included in catalogs and by internet retailers on their websites.

To keep up with advances in energy efficiency, Directive 2010/30/EU was introduced in December 2010 and required the new EU Energy Label to be displayed on all appliances from December 2011. For some product categories, the lower classes (E, F, G) were phased out due to ecodesign requirements, or they became so rare that they were no longer needed. At the same time, the "A" class was sometimes no longer enough to describe the most energy-efficient products. The directive introduced the new energy efficiency classes A+, A++, and A+++. It used pictograms instead of words, allowing manufacturers to use a single label for products sold in different countries. It also introduced the Energy Efficiency Index (EEI), an indicator of the annual power consumption relative to a reference consumption based on the storage volume and type of appliance (refrigerator or freezer). In addition, several product attributes unrelated to electricity usage were incorporated into the EEI formula. This labeling system aimed to simplify consumer understanding and com-parison of different appliances' energy efficiency. The 2010 Energy label also required the reporting of electricity consumption in kWh/annum and noise level in decibels on the label.

An update to the labeling requirements for refrigerators and freezers took effect on March 1, 2021, following Regulation (EU) 2017/1369 of July 2017. This update introduced a simpler and more informative classification system, using only the letters A to G. Under the previous 2010 EU Energy Label, the continuous improvement in appliance energy efficiency meant that many

products clustered in the top categories (A+, A++, and A+++), making them appear largely undifferentiated to c onsumers. The new regulation was therefore designed to restore meaningful distinctions in energy efficiency among products. For example, a refrigerator previously labeled A+++ could be reclassified as B, C, D, E, or even F under the new system. The core principle of the revised framework was to keep the A category initially empty and to sparsely populate the B and C categories, thereby encouraging innovation and the development of more energy-efficient technologies.

During the transition to the rescaled A–G energy labels—effective from 1 March 2021—retailers were required to replace old labels with the new ones within 14 working days, both in physical stores and online. An exception applied to products that were placed on the EU market before 1 November 2020 and discontinued by the manufacturer, especially when re-testing under new protocols was infeasible. These discontinued models could continue to be sold with the old label only until 30 November 2021, after which they were no longer permitted to be displayed or sold. The timeline of the regulation is illustrated in Figure 1.

Figure 1: Timeline of Old and New EU Labeling Regulation



Minimum ecological requirements The Eco-design Directive 2009/125/EC complements the EU Energy Labeling Regulation by setting minimum energy efficiency and environmental standards for products sold in the EU. Manufacturers must ensure compliance with these requirements, as non-conforming models are effectively banned from the market. In line with the 2021 revision of the Energy Label, the Eco-design Regulation (EU) 2019/2019 introduced stricter minimum efficiency thresholds for refrigeration appliances. These new standards, effective from March 1, 2021, led to the phase-out of the least efficient products, roughly corresponding to the former F and G classes. Together, the updated label and eco-design rules aim to promote innovation, enhance product efficiency, and enable consumers to make more sustainable choices.<sup>3</sup>

 $<sup>^3</sup>$ See Commission Regulation (EU) 2019/2019 laying down eco-design requirements for refrigerating appliances pursuant to Directive 2009/125/EC.

# 3 Data and descriptive analysis

#### 3.1 Data

The data used in this study are obtained from the GfK Market Research Database, which includes detailed product-level information on the refrigerator market in four EU countries—Belgium, France, Germany, and Poland—over the period January 2019 to December 2022. The dataset covers both sales volumes and prices, along with a rich set of product characteristics, and distinguishes between two distribution channels: traditional (brick-and-mortar) and online retail. The data are collected from a comprehensive sample of retailers, representing approximately 87% of total refrigerator sales in these countries. Although GfK does not release retailer-level information, the extensive product-level panel structure makes the dataset particularly well-suited for analyzing market outcomes and consumer responses to changes in labeling and energy efficiency regulations.

Each refrigerator or "product" is described by two identifiers: (i) the brand, such as Samsung or Bosch; (ii) the model, such as RB3EJ5200SA/EF or BRB26600FWW/EF in the case of Samsung. An observation in our panel dataset is thus a product (brand and model), distribution channel (traditional or online), country, and period (month). The majority of products belong to well-known brands, including Samsung, Siemens, Miele, LG, Whirlpool, and Bosch. The initial data set includes 713,118 observations for Belgium (122,047), France (190,586), Germany (277,763), and Poland (122,722). The monthly sales of refrigerators, measured in units per 1,000 inhabitants in the four countries, are shown in Figure B.1 in the Appendix.

The dataset is processed as follows. First, we drop observations with missing or zero sales, so-called trade brands, and duplicate records. These observations are excluded primarily due to missing information on energy labels and energy consumption. Next, we exclude observations with missing data or outliers in prices, annual energy usage, and refrigerator dimensions. After this step, the dataset is reduced to 632,577 observations: 113,119 for Belgium, 164,148 for France, 241,429 for Germany, and 113,881 for Poland. In terms of sales coverage, we retain 84.8% of total sales for Belgium, 64.2% for France, 88.6% for Germany, and 99.9% for Poland. This indicates that trade brands account for a substantial share of total sales in France, while they are virtually absent in Poland.

We aggregate online and offline sales for identical products by country and month, which substantially reduces the number of observations relative to the raw data. The final dataset used for the reduced-form energy regressions includes 17,925 unique refrigerator models sold across the four countries, yielding a total of 412,621 product–country–month observations: Belgium (80,625), France (107,518), Germany (158,800), and Poland (65,678).

**Product categories and aggregation:** Following the data structure, we classify refrigerators into two main types: built-in and freestanding. Built-in refrigerators are further divided into three

groups: (1) single-door models up to 90 cm; (2) single-door models over 90 cm; and (3) double-door models with a top or bottom freezer. Freestanding refrigerators follow the same three-group classification, with two additional categories: (4) models with three or more doors and (5) side-by-side refrigerators. Next, we aggregate products that share the same old and new energy labels and belong to the same brand and main product category defined above. Many products sold by the same manufacturer differ only marginally in characteristics and account for very small sales volumes, resulting in negligible market shares in each period. This justifies the aggregation, whose purpose is to group highly similar products and reduce the number of unique items in the dataset, thereby avoiding complications in estimating plausible substitution patterns.

We discuss the energy labeling regulation in more detail in Section 2.1, while the procedure for assigning old and new energy labels is described in Appendix A.1. In brief, the old energy labels ranged from D, C, B, A, A+, A++, to A+++, whereas the new energy labels range from G, F, E, D, C, B, to A. In our analysis, we exclude products with infrequently observed labels—specifically, the least efficient old labels (A, B, C, and D) and the most efficient new labels (A and B).

After aggregation and further data cleaning—specifically, removing products and brands with very low sales—we obtain a final dataset comprising 5,932 unique products sold across four countries during the study period. Table 1 presents the distribution of unique products across these categories. The corresponding number of observations is: Belgium (25,953), France (29,710), Germany (40,325), and Poland (17,921).

Main Type	Built-in	Freestanding	Total
1 door 81-90 cm	464	510	974
1  door > 90  cm	790	489	$1,\!279$
2 doors freezer bottom (and top)	811	1,573	2,384
2 doors freezer top	0	512	512
3+ doors	0	333	333
Side-by-side	0	450	450
Total	2,065	3,867	5,932

Table 1: Refrigerator types (unique products in the sample)

Figure 2 illustrates the changes in average sales-weighted prices in Euros PPP and refrigerator sizes over time in the countries considered.<sup>4</sup> Prices exhibit seasonal fluctuations and an upward trend, with the increase accelerating toward the end of the period, which is due to higher inflation rates. The size of sold refrigerators also shows seasonal variations and a clear upward trend, particularly in Germany, which impacts the average energy consumption.

<sup>&</sup>lt;sup>4</sup>Nominal prices in euros are the lowest in Poland and are rescaled by dividing them by the PPP factor, which ranges between 0.591 and 0.616.

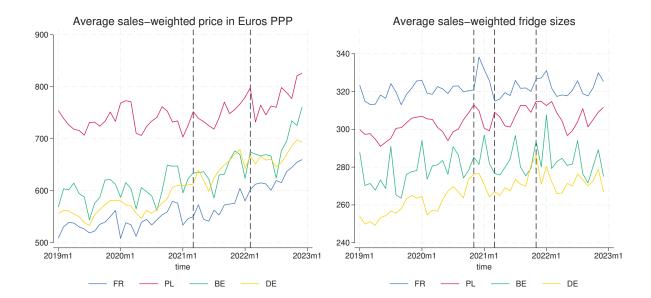


Figure 2: Average sales-weighted price and fridge size

#### 3.2 Energy usage and labels

A key characteristic of refrigerators is their annual energy consumption (kWh), displayed on the EU Energy Label together with the corresponding energy efficiency class. Depending on the timing of product introduction, the GfK database contains varying information: some models report both old and new energy consumption values, while others include only one of these measures. The same applies to the associated efficiency labels.

To ensure consistency, we construct harmonized measures of energy usage based on the sales period and data availability. When new energy consumption values are available, we use the new value; when these are missing, we rely on the old measure. For the remaining few cases with missing old and new data (1,698 observations before aggregation), energy consumption is imputed using information from the European Product Registry for Energy Labelling (EPREL)—an EU-wide online platform providing detailed, product-level information on the energy performance of appliances sold in the European Union.<sup>5</sup> Because the methodologies for measuring energy consumption differ between the old and new labeling schemes, these differences may influence the observed average energy efficiency of refrigerators sold during the transition period.

Figure 3 presents sales-weighted annual energy consumption between January 2019 and December 2022 relative to Germany in January 2019. In all four countries in our data, there was

<sup>&</sup>lt;sup>5</sup>Manufacturers and importers are legally required to register their products in EPREL before sale, making it a comprehensive reference source for regulated product categories, including refrigerators, washing machines, air conditioners, televisions, and lighting equipment. However, EPREL cannot serve as the primary data source for energy usage in our study because product identifiers differ substantially between the GfK and EPREL databases, and many products sold in earlier years of our sample are not covered in EPREL.

a decline in the average energy consumption of purchased products after March 2021. In particular, comparing the average energy consumption in March 2021 with that in the last period of the data, December 2022, there was a decline of 2.9% in France, 4.6% in Poland, 5.1% in Germany, and 7.3% in Belgium.

However, the sales-weighted annual energy consumption does not capture changes in the product range and characteristics over time. To address this, we use a regression framework that accounts for the impact of refrigerator attributes on annual energy consumption (kWh per year), while also controlling for differences in the portfolio of products s old. Specifically, we estimate the following hedonic model specification:

$$\log(y_{it}) = \alpha + X_{it}\beta + \delta_t d_t \mathbf{1}(k=t) + u_{it}, \tag{1}$$

where  $\log(y_{it})$  denotes the logarithm of the annual energy consumption of refrigerator i available in month t.<sup>6</sup> The error term is denoted by  $u_{it}$  and the vector  $X_{it}$  accounts for the following refrigerator characteristics.

First, we include dummy variables to indicate the main types of refrigerators, distinguishing between single-door models up to 80 cm, those between 81–90 cm, and those above 90 cm in height. We also differentiate between double-door refrigerators with the freezer located either at the top or bottom, as well as three-door and side-by-side models. These categorical variables are interacted with the logarithms of refrigerator dimensions—namely depth, width, height, and total capacity in litres—to allow for a flexible functional form that captures the effect of size on energy consumption.

Furthermore, the characteristics include information on whether the refrigerator is freestanding or built-in, as well as the type of front decoration, distinguishing between materials such as stainless steel and other decorative panels. The cooling system is another crucial determinant, capturing the presence of no-frost technology, which can be either partial or full, along with the type of cooling mechanism, including ventilated air circulation, inverter motors, and the presence of an additional cooling compressor. Features related to temperature regulation, such as separate temperature control and the inclusion of a chiller zone, are also accounted for.

Next, we control for convenience-related attributes, particularly water and ice dispensing functionalities. These include the presence of a water dispenser, a water container, a direct water connection, an ice cube dispenser, and a crushed ice function. Additional features such as the number of drawers, the presence of a digital display, smart connectivity, LED lighting, and the mounting mechanism (either door-mounted or sliding) are included in the specification.

The estimated coefficients  $\delta_t$  of the monthly dummy variables  $d_t \mathbf{1}(k=t)$  represent the qualityadjusted energy consumption index over time. The vector of coefficients  $\gamma = (\alpha, \beta, \delta)$  is estimated

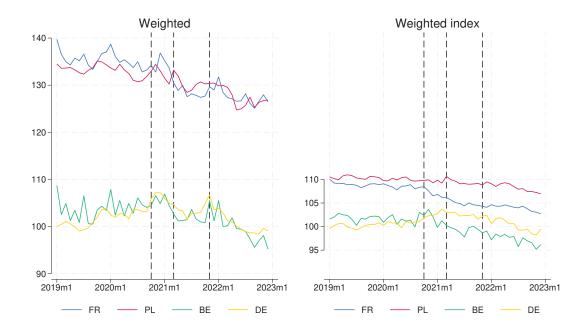
<sup>&</sup>lt;sup>6</sup>As a robustness check, we also estimate the model without taking logarithms, which yields a similar quality-adjusted energy consumption index.

using ordinary least squares (OLS), with sales in a given month used as weights.

The estimation results for the logarithm of annual energy consumption are reported in Table B.1 in the Appendix. The refrigerator's physical dimensions—width, depth, height, and total capacity in liters—interacted with the main refrigerator-type dummy variables, emerge as the most significant determinants of energy usage. In addition, several other product features included as dummy variables exert a notable influence on energy consumption. These include whether the appliance is built-in or freestanding, the location of the freezer compartment, and additional functionalities such as ice cube dispensers, chiller zones, ventilated air circulation, digital displays, smart connectivity, and no-frost technology.

The quality-adjusted annual energy consumption index is presented in Figure 3, illustrating changes in the average energy consumption of refrigerators sold each month across the four countries in our analysis between January 2019 and December 2022, after controlling for product portfolios and their attributes. Between March 2021 and December 2022, after adjusting for refrigerator characteristics that impact energy consumption, the decline was 2.8% in France, 3.4% in Belgium, and 3.5% in both Germany and Poland.

Figure 3: Average and quality-adjusted annual energy consumption (weighted by sales)



Based on these results, we conclude that the introduction of new energy labels had a significant but modest impact on the average energy efficiency of products sold in these four countries between March 2021 and December 2022. While controlling for refrigerator characteristics reduces cross-country differences, it does not significantly alter the overall trend over time. This finding highlights

the need for further investigation using a structural model of demand and supply, which we discuss in the next section.

Old and New Energy Labels For some products with old energy labels, sales were still recorded after March 2021, and no information on the new energy labels was available in the data. This may be because these products continued to be sold with old labels even after the regulation was introduced in March 2021, as discussed in Section 2.1. For such products without new labels, we predicted the missing labels using product characteristics and a random forest algorithm. The algorithm achieved a 99% prediction accuracy for cases where both old and new labels were known. Consequently, all products sold after March 2021 are assigned a new label in the data. Figure 4 illustrates the transition from old to new energy labels after infrequent labels were excluded.

There are notable differences across countries in the sales of products with different labels. Germany had the highest sales of products with the old A+++ and A++ labels, which are replaced by products with the new E, D, and C labels. Sales of the A+++ and A++ refrigerators in Belgium, while lower than in Germany, are higher than in France and Poland. The shift to the new E, D, and C labels is proceeding at a slower pace in Belgium compared to Germany, yet more rapidly than in Poland and France. Poland is positioned third in terms of the proportion of products with the old A+++ and A++ labels and is similarly ranked in the transition to the new E, D, and C labels. France is lagging in the transition, which may be, however, because we lost a greater share of sales than in other countries by dropping trade brands, as discussed above.

#### 4 Structural Model

We first present the demand model, specifying how consumers choose among a wide range of differentiated refrigerators (Subsection 4.1). Next, we discuss the oligopolistic supply side, where marginal costs depend on several relevant product characteristics (Subsection 4.2). Both parts are essential to perform our subsequent policy counterfactuals.

#### 4.1 Demand

Overview As discussed above, consumers primarily base their refrigerator purchase decisions on the purchase price and on the associated electricity costs. In practice, consumers may not be fully aware of the electricity costs associated with a particular refrigerator, and may instead be guided to some extent by the energy labels, i.e., the old labels before March 1, 2021, and the new labels afterwards (see Figure 4 above). We could, in principle, specify consumer utility to depend on both the energy label and the electricity costs. In practice, distinguishing between them is difficult, and we instead consider two utility specifications that have distinct advantages and disadvantages. In our *labels* specification, a consumer's utility from a refrigerator depends on

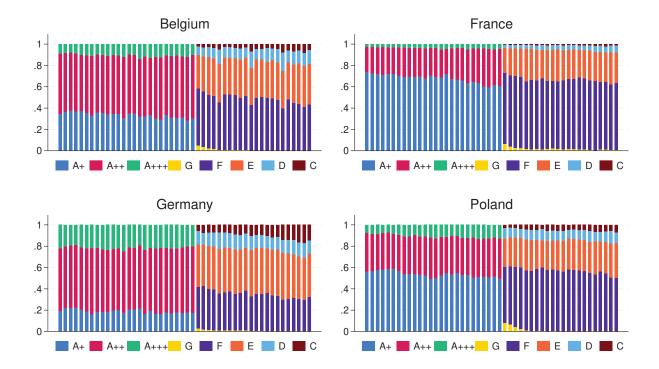


Figure 4: Old and new energy labels between January 2019 and December 2022

the energy label but not on the electricity costs. The idea of this specification is that a consumer uses the energy label directly as a proxy for the expected electricity costs. In our electricity cost specification, a refrigerator's utility does not directly depend on its energy label. Instead, it depends on the expected electricity costs associated with the label, computed from the portfolio of products available in each country and period. This specification is less flexible than the labels specification, but enables us to more directly estimate the extent of electricity cost undervaluation and conduct additional welfare analysis.

In addition to price and energy costs, consumer choices are influenced by other product characteristics. Furthermore, they are shaped by kitchen design and space constraints, implying limited or no substitution across the main refrigerator types. As discussed earlier, we classify refrigerators into two broad categories, built-in and freestanding, without any possibility of substitution. Based on dimensions, we include three nests for built-in refrigerators and six nests for freestanding refrigerators. This nesting structure captures a (potentially) stronger degree of substitution within than between nests.

**Utility** More formally, the nested logit choice model can be described as follows. A market is defined by country c, product category m (frestanding or built-in), and period t. In each market and period, there are  $M_{cmt}$  potential consumers. For brevity, we omit the period and category subscripts

in what follows. Each consumer i in country c chooses among  $J_c$  differentiated refrigerator models  $(j = 1, ..., J_c)$  or the outside good (j = 0). The choice set is divided into nests g, as defined above. The indirect utility of consumer i in country c from choosing product j is specified as:

$$u_{ijc} = \underbrace{x_{jc}\beta_c - \alpha_c p_{jc} - \alpha_c \gamma_c G_{lc} + \lambda_{lc} + \xi_{jc}}_{\delta_{jc}} + \zeta_{igc} + (1 - \sigma)\varepsilon_{ijc}, \tag{2}$$

where  $\delta_{jc}$  is the mean utility for product j in country c,  $\zeta_{igc}$  represents a group-specific valuation common to all products within the same group g, and  $\varepsilon_{ijc}$  is an individual-specific valuation for product j, assumed to be an i.i.d. extreme value. The nesting parameter  $\sigma \in (0,1)$  captures the degree of preference correlation among products within the same group and takes values. A higher  $\sigma$  indicates stronger substitution between products in the same group. If  $\sigma = 0$ , a simple logit model obtains without preference correlation for products in the same nests.

The mean utility of the outside good 0 is normalized to zero, i.e.,  $\delta_{0c} = 0$ . The mean utility of the refrigerator models  $j = 1, \dots, J_c$ ,  $\delta_{jc}$ , depends on a vector of product characteristics  $x_{jc}$  of model j sold in country c, such as size, various options and brand effects, and on the price  $p_{jc}$  of the product j in country c. It also depends on either the expected electricity costs associated with label l in country c of product j,  $G_{lc}$ , or on a fixed effect for label  $\lambda_{lc}$ . Finally,  $\xi_{jc}$  is an unobserved quality term specific to the country c and product j.

In our labels specification, we restrict  $\gamma_c$  to be zero, thus omitting the term  $G_{lc}$  and estimate the fixed effects  $\lambda_{lc}$  for each label in each country. Note that this separately includes old labels (for the period before March 1, 2021) and new labels (for the subsequent period). With this flexible specification, we can estimate, in each country, the willingness to pay (WTP) for both old and new labels relative to the lowest label in each system, by dividing the fixed effects by the price coefficient  $\alpha_c$ , i.e.,  $\lambda_{lc}/\alpha_c$ . On this basis, we assess whether consumers over- or underestimate the value of labels compared to the actual savings in electricity costs over a 10–15 year horizon. However, since these estimates are relative, the interpretation also depends on consumer valuation of the base categories.

Conversely, in the electricity cost specification, we restrict  $\lambda_{lc}$  to be zero, thus omitting the label fixed effects and estimate a valuation coefficient  $\gamma_c$  for the present value of the expected electricity cost  $G_{lc}$  throughout a refrigerator's life, where  $\gamma_c < 1$  refers to undervaluation and  $\gamma_c > 1$  refers to overvaluation. To measure  $G_{lc}$ , we start from a model j's annual electricity usage (in kWh),  $e_{jc}$ , and make the following assumptions. First, consumers are not aware of a model's electricity usage, but they still have an awareness of average electricity usage at the level of the label l,  $e_{lc}$ , as they interpret labels as signals of relative energy usage. Second, consumers keep the refrigerator turned on throughout the entire year and use it for S = 10 years. Third, electricity prices follow a random walk, so the expected electricity price per kWh at time s is equal to the current price,

i.e.,  $\mathbb{E}(g_s) = g$ . Finally, the annual interest rate is r. The present value of expected future electricity costs is then

$$G_{lc} = \rho g e_{lc}$$

where  $\rho = (1/r) \cdot (1 - (1+r)^{-S})$  is a capitalization coefficient (e.g.,  $\rho = S$  as  $r \to 0$ ).

The labels specification is more flexible because it includes a fixed effect for each old and new label (relative to a base) and for each country, amounting to a total of 6 effects over 4 countries. The electricity cost specification puts more structure, by estimating 2 undervaluation coefficients for each country, before and after the regulation. Although this is somewhat more restrictive, it also creates a more solid basis in some of the policy counterfactuals. As such, the two approaches provide complementary insights.

**Estimation** Assuming consumers choose the product that provides the highest utility results in an aggregate market share system for each product. The market share system can be inverted to obtain the following estimating equation (Berry, 1994).

Labels specification:

$$\ln s_{jc}/s_{0c} = x_{jc}\beta_c - \alpha_c p_{jc} + \lambda_{lc} + \sigma \ln s_{j|qc} + \xi_{jc},$$

Electricity cost specification:

$$\ln s_{jc}/s_{0c} = x_{jc}\beta_c - \alpha_c p_{jc} - \alpha_c \gamma_c G_{lc} + \sigma \ln s_{j|qc} + \xi_{jc},$$

where  $s_{jc} = q_{jc}/M_c$  is the market share of product j (sales volume divided by the potential market size  $M_c$  in country c),  $s_{0c}$  is the market share of the outside good, and  $s_{j|gc}$  is the market share of product j within group g.

The demand model enables the computation of consumer surplus and price elasticities. The elasticity of demand for product j with respect to the price of product k is given by:

$$\frac{\partial s_j}{\partial p_k} \frac{p_k}{s_j} = -\alpha_c \left( \frac{1}{1 - \sigma} D_{jk} - \frac{\sigma}{1 - \sigma} s_{j|g} D_{jk}^g - s_j \right) p_j, \tag{3}$$

where  $D_{jk} = 1$  if j = k (own-price elasticity) and  $D_{jk}^g = 1$  if j and k belong to the same group (cross-price elasticity within the same group). Products in the same group have higher cross-price elasticities than those in different groups. This model allows us to estimate substitution patterns within product categories (e.g., freestanding side-by-side refrigerators) and assess how price and

<sup>&</sup>lt;sup>7</sup>This specification follows a similar one used in the automobile demand literature, such as Allcott and Wozny (2014) and Grigolon, Reynaert, and Verboven (2018). A key simplifying feature in our setting is that annual usage is constant across consumers (as a refrigerator is constantly used), whereas in automobile demand, consumers differ in their annual mileage.

product characteristics affect demand. Additionally, it provides insights into consumer preferences and market dynamics in the four countries.

The demand equation is estimated using instrumental variables (IV) to account for the endogeneity of the price variable  $p_{jc}$  and the within-group market shares  $s_{j|gc}$ , both of which may be positively correlated with the error term. A positive unobserved demand shock for a given product increases its within-group market share and simultaneously raises its price. As instruments, we use the variables suggested by BLP 1995): sums of characteristics and counts of the number of products across all of the firm's other products and across all competing firms' products in the same market (defined by period and country). These instruments are constructed for a wide range of observable characteristics, such as product size, noise level, star rating, design features, and technical specifications. According to a Hausman specification test, the null hypothesis of exogeneity of prices and within-group market shares is rejected at the 1% significance level.

#### 4.2 Supply

We assume multi-product Bertrand price-setting firms to infer marginal costs and current economic profits, and to perform policy counterfactuals. For simplicity, we now also remove the country subscript c. Let  $F_f$  be the set of products sold by firm f. The profits of firm f are given by:

$$\Pi_f(p) = \sum_{k \in F_f} (p_k - c_k) s_k(p) M \tag{4}$$

where  $c_k$  is the constant marginal cost of product k in country c, and  $s_k(p)$  is product k's market share in country c as a function of the price vector in country c. The first-order conditions that define the Bertrand-Nash equilibrium are given by:

$$s_j(p) + \sum_{k \in F_f} (p_k - c_k) \frac{\partial s_k(p)}{\partial p_j} = 0$$
 (5)

for products j = 1, ..., J. This can be written in vector notation as:

$$s(p) + (\theta^F \odot \Delta(p))(p - c) = 0 \tag{6}$$

where p and s(p) are  $J \times 1$  price and market share vectors,  $\Delta(p) \equiv \frac{\partial q(p)}{\partial p'}$  is a  $J \times J$  matrix of ownand cross-price derivatives,  $\theta^F$  is a  $J \times J$  block-diagonal matrix, with ones for products of the same firm and zeros otherwise, and  $\odot$  denotes element-by-element multiplication of two matrices.

The system of first-order conditions (6) can be inverted at the current price and market shares to back out the current marginal costs  $c^0$ :

$$c^0 = p + (\theta^F \odot \Delta)^{-1} s \tag{7}$$

For our policy counterfactuals, it is useful to know how the backed-out marginal costs depend on product characteristics. We specify the marginal cost of product j as:

$$\ln c_j^0 = w_j \delta + \mu_l + \omega_{jc},$$

where  $w_j$  is a vector of characteristics that may affect marginal costs and  $\mu_l$  are label-specific marginal costs.

Counterfactuals After recovering marginal costs and estimating marginal cost parameters, the system of first-order conditions can be used to perform counterfactual policy scenarios. Intuitively, a new policy may consist of a demand and/or a cost shock, which will result in a new price equilibrium and affect sales, profits as given by (4), consumer surplus, and other outcomes. Formally, this amounts to solving the system of equations (6) to compute the new equilibrium price vector  $p^1$  after a policy-induced demand or cost shock. One can then, in turn, compute the new equilibrium sales  $s^1M$ , and other outcomes.

More specifically, we consider three policy counterfactuals. The first counterfactual evaluates the impact of the new labeling regulation by evaluating what outcome would have prevailed if the old labels had remained in place. The second counterfactual aims to evaluate the impact of a ban on the lowest efficiency labels F and G. One approach would be to eliminate all products with F and G labels. However, this would also reduce product variety, and therefore does not capture the pure impact of a ban very well. To keep variety constant, we therefore evaluate the impact of mandating all refrigerators with F and G label to become an E label. This constitutes both a change in the mean valuation and in the marginal cost of production for the affected labels, with an impact on equilibrium prices and other outcomes.

The third counterfactual evaluates the impact of a subsidy on refrigerators based on a label's average energy usage. Although this approach is simple, it creates two difficulties. First, it raises government expenditures. Second, although it shifts demand towards better labels, it also raises overall demand, so that overall energy consumption may increase in response to the subsidy. To address both issues, we instead evaluate the impact of *feebates* as implemented in the automobile sector in several countries. See, for example, Adamou et al. (2014) and Durrmeyer and Samano (2017). A *feebate* essentially consists of a combination of a subsidy ("rebate") for energy-efficient products, and a tax ("fee") for energy-intensive ones.

More specifically, consider the following *feebate* scheme:

$$t_{lc} = \tau \left( G_{lc} - \tilde{G}_c \right), \tag{8}$$

where  $\tau$  is the *feebate* rate per unit of electricity cost, and  $\tilde{G}$  is the pivot point. Products with energy costs above  $\tilde{G}$  are taxed, while those with costs below  $\bar{G}$  receive a subsidy. In practice, the

feebates then amount to subsidizing the good labels and taxing the bad labels at the same rate.<sup>8</sup>

Implementing the feebate scheme amounts to setting the feebate rate  $\tau$  and the pivot point  $\tilde{G}$ . The feebate rate can be a Pigouvian tax that corrects for two market failures that are responsible for excessive demand for energy-intensive products: an externality associated with the social costs from energy emissions and an internality associated with the undervaluation of private electricity costs. The Pigouvian feebate rate would then be equal to  $\tau_c = \psi + 1 - \gamma_c$ , where  $\psi$  is the standard emission externality and  $1 - \gamma_c$  reflects the part of the electricity cost that consumers fail to take into account ("belief error").<sup>9</sup> Our counterfactual analysis will take a conservative approach by setting  $\tau_c = 1 - \gamma_c$ . We thereby abstract from the unpriced external costs and account only for the undervaluation of private energy costs. Given this feebate rate, we set the pivot point such that the net subsidy amount is close to zero.

Using these different policy scenarios and the corresponding sales of refrigerators by type, we can calculate the changes in the average energy consumption of refrigerators in each country and evaluate the trade-off between the loss of consumer surplus due to a limited choice set and higher prices, and increased energy efficiency when the least efficient products are removed from the market.

## 5 Empirical Results

We begin by discussing the estimates from our two nested logit demand specifications. We then interpret what the estimated coefficients for energy labels and electricity costs imply about consumers' valuation of energy savings. Finally, we present the results of the marginal cost and energy usage regressions.

The first specification, referred to as the *labels specification*, includes fixed effects for the old and new energy labels, defined relative to a base category within each labeling system. This model excludes the average cost of electricity, which is inherently correlated with the labels. Here, consumers are assumed to interpret the labels as qualitative indicators of energy efficiency rather than translating them directly into quantitative cost implications.

The second specification, the *e lectricity c ost s pecification*, excludes the label fixed effects and instead incorporates the average electricity cost associated with each label. In this case, consumers are assumed to respond directly to expected electricity costs, which are proxied by the average electricity expenses corresponding to the respective label categories.

<sup>&</sup>lt;sup>8</sup>This formula is based on the average electricity cost per label,  $G_{lc}$ , but a more precise approach would apply it at the product level, using actual electricity costs  $G_j$  instead of  $G_{lc}$ .

<sup>&</sup>lt;sup>9</sup>For taxing internalities see, for example, Allcott (2013) and Grigolon et al. (2018).

#### 5.1 Demand estimates

Table 2 reports the estimates for the parameters that are allowed to vary across countries. The signs and magnitudes of the coefficients are intuitive and broadly consistent with expectations. The price coefficient,  $\alpha$ , is negative and statistically significant in all countries, and slightly larger in absolute value in Belgium and France than in Germany and Poland. Consumers in all markets prefer larger refrigerators (measured in litres), although the strength of this preference differs across countries, consistent with the descriptive patterns shown in Figure 2. French consumers exhibit the strongest preference for larger refrigerators, followed by Belgian consumers, while preferences are noticeably weaker in Poland and Germany. These cross-country differences may reflect cultural and economic factors, such as average household size, available living space, and shopping frequency.

Country-specific brand effects are also included in the model but omitted from the table for brevity. These effects are statistically significant and heterogeneous across countries, highlighting the importance of domestic brand reputations. Monthly time dummies capture seasonal fluctuations in demand, while country-specific trends indicate that market dynamics evolve differently across countries.

Table B.2 in the Appendix shows the estimation results for the parameters that are common across the four countries, as they are not major sources of cross-country heterogeneity in consumer preferences. In both the labels and the electricity cost specifications, the nesting parameter  $\sigma$  is large and significant (respectively 0.842 and 0.683), suggesting a substantial degree of substitution between products within the same nest. The valuations for several other features are also of the expected sign and significant in both specifications. For example, freestanding models are valued less than built-in ones. Noisier refrigerators (measured in decibels) are consistently less preferred. The estimates also reveal comparable heterogeneous preferences for exterior finishes (captured by the "deco" dummies) and positive valuations for features such as separate temperature controls, full no-frost, LED lighting, ice cube dispensers, and smart connectivity.

#### 5.2 Energy Label and Electricity Cost Valuations

Label Specification The results indicate that the introduction of the new labeling scheme reduced average consumer utility in all countries except Poland, as reflected by the negative and statistically significant coefficients on the *New label dummy* in Table 2. This decline likely captures transitional effects associated with the policy change rather than a genuine reduction in consumer welfare. Consequently, it is more informative to focus on the relative valuations of the individual energy labels.

Table 3 presents the estimated willingness to pay (WTP) for each energy label, calculated as  $\lambda_{lc}/\alpha_c$ , relative to label A+ under the old system and label G under the new system. Across countries, consumers consistently exhibit higher WTP for more energy-efficient labels, confirming

Table 2: Demand Estimation Results: Labels and Electricity Cost Specifications

	Belgium	France	Germany	Poland
Panel A: Labels				
Price $(\alpha_c)$	-0.0028***	-0.0036***	-0.0025***	-0.0027***
	(0.000)	(0.000)	(0.000)	(0.000)
log(total litres)	1.1751***	1.5894***	0.2871***	0.2691***
	(0.058)	(0.059)	(0.085)	(0.082)
log(freezer litres)	0.0515***	0.2707***	0.2321***	0.6921***
- ,	(0.009)	(0.012)	(0.011)	(0.020)
No freezer	-0.2961***	-0.0111	0.0136	0.8992***
	(0.032)	(0.041)	(0.042)	(0.064)
Covid	-0.9652***	-1.2975***	-0.1636***	-0.4168***
	(0.051)	(0.049)	(0.038)	(0.058)
Time	0.0024**	0.0027***	0.0013*	-0.0048***
	(0.001)	(0.001)	(0.001)	(0.001)
New label dummy	-0.4313***	-0.2417***	-0.2801***	-0.0370
- · · · · · · · · · · · · · · · · · · ·	(0.062)	(0.056)	(0.053)	(0.084)
New C	1.1396***	1.3226***	1.3128***	1.1058***
	(0.075)	(0.089)	(0.065)	(0.090)
New D	0.9417***	0.8332***	0.9680***	1.3330***
11011 B	(0.065)	(0.056)	(0.057)	(0.085)
New E	0.6406***	0.4730***	0.4656***	0.4846***
11011 12	(0.061)	(0.046)	(0.054)	(0.075)
New F	0.3692***	0.2597***	0.3567***	0.2071***
	(0.059)	(0.048)	(0.052)	(0.078)
Old A+++	0.6291***	0.8368***	0.7426***	1.1875***
	(0.038)	(0.059)	(0.037)	(0.061)
Old A++	0.3061***	0.1833***	0.2771***	0.4436***
	(0.021)	(0.024)	(0.017)	(0.025)
Panel B: Electric		/	,	,
Price $(\alpha_c)$	-0.0020***	-0.0028***	-0.0021***	-0.0020***
( 0)	(0.000)	(0.000)	(0.000)	(0.000)
log(total litres)	0.9809***	1.2940***	0.2689***	-0.0682
36(*****	(0.047)	(0.052)	(0.076)	(0.077)
log(freezer litres)	-0.0086	0.1878***	0.1826***	0.5578***
36( 11 1 1 11)	(0.008)	(0.011)	(0.009)	(0.017)
No freezer	-0.4806***	-0.2570***	-0.2608***	0.5866***
	(0.030)	(0.037)	(0.036)	(0.058)
Covid	-0.8680***	-1.2163***	-0.1771***	-0.3436***
	(0.049)	(0.047)	(0.037)	(0.055)
Time	0.0063***	0.0057***	0.0038***	-0.0025**
	(0.001)	(0.001)	(0.001)	(0.001)
Old $\gamma_c$	0.5100***	0.5600***	0.8300***	1.2400***
, -	(0.000)	(0.000)	(0.000)	(0.000)
New $\gamma_c$	0.7000***	0.6300***	0.9000***	1.1900***
, .	(0.000)	(0.000)	(0.000)	(0.000)
	` -/	- /	` -/	

Notes: Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

that labeling effectively signals product quality and energy performance.

There are notable differences across countries. Under the old labeling system, Polish and German consumers exhibit higher WTP than their Belgian and French counterparts. Under the new system, German consumers display the highest WTP for label C (525 euros), while Polish consumers place a relatively strong value on label D (494 euros), and Belgian consumers on label E (229 euros), each relative to the base category G.<sup>10</sup>

Table 3: Willingness to pay for labels (Euros) relative to A+ for old labels and G for new labels

Label	Belgium	France	Germany	Poland
С	407	367	525	410
D	336	231	387	494
$\mathbf{E}$	229	131	186	179
F	132	72	143	77
G	base	base	base	base
A+++	225	232	297	440
A++	109	51	111	164
A+	base	base	base	base

We assess whether consumers correctly value future energy savings by comparing the estimated willingness to pay (WTP) for both the new and old energy labels—expressed relative to the former base label A+—with the corresponding expected electricity savings. Specifically, for each refrigerator, we compute the annual electricity cost as the product of the reported annual energy consumption (in kWh) and the country-specific electricity price per kWh (in euros, PPP-adjusted) applicable to the observation period. We then calculate the average annual electricity cost by label and country over the full sample period.

Dividing the estimated WTP for each label by the average annual electricity cost of refrigerators in the same label category yields the number of years of electricity expenses that consumers are willing to pay upfront relative to the base label A+. Positive values indicate that consumers are willing to pay more than the present monetary value of expected future savings (i.e., they overpay), while negative values imply that consumers undervalue potential energy savings.

The results in Table 4 reveal substantial cross-country heterogeneity. In Poland, consumers markedly overpay relative to the implied electricity savings—especially for the new labels C and D and the top old label A+++. French and German consumers also tend to overpay for the top new label C, while displaying only modest over- or underpayment for other labels. In Belgium, consumers slightly overpay for the top label C and generally undervalue the remaining labels.

**Electricity Cost Specification** The second specification explicitly links consumer utility to the average electricity cost associated with each label, allowing us to test whether consumers internalize

<sup>&</sup>lt;sup>10</sup>For comparison, Houde (2017) estimates WTP for the *Energy Star* label in the U.S. between 16and 75, corresponding to roughly 1.2–5.7% of the average refrigerator price.

4.0

0.8

base

7.1

1.2

base

6.4

1.7

base

5.8

2.0

base

A+++A++

A+

		W	TP		Elect	ricity sav	vings (10 ye)	ars)
Label	Belgium	France	Germany	Poland	Belgium	France	Germany	Poland
С	5.0	8.1	7.9	7.7	3.3	3.7	4.9	3.5
D	3.9	3.9	4.9	8.2	4.2	2.2	3.8	1.8
$\mathbf{E}$	1.3	1.4	1.1	2.5	1.7	1.0	1.5	0.6
F	(0.3)	0.1	0.4	0.8	(0.6)	(0.8)	(0.4)	(0.7)
G	(2.1)	(1.1)	(1.3)	(0.2)	(0.9)	(1.6)	(0.9)	(2.1)

8.8

2.6

base

7.3

2.2

base

5.5

1.5

base

6.6

1.9

base

Table 4: Willingness to Pay (WTP) and Electricity Savings by Energy Label relative to Label A+ (in years of energy costs)

energy costs when making purchase decisions rather than relying solely on the qualitative efficiency signal conveyed by the label.

Nonetheless, consumers are unlikely to process detailed numerical information on annual energy use or electricity prices. They may not know the current or expected future cost per kWh, nor possess the motivation or cognitive capacity to translate kWh figures into long-term financial implications. This behavioral assumption is consistent with evidence from Davis and Metcalf (2016), who find that U.S. consumers respond primarily to simplified or salient cost information rather than to detailed technical data.

The results, reported in the bottom panel of Table 2, indicate that consumers in all countries except Poland systematically undervalue electricity costs in their purchase decisions, as reflected by  $\gamma_c < 1$  under both labeling regimes. Belgian and French consumers exhibit the strongest undervaluation, though the gap narrows modestly following the 2021 reform. German consumers show a more moderate degree of undervaluation, while Polish consumers appear to overvalue energy costs—possibly due to higher electricity prices when accounting for PPP, or greater awareness of household energy expenditures.

These findings are consistent with recent survey evidence (November–December 2023, six EU countries) showing that French households are the least concerned with energy savings at home. For instance, 78% of Polish respondents reported purchasing energy-efficient appliances to reduce energy use, compared with 59% in Germany and only 48% in France (Belgium was not surveyed). When asked, "In which areas do you primarily take actions to save energy?", 32% of Polish respondents answered "home appliances," compared with 36% in Germany and only 19% in France.<sup>11</sup>

These findings carry important policy implications. The persistent undervaluation of energy costs suggests that labels and energy-use information alone may be insufficient to stimulate the adoption of energy-efficient appliances. Such measures should therefore be complemented by tar-

 $<sup>^{11}</sup>$  "Social attitudes towards energy, energy transition and environmental policy in the EU," published 7 October 2024, DOI:10.17632/xpx2z7y29p.1.

geted information campaigns, behavioral nudges, or fiscal incentives designed to make energy savings more salient to consumers. In contrast, the apparent overvaluation observed among Polish consumers indicates that the effectiveness of these interventions may depend strongly on local market conditions and electricity price levels.

#### 5.3 Marginal cost and energy usage estimates

Table 5 presents the results of the marginal cost regressions for the two nested logit model specifications in columns (1) and (2), and the electricity usage regression in column (3). The marginal costs are backed out using equation 7, while the electricity usage is reported on the old and new energy labels. The estimated marginal costs are broadly consistent across specifications. In particular, marginal costs tend to be higher for more energy-efficient refrigerators, as indicated by the positive coefficients on the corresponding energy labels. Conversely, electricity usage decreases with higher energy efficiency, confirming that more efficient products consume less energy.

The estimated coefficients from these regressions are used in the counterfactual simulations based on the label and electricity cost demand models. Specifically, the marginal cost estimates are employed to adjust refrigerator production costs, while the electricity usage estimates are used to modify consumer utility, thereby capturing differences in energy consumption across efficiency labels.

# 6 Counterfactual Scenarios

In this section, we employ the structural framework to perform three counterfactual policy simulations. These simulations draw on the two estimated nested logit demand specifications—one based on *energy labels* and the other on *electricity costs*—in conjunction with the oligopoly model of Bertrand–Nash competition.

Table 6 summarizes the results for three policy scenarios: (1) maintaining the old labeling regulation; (2) banning and reclassifying products with energy labels F and G into label E; and (3) introducing a *feebate* system, which combines subsidies for energy-efficient products with taxes on less efficient ones. These simulations are conducted for December 2022, the last period in our data.

Continuing with Old Labels The first scenario examines what would have occurred if the previous labeling regime had remained in place. We use the energy labels specification to implement this simulation, and as a robustness check, the electricity cost specification. We assess whether the introduction of the new labeling framework effectively reduced energy usage, which could stem either from enhanced consumer awareness—if clearer labeling encouraged the purchase of more efficient refrigerators—or from manufacturers upgrading their product portfolios to comply with stricter efficiency standards.

Table 5: Marginal costs regression (OLS): Labels vs. Electricity Costs

	(1) Labels	(2) Elect. costs	(3) Elect. usage
New C	0.389***	0.609***	-0.643***
	(0.010)	(0.024)	(0.006)
New D	0.400***	0.643***	-0.515***
	(0.007)	(0.019)	(0.005)
New E	0.275***	0.431***	-0.286***
	(0.007)	(0.016)	(0.004)
New F	0.214***	0.306***	-0.095***
	(0.006)	(0.016)	(0.004)
Old A+++	0.291***	0.498***	-0.559***
	(0.004)	(0.011)	(0.003)
Old A++	0.120***	0.195***	-0.201***
	(0.003)	(0.007)	(0.002)
new_reg	-0.112***	-0.139***	0.069***
	(0.006)	(0.016)	(0.004)
Freestanding	-0.556***	-1.054***	-0.001
<u> </u>	(0.011)	(0.028)	(0.007)
log(noise DB)	-0.081***	0.116**	0.297***
,	(0.021)	(0.051)	(0.013)
Freezer stars	0.029***	0.150***	0.391***
	(0.002)	(0.006)	(0.001)
Deco A	-0.053***	-0.117***	0.081***
	(0.011)	(0.028)	(0.007)
Deco B	0.251***	0.516***	0.082***
	(0.004)	(0.010)	(0.003)
Deco C	0.251***	0.399***	0.028***
	(0.004)	(0.011)	(0.003)
$\log(\text{litres})$	0.761***	1.458***	0.386***
,	(0.003)	(0.007)	(0.002)
Temperature control	0.126***	-0.078***	0.170***
-	(0.003)	(0.008)	(0.002)
Full nofrost	0.066***	0.012	0.083***
	(0.004)	(0.009)	(0.002)
Led light	0.049***	0.111***	0.050***
	(0.003)	(0.006)	(0.002)
Icecube dispenser	0.394***	0.262***	0.089***
-	(0.005)	(0.013)	(0.003)
Smart connect	0.275***	0.120***	0.002
	(0.008)	(0.019)	(0.005)
Constant	2.541***	-2.147***	1.820***
	(0.077)	(0.191)	(0.049)
Observations	91,204	91,204	91,204
R-squared	0.864	0.730	0.848

Notes: Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

We implement this scenario by predicting the old energy labels for all products sold in December 2022 using a random forest model trained on product characteristics and energy consumption. For the same product portfolio, we then replace the new labels with their predicted old equivalents, thereby simulating how products would have been presented under the previous labeling regime. The newly assigned old labels are subsequently used to recalculate consumer valuations, reflecting how the former system might have influenced purchasing d ecisions. All other product attributes, including energy usage and marginal costs, are held constant to isolate the effect of the labeling change.

The impact of maintaining the old labeling system varies across countries. Overall energy use would be considerably higher under the old labels in Belgium (18.8%) and Germany (10.6%), while the increase would be modest in France (2.8%), and energy use would actually be lower in Poland (-5.8%). Two main effects contribute to these o utcomes. First, refrigerator sales would be higher under the old labeling system in Belgium (13.6%), Germany (6.7%), and France (2.6%), but lower in Poland (-1.6%). Second, the average energy efficiency of refrigerators would deteriorate under the old system in Belgium (4.5%), Germany (3.6%), and—only marginally—in France (0.3%), while improving in Poland (-4.3%).

Banning New F and G Labels The second scenario—banning products with labels F and G—is a stricter regulatory intervention aimed at speeding up the phase-out of low-efficiency models. We implement it primarily with the *energy-labels specification*, and we replicate the exercise as a robustness check with the *electricity-cost specification*. Rather than shrinking product variety, we replace all refrigerators labeled F or G with otherwise comparable models relabeled E.

Operationally, we adjust consumer valuations by changing the energy label for products in F and G to E, and simultaneously adjust marginal costs and energy use for those products. Because E-label models are more efficient, the adjustments imply lower energy consumption and, in our estimates, higher marginal production costs. The magnitudes of these changes come from regressions of log marginal costs and log energy usage on label dummies, brand fixed effects, and product characteristics (Table 5). Thus, for items originally in F or G, we replace their cost and energy values with the corresponding estimates for label E.

Replacing refrigerators with energy labels F and G by models with label E leads to a substantial reduction in energy consumption—by 8.1% in France, 6.0% in Germany, 2.7% in Poland, and 0.7% in Belgium. This decline occurs despite an increase in total refrigerator sales of 8.0% in Poland and Belgium, 5.5% in France, and 0.8% in Germany. The overall improvement in energy efficiency results from the removal of the least efficient models from the market and their replacement with more energy-efficient alternatives, which results in substantially higher average energy efficiency of refrigerators sold.

**Feebate** Finally, as discussed in Section 4.1, the third scenario implements a *feebate* policy designed to correct the internality arising from consumers' undervaluation of electricity costs when purchasing refrigerators. This counterfactual is estimated using the *electricity-cost specification*. The *feebate* is defined as:

$$t_{lc} = \tau \left( G_{lc} - \tilde{G}_c \right),\,$$

where  $\tau = 1 - \gamma_c$  is the feebate rate per unit of electricity cost, and  $\tilde{G}_c$  denotes the pivot point. Products with energy costs above  $\tilde{G}_c$  are taxed, while those below it receive a subsidy. In this simulation, we adjust consumer utility to reflect these incentives, while keeping the product portfolio unchanged. Unlike an outright ban, feebates preserve product variety, allowing producers to internalize environmental costs and consumers to respond to efficiency-based price signals.

As shown in Table 6, the overall effects on sales and prices are small. Average energy use declines slightly in Belgium and France (both by -1.9%) and marginally in Germany (-0.3%), while it increases modestly in Poland (+1.1%). These results suggest that, although *feebates* are less disruptive to market structure than banning low-efficiency models, their short-term impact on energy savings is comparatively limited.

Table 6: Counterfactual Policy Simulations

Old labels continue						
Average energy (kWh per sa			(kWh per sales)			
Country	Sales (%)	Energy (%)	$\mathbf{Price}\;(\%)$	Before	After	Change $(\%)$
Belgium	13.6	18.8	0.0	185	193	4.5
France	2.6	2.8	0.0	246	246	0.3
Germany	6.7	10.6	0.0	192	199	3.6
Poland	-1.6	-5.8	0.4	246	236	-4.3

	Banning new F and G labels					
				Average	e energy	(kWh per sales)
Country	Sales (%)	Energy $(\%)$	$\mathbf{Price}\ (\%)$	Before	After	Change $(\%)$
Belgium	8.0	-0.7	2.6	185	170	-8.0
France	5.5	-8.1	4.0	246	214	-12.9
Germany	0.8	-6.0	1.7	192	179	-6.8
Poland	8.0	-2.7	2.9	246	222	-10.0

			Feebate			
			Average energy (kWh per sales)			(kWh per sales)
Country	Sales (%)	Energy (%)	$\mathbf{Price}\;(\%)$	Before	After	Change $(\%)$
Belgium	0.8	-1.9	0.0	185	180	-2.7
France	-0.1	-1.9	0.0	246	241	-1.7
Germany	0.0	-0.3	0.0	192	191	-0.8
Poland	0.0	1.1	0.0	246	249	1.0

### 7 Conclusion

In this paper, we analyze changes in the annual energy consumption of refrigerators sold in four European countries—Belgium, France, Germany, and Poland—between 2019 and 2022. Specifically, we investigate whether the introduction of the new EU energy labeling regulation, effective from March 2021, improved the energy efficiency of products sold.

Our descriptive analysis reveals substantial cross-country variation in average sales-weighted energy consumption. Germany and Belgium exhibit lower average energy use, reflecting differences in product portfolios and consumer preferences, whereas consumers in France and Poland tend to purchase less efficient mo dels. Be tween March 2021 and December 2022, the average energy consumption of refrigerators declined by 2.9% in France, 4.6% in Poland, 5.1% in Germany, and 7.3% in Belgium. After controlling for refrigerator characteristics, the reductions remained significant though slightly smaller—2.8% in France, 3.4% in Belgium, and 3.5% in both Germany and Poland. These results suggest that the new labeling scheme produced a measurable improvement in energy efficiency within less than two years of im plementation. However, we cannot say for sure whether a comparable reduction in energy usage would be achieved under the old labeling regulation.

We subsequently estimate two nested logit demand models for refrigerator purchases. The first incorporates the cost of electricity consumption over a 10-year horizon. The results indicate that, except in Poland, consumers tend to undervalue electricity costs when purchasing refrigerators under both the old and the new labeling regimes. This undervaluation is most pronounced in France and Belgium, and is more moderate in Germany. In contrast, Polish consumers appear to slightly overvalue electricity costs, suggesting higher salience of energy expenses or greater awareness of household electricity prices.

The second specification includes country-specific dummy variables for energy labels, allowing us to estimate country-specific willingness-to-pay (WTP) coefficients for each label. The results show that in Poland, consumers substantially overpay relative to the cost savings implied by the labels—particularly for the new C and D labels and the old A+++ label. In France and Germany, consumers also tend to overpay for the new top label C, while showing only minor over- or underpayment for other categories. In Belgium, consumers slightly overpay for label C and underpay for most others.

Several factors may explain these cross-country differences. The refrigerator portfolio in Poland is, on average, less energy-efficient than in other countries, which likely makes energy consumption more salient to Polish consumers. Electricity prices, adjusted for purchasing power parity, are also relatively high in Poland, which may further increase the perceived importance of energy efficiency.

Using the estimated model, we perform counterfactual simulations to evaluate the effects of three alternative policy interventions. First, we assess a scenario in which the old labeling regulation had remained in place. The energy consumption under the old scheme would have been substantially

higher in Belgium (+18.8%), Germany (+10.6%), and France (+2.8%), but lower in Poland (-5.8%). These differences are primarily driven by large increases in refrigerator sales in Belgium (13.6%) and Germany (6.7%) under the old scheme. In Poland, by contrast, the model predicts a slight decline in sales under the old scheme (-1.6%) and a shift in demand toward more energy-efficient refrigerators.

Second, we simulate a ban on the least efficient products—replacing refrigerators labeled F and G with those labeled E. This intervention maintains product variety while shifting demand toward more efficient categories. The results show clear efficiency gains: the energy use declines by 8.1% in France, 6.0% in Germany, 2.7% in Poland, and 0.7% in Belgium, even though total sales increase in all four countries.

Third, we examine a *feebate* policy, where inefficient refrigerators are taxed and efficient ones are subsidized based on their relative energy use. This market-based policy yields relatively modest efficiency improvements: energy consumption decreases by 1.9% in both Belgium and France and 0.3% in Germany, but rises slightly in Poland (+1.1%). These results suggest that while *feebates* are less disruptive to market structure, their short-term energy savings are limited.

Taken together, the simulations reveal strong cross-country heterogeneity in the effectiveness of energy-efficiency policies. Reclassifying inefficient products (the ban scenario) produces the largest and most consistent reductions in energy use, while correcting consumer misperceptions (the *feebate* scenario) delivers only modest gains. These findings highlight the need for country-specific policy calibration: while the new EU labeling scheme effectively steers markets toward greater efficiency, the persistence of consumer undervaluation in France and Belgium suggests that complementary informational or fiscal measures remain necessary.

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# Appendix A

#### A.1 Energy Labels of Refrigerating Appliances

The new energy efficiency class of refrigerating appliances is determined based on the Energy Efficiency Index (EEI), as shown in Table A.1. The EEI calculation has changed and become stricter after March 2021.

The first step in calculating the Energy Efficiency Index (EEI) is to measure the annual energy consumption in kWh/annum, denoted as

$$AE_C = \frac{365 \times E_{24h}}{L},$$

where  $E_{24h} = 0.5 \times (E_{16} + E_{32})$  represents the energy consumption measured over 24 hours at ambient temperatures of 16 °C and 32 °C in a test room, respectively. The load factor L is set to 0.9 for refrigerating appliances with only frozen compartments and 1.0 for all other appliances.

The measurement should include the energy consumed during normal operation, including any defrosting cycles. The appliance should be tested when it is empty. The reported value shall not be greater than the measurement by more than 10%.

Old Label	Old EEI Range (%)	New Label	New EEI Range (%)
A+++	EEI < 22	A	EEI < 41
A++	$22 \le \text{EEI} < 33$		
A+	$33 \le \text{EEI} < 42$		
A	$42 \le \text{EEI} < 55$	В	$41 \le \text{EEI} < 51$
		С	$51 \le \text{EEI} < 64$
В	$55 \le \text{EEI} < 75$	D	$64 \le \text{EEI} < 80$
С	$75 \le \text{EEI} < 95$	E	$80 \le \text{EEI} < 100$
D	$95 \le \text{EEI} \ge 110$	F	$100 \le \text{EEI} < 125$
${ m E}$	$110 \le \text{EEI} \ge 125$		
F	$125 \le \text{EEI} \ge 150$	G	$EEI \ge 125$
G	$EEI \ge 150$		

Table A.1: The Energy Efficiency Index (EEI)

The Energy Efficiency Index (EEI) of household refrigerating appliances is calculated as:

$$EEI = \frac{AE_C}{SAE_C} \times 100$$

where  $SAE_C = C \times D \times \sum_{c=1}^n A_c \times B_c \times \left[\frac{V_c}{V}\right] \times (N_c + V \times r_c \times M_c)$  represents the standard annual energy consumption (kWh/annum), where: (i)  $V_c$  is the volume (dm<sup>3</sup>) of compartment  $c = 1, \ldots, n$ , (ii) V is the total volume (dm<sup>3</sup>), and (iii) the remaining terms  $(C, D, A_c, B_c, N_c, r_c, M_c)$  are modeling parameters and compensation factors.

## A.2 Electricity prices

In this section, we discuss the development and regulation of electricity prices in the four countries considered in this analysis. The corresponding price levels in Euros PPP per kWh are presented in Figure A.1.

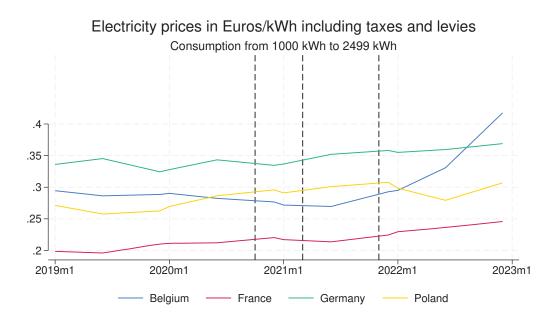


Figure A.1: Electricity prices in the four countries.

Belgium: The retail electricity market is liberalized with prices determined by suppliers but including regulated components such as network tariffs and levies. In response to the sharp rise in energy prices in 2021–2022, the federal government implemented several relief measures. On 1 February 2022, it was announced that all households with a residential electricity contract would receive a one-time rebate of €100, applied directly as a deduction on their electricity bills. The rebate was automatically credited on bills issued between 18 April and 31 July 2022, reaching approximately 4.1 million households out of an estimated 4.9 million eligible beneficiaries.

In addition, the government temporarily reduced the value-added tax (VAT) on electricity from 21% to 6%, and extended the eligibility criteria for the "social tariff"—a subsidized tariff set at the lowest market price—to include a larger share of vulnerable households. These measures complemented existing regional support schemes and were designed to mitigate the impact of the global energy crisis on consumers.

**France:** In France, residential electricity consumers can opt for a regulated sales tariff (*Tarif Réglementé de Vente*, TRV), overseen by the government and set on the recommendation of the Energy Regulation Commission (CRE). In response to surging wholesale prices during the energy

crisis, the government introduced a comprehensive "tariff shield" (bouclier tarifaire) starting in October 2021, which effectively limited increases in regulated tariffs. This was implemented through a combination of measures: a sharp reduction in the main tax on electricity (TICFE), from around €22.50/MWh to €0.50–€1.00/MWh for households; an increase in the annual volume of "regulated access to historic nuclear electricity" (Accès Régulé à l'Électricité Nucléaire Historique, ARENH) from 100 to 120 TWh to give alternative suppliers access to lower-cost nuclear generation; a compensation scheme for electricity and gas suppliers to cover the gap between wholesale procurement costs and retail tariff revenues; and a legal obligation for incumbent suppliers of regulated tariffs (EDF for electricity, Engie for natural gas) to limit tariff increases to 4% in 2022 instead of the much larger increases implied by market conditions. These price-control measures were complemented by targeted subsidies to households. First, an additional "energy cheque" of €100 was granted to the approximately 5.8million low-income households already eligible for the regular annual energy cheque. Second, a one-off €100 "inflation allowance" (indemnité inflation) was paid to about 38million people with incomes below a certain threshold.

Germany: In Germany, retail electricity prices for households are not directly regulated. Instead, they are determined by market dynamics, although they include several regulated components such as grid fees, taxes, and surcharges. Between 2019 and 2021, household electricity prices remained in the low range of 30 euro cents/kWh on average. In 2020, the average price was approximately 31.5 euro cents/kWh, with a significant share made up of politically controlled elements like surcharges and taxes.

In mid-2022, the Renewable Energy Surcharge (*EEG-Umlage*)—which had accounted for about 3.72 euro cents/kWh—was abolished, which partially offset the upward pressure on retail prices caused by rising procurement and wholesale costs. Nevertheless, by late 2022, average retail prices for households had risen sharply to around 40.1 euro cents/kWh, mainly due to the energy crisis and wholesale market volatility.

In September 2022, the federal government announced an electricity price cap as part of its "protective shield" measures. Under this policy, household electricity prices were capped at 0.40 euro/kWh for 80% of annual consumption, with usage above this threshold billed at market rates. These measures were formalised in the Electricity Price Control Act (StromPBG) passed in December 2022, and were financed in part through the collection of surplus profits from energy generators.

**Poland:** In the Polish electricity tariff system, separate prices are set for household (residential) customers and for commercial or industrial users. In 2021, there were about 15.5 million residential consumers, with an average annual electricity consumption of about 2,000 kWh. Residential customers are subdivided into tariff types based on the time-of-use pricing structure.

The most common tariff, G11, is a single-zone (flat-rate) tariff in which the price per kilowatt-hour is constant throughout the entire day and night. This tariff accounts for around 87% of all residential customers (about 13.5 million), with average annual consumption of approximately 1,800 kWh. The second most common tariff, G12, is a two-zone (time-of-use) tariff in which electricity is billed at two different rates: a higher day rate and a lower night (and sometimes off-peak) rate, intended to encourage shifting consumption to cheaper hours. Households in this group have a higher average consumption—about 3,200 kWh per year—often because they use electricity-intensive appliances (e.g., electric heating or water heating) during off-peak hours.

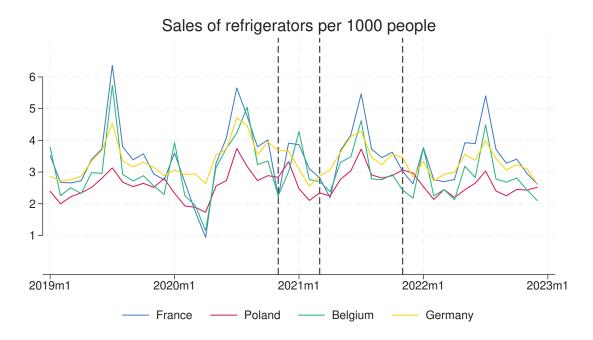
During the period 2019–2021, all household electricity tariffs remained regulated and suppliers were required to apply these regulated rates. In response to the surge in energy prices in 2021–2022, partly triggered by the energy crisis and high inflation, the government implemented the *Anti-Inflation Shield*, which included a reduction of VAT on electricity from 23% to 5% (effective from January 2022) and temporary exemptions from excise duty for households, but did not involve tariff freezes.

Starting from 1 January 2023, the government introduced further extraordinary measures under the Act on Special Solutions for the Protection of Electricity Consumers, especially targeting households consuming up to 2,000 kWh annually (higher thresholds applied to larger families and households with persons with disabilities). For eligible households, retail electricity prices were capped at the 2022 tariff levels approved by URE and frozen for the entire year. Consumption above the threshold was billed at a higher, but still capped, statutory maximum price. Suppliers were reimbursed for the difference via state compensation.

# Appendix B

# B.1 Descriptive statistics and estimations

Figure B.1: Sales of refrigerators in thousands (with trade brands)



The population is fixed for 2018 as follows: Belgium (11.43 million), France (67.16 million), Germany (82.19 million), and Poland (37.97 million).

Table B.1: Annual energy consumption regression

Variables	Coeff	Litres	Depth	Width	Height
Main type 1	-0.0102	-0.0155	-0.0265	-0.5119***	0.4955***
Materia	(0.396)	(0.038) 0.3065***	(0.063)	(0.133)	(0.047) -0.3971***
Main type 2	-1.9918 (1.514)	(0.081)	-0.0130 (0.189)	0.6067** (0.307)	(0.107)
Main type 3	3.3138***	0.7534***	-0.5730***	-0.0244	-0.8286***
	(0.316)	(0.033)	(0.045)	(0.068)	(0.053)
Main type 4	-1.4416***	0.4672***	-0.3948***	0.4787***	-0.2127**
36	(0.501)	(0.067)	(0.075)	(0.126)	(0.093)
Main type 4	-0.8447 (1.466)	0.3680*** (0.074)	0.1502 $(0.122)$	0.3549*** (0.108)	-0.4531* (0.238)
Main type 5	-7.6185**	0.2302***	0.0020	-0.3168***	1.7214***
VI	(3.041)	(0.064)	(0.105)	(0.111)	(0.644)
Freezer bottom	0.0172				
	(0.029)				
Freezer top	0.3814***				
Freestanding	(0.006) -0.0954***				
Treestanding	(0.017)				
Stars	0.0130***				
	(0.004)				
Drawers	0.0036				
Temp. control	(0.009) -0.0838***				
remp. control	(0.005)				
Water dispenser	0.1002***				
_	(0.012)				
Water container	-0.0463***				
Water direct	(0.013) -0.0454***				
water direct	(0.013)				
Icecube dispenser	-0.0254**				
•	(0.013)				
Crushed ice	0.0266**				
Chiller zone	(0.013)				
Chiner zone	-0.0522*** (0.006)				
Ventilated air	-0.0237***				
	(0.004)				
Mounting door	-0.0383**				
Mounting slide	(0.015) -0.0020				
Mounting singe	(0.015)				
Display	-0.0508***				
	(0.004)				
Smart connect	-0.0341***				
Nofrost	(0.009) 0.1265***				
Nonost	(0.006)				
Full nofrost	0.0390***				
	(0.005)				
Led light	-0.0101***				
Inverter motor	(0.004) -0.1092***				
mverter motor	(0.006)				
Cooling	0.0601***				
_	(0.007)				
Cooling compressor	0.0072*				
Fullbody steel	(0.004) 0.0348**				
runbody steel	(0.014)				
Deco dummy 1	-0.0263				
	(0.019)				
Deco dummy 2	-0.0363*				
Deco dummy 3	(0.019) -0.0030				
Deco duminy 3	(0.019)				
Constant	4.6585***				
	(0.017)				
Observations	16,678				
R-squared	0.847				

Table B.2: Labels vs. Electricity Cost Specifications: common parameters

	Labels	Electricity cost
sigma	0.8422***	0.6828***
	(0.022)	(0.018)
Frestanding dummy	-1.4073***	-1.1487***
	(0.049)	(0.043)
log(noise in Db)	-1.2635***	-2.0626***
	(0.105)	(0.078)
Freezer stars	-0.1373***	-0.1359***
	(0.011)	(0.010)
Deco A	-0.1424***	-0.1152***
	(0.036)	(0.034)
Deco B	0.3343***	0.2868***
	(0.018)	(0.016)
Deco C	0.3450***	0.2245***
	(0.025)	(0.021)
Temperature control	0.2892***	0.1889***
-	(0.025)	(0.021)
Full nofrost	0.0576***	0.0427***
	(0.012)	(0.011)
Led light	0.1118***	0.1697***
<u> </u>	(0.010)	(0.011)
Icecube dispenser	0.8031***	0.4687***
•	(0.079)	(0.064)
Smart connect	1.1534***	0.8453***
	(0.079)	(0.065)
Observations	91,204	91,204
R-squared	0.799	0.814

Notes: Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

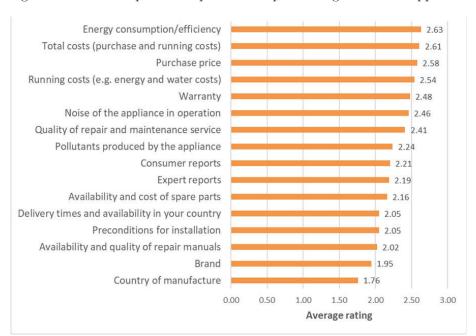


Figure B.2: Most important aspects when purchasing household appliances

Note: Average importance rated 0-3 (higher = more important). Source: EPREL Services survey, 2025.



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ISSN 2957-0506