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Abstract

This paper studies seven rebate programs aiming at accelerating the replacement of energy-intensive household appliances. Based on a large product-level data set for several European countries, we study the effects on unit sales and prices of both subsidized and non-subsidized products. The empirical identification strategy exploits the temporary implementation of the rebates in regional segments of the European Common Market. The results for unit sales indicate that subsidies can be an effective instrument for stimulating purchases of energy efficient appliances. While the strength of the stimulus proves sensitive to program design, we find limited evidence of intertemporal substitution, and no indication that program effects are driven by a drop in sales of non-subsidized products. In some cases, sales of non-subsidized products increase, a finding that we attribute to information campaigns associated with the rebate programs. Price effects are modest, implying that subsidies are mostly passed through to consumers. Considering the actual energy savings, however, our analysis shows that rebate programs are a relatively expensive way to improve energy efficiency.

JEL-Codes: H230, Q480, D120.

Keywords: rebate programs, energy efficiency, household appliances, program evaluation.

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1 Introduction

Given the importance of households' demand for energy, in many countries governments incentivize consumers to purchase household appliances that meet high energy efficiency standards through various measures, including partial rebates of the purchase price (e.g., Du Can et al., 2014; Markandya et al., 2009). Rebate programs typically aim at promoting the early replacement of energy-intensive household equipment or vehicles. Examples are the *Cash for Appliances* (2009-2013) and *Cash for Clunkers* (2009) programs in the U.S. (e.g., Houde and Aldy, 2017; Mian and Sufi, 2012) and the *Cash for Coolers* (2009-2012) initiative in Mexico (Davis, Fuchs, and Gertler, 2014; Boomhower and Davis, 2014). Numerous rebate programs have also been implemented in the European Union (EU), notably the *Umweltprämie* in Germany (2009), *Trennungsprämie* in Austria (2009-2010), *Otthon Melege* in Hungary (2015-2020), and ongoing programs such as *EcoCheques* in Belgium, and *Plan Renove* in Spain, among others.

Whether these policies contribute to a transition towards higher energy efficiency of household appliances is not obvious. Retailers may raise prices in order to capture a part of the subsidy. Even if households enjoy a decline in the effective price, they might not be aware of a program or are reluctant to participate. A high take-up rate of subsidies and a large number of replaced appliances are also not necessarily indicative of program effectiveness. If a large fraction of participants would have purchased a new device even in the absence of a subsidy, the effect on energy consumption would be small. Intertemporal effects may also work against a program's effectiveness, if consumers postpone or bring forward replacements that they intended to do anyway.

To shed light on these issues, this paper empirically explores the effects of a number of programs implemented in the EU. We utilize a large micro-level data set with an extensive coverage of unit sales and prices of major domestic appliances at the product level on a monthly basis from 2004 until 2017 in eight European countries. During the observation period, seven rebate programs targeting different segments of the market were carried out in three of these countries at different points in time. The identification strategy exploits the trading of products within the EU's common market: Counterfactuals for sales and prices of subsidized products before, during, and after a program are constructed from the contemporaneous sales and prices of exactly the same product in other EU countries.

Our results indicate that rebate programs can induce strong positive effects on the purchases of subsidized products, which are not merely reflective of intertemporal shifting. Based on estimated program effects, information on the average annual energy consumption of subsidized products relative to the regional segment of the market, and administrative data on appliances' average life-cycle within households, we provide estimates of the energy savings and cost effectiveness of each program. Despite the strong effects on purchases, we find that rebate programs are a relatively costly way to enhance energy efficiency. Cost effectiveness is low, in particular, when programs are repeated and when the minimum energy efficiency of subsidized products is set relatively low. In the latter case, we find that programs trigger substitution effects within the set of subsidized products, thereby lowering the energy savings.

The paper makes three contributions to the literature. First, using a comprehensive product-level data set, we find that rebate programs can exert strong positive effects on the purchases of subsidized products. Even though there is some evidence of intertemporal shifting of sales, substitution effects over time are limited. Hence, rebate programs can have a lasting positive impact on the energy efficiency of the stock of household appliances. Our findings, therefore, deviate from the general assessment of the literature, which mostly finds that replacement rebates are largely ineffective due to program-induced rises in sales being (more than) offset by pre- and post-program declines. Mian and Sufi (2012) and Green et al. (2020), for example, show that the main effect of the US vehicle scrappage program, implemented as part of the 2009 Recovery and Reinvestment Act, was to shift consumer spending over time. This finding is confirmed by Li, Linn, and Spiller (2013). Hoekstra, Puller, and West (2017) also find strong short-term effects on car sales, but document that sales perform much worse in the post-program period compared to the counterfactual, pointing to long-term losses in consumer spending, which the authors attribute to fuel efficiency restrictions. Houde and Aldy (2017) analyse state-level rebate programs for household appliances in the US also initiated by the Recovery Act and find that a substantial fraction of the sales response is driven by inframarginal consumers. We argue that a potential explanation of the more positive assessment of the analyzed programs lies in their different motivation: While stimulus programs, which are the subject of analysis of most of the recent literature, combine the objective of enhancing energy efficiency with the aim to stimulate consumer spending and the economy, the focus of the programs under consideration in this paper is solely on improvements in energy efficiency. This focus on energy efficiency is similar to the *Cash for Coolers* program analyzed by Davis, Fuchs, and Gertler (2014), who also find lasting positive replacement effects for refrigerators and air conditioners.

The second contribution of the paper is rooted in the broad market-based perspective of our analysis. We explore not only effects on purchases of subsidized, but also on non-subsidized products. This enables us to test whether the program response is driven by consumers who already had an intention to replace, but have just revised plans and upgraded in terms of energy efficiency in order to take advantage of a subsidy. If this were the case, actual energy savings are lower, since, even in the absence of a subsidy, purchases would have resulted in a reduction of energy consumption due to replacement anyway. Interestingly, we do not find significant adverse effects on the unit sales of non-subsidized products, even if we narrow the analysis to a subset of close substitutes for subsidized models. In fact, in several instances, non-subsidized appliances exhibit a significantly positive program response. Since imperfect information and consumer inattention are discussed as possible causes of the energy efficiency gap (Allcott and Greenstone, 2012, Gerarden, Newell, and Stavins, 2017), positive responses of non-subsidized products could be the result of information campaigns associated with the programs. The strong empirical response of subsidized products to the rebate programs would then be driven partly by information and advertising effects. This is consistent with the weaker effects found for repeated programs.

The paper's third contribution is the separate analysis of unit sales and prices at the product level, which allows us to explore the extent to which subsidies are capitalized into consumer prices. The existing literature has focused mostly on sales and, due to data restrictions, has usually not discussed price effects. An exception is Sallee (2011), who considers the incidence of a federal tax credit for hybrid cars and finds that despite the limited supply of these vehicles, the credit is fully shifted to consumers. While our results document some increases in consumer prices during a program's implementation, these increases are modest ranging from 1% to 3.5%. Since the subsidies amount to about 20% of the average market price, on average, this indicates that they are mostly passed through to consumers. This holds even when the rebate is paid out by the retailer.

The paper proceeds as follows. Section 2 provides a discussion of the potential consumer/retailer responses, which identifies the relevant margins of adjustment. Section 3 gives a brief overview of the background and design of seven subsidy programs implemented in different regions of the EU. Section 4 describes the data. The methodology for the empirical analysis is laid out in Section 5 before Section 6 presents the results of the regression analysis and the analysis of cost effectiveness. Section 7 concludes.

2 Responses to Replacement Subsidies

Rebate programs promoting the replacement of low-energy-efficiency household appliances affect multiple margins of consumer behavior. The sought-after program effect is to change the behavior of consumers with no intention to replace an existing appliance. If such consumers are induced to replace and dispose of an old appliance with high energy consumption, the energy efficiency of the stock of appliances increases. Provided that appliance usage is unchanged,[1] this translates into a lower energy demand.

A general concern with any rebate program is that it may subsidize purchases by consumers who would have bought a subsidized product even in the absence of a subsidy. Those so-called inframarginal consumers receive a windfall gain. If the majority of subsidy recipients are inframarginal participants, as in Boomhower and Davis (2014) or Houde and Aldy (2017), for instance, a program could be ineffective with no change in energy demand.

[1] For a survey of the so-called "rebound effect," see Greening, Greene, and Difiglio (2000).

By targeting a subsidy to a subgroup of products with specific attributes, a program's design could also change the behavior of those who already have an intention to buy. Without subsidies, each consumer with such an intention will decide on the preferred product with a certain bundle of characteristics. Due to the subsidy, the consumer may revise plans and opt for a subsidized product instead. The effect on energy consumption depends on the direction of adjustment: Buying a more energy efficient device (upgrading) decreases energy consumption, while choosing a less efficient device (downgrading) yields the opposite outcome.[2] By setting an energy-efficiency threshold of product eligibility, downgrading can be prevented. Selecting this threshold optimally is not trivial though: Whereas a high threshold-level incentivizes upgrading, the program may exert little effects, if the bulk of consumers purchase products with lower energy efficiency and, hence, do not participate.

An interesting aspect of upgrading is that it would manifest not only in higher sales of subsidized products, but also in lower sales of those products that the consumer would have opted for in the absence of a program. If the utility loss for the consumer increases with the difference between a product's characteristics and those of the preferred product, as in Ito and Sallee (2018), one would expect that this effect is most relevant for close substitutes.[3]

If consumers differ in the extent to which their purchase decisions are distorted, determination of consumer eligibility could be as important to a program's effectiveness as product eligibility (Allcott, Knittel, and Taubinsky, 2015). Some programs feature "tagging" of a subsidy to specific types of households, such as low-income households. This may improve energy efficiency, if these households are less informed about energy costs or face higher financial constraints and, therefore, use appliances with relatively high energy consumption.[4]

[2] Houde and Aldy (2017) note that if programs are tied to energy labels, upgrading may also involve the purchasing of appliances with larger capacity, which reduces energy savings.

[3] Upgrading may also be observed for inframarginal consumers. The windfall gain from the subsidy may lead to an income effect, which can induce the purchase of a more expensive appliance than planned (Houde and Aldy, 2017).

[4] Rebate programs are generally targeted to households that already own an appliance. However, depending on the type of product and the program design, subsidies may also lead to sales to consumers, who do not own an appliance. In this case, the stock of appliances and, hence, energy demand increases. As our analysis deals with basic household appliances in developed countries, first-time purchases are unlikely to be important. Whether or not program design includes a scrappage requirement has first of all effects on the market for used appliances.

A key feature of many rebate programs is their short duration and typically tight budgets disbursing subsidies on a first-come first-serve basis. Consumers with an intention to buy, therefore, may consider accelerating or postponing their purchases to take advantage of a program (e.g., Houde and Aldy, 2017). This implies that sales of products would decline immediately after, and, given pre-announcement, immediately before a program period. For consumers who plan to replace an appliance, bringing forward (postponing) purchases contributes to a decline (increase) in energy consumption as the energy efficiency of the stock of appliances improves earlier (later) than without a program. The size of the acceleration effect is larger the further in the future intended replacements would have taken place in the absence of a subsidy. If replacement is expedited only by a few months, however, effects on energy demand are likely to be negligible.

If programs are implemented locally and if budgets are small relative to the size of the market, producers are unlikely to respond. At the level of local retailers, serving only a small regional segment of the market, temporary demand increases may nevertheless trigger price responses. In particular, retailers may consider selling subsidized products at higher prices. They might also offer fewer discounts, which are an important source of price movements (Nakamura and Steinsson, 2008). With fewer discounts, expansion in sales would be less pronounced. The program design probably matters here as well. As noted in the context of retail sales taxes, the salience of the policy intervention is important for economic incidence (Chetty, Looney, and Kroft, 2009). A rebate administered through the retailer may be less salient, and retailers may find ways to capture part of the benefit through higher prices. In programs that reimburse the consumer directly, retailers do not know consumer take-up, so that the effective decline in prices might be stronger. Not all price effects are relevant to the consumer response, however. Since a product's price also reflects consumers' search efforts for best offers (Coibion, Gorodnichenko, and Hong, 2015), if a subsidy leads to a reduction in this effort, retail prices might go up without necessarily compromising program effectiveness.

Rebate program may exert further behavioral effects on the willingness of households to replace existing with new and more energy efficient appliances. The literature has pointed out that households may lack information on the potential savings from investing in more energy efficient technology, or fail to pay attention (Allcott and Greenstone, 2012, Gerarden, Newell, and Stavins, 2017). Rebate programs, in particular, if promoted and advertized, may improve information and nudge households to be more attentive to energy consumption and their energy bill. A critical issue in this context is whether rebate programs also help consumers make better informed choices among product alternatives. If the programs are tied to energy labels, which provide a coarse ranking of products in terms of energy efficiency, behavioral responses might be relatively strong since consumers have been found to take the labels into account (Sammer and Wüstenhagen, 2006, Newell and Siikamäki, 2014, Houde, 2018). However, since the energy labels serve as a substitute to more accurate information on energy consumption (Houde, 2018), their design and information content become crucial for the effectiveness of rebate programs in reducing energy consumption.

3 Program Design

The empirical analysis studies seven rebate programs for the purchase of energy efficient household appliances implemented between 2009 and 2016 by three member states of the European Union, namely Austria, Hungary and Croatia. The Hungarian and Croatian policies were financed with revenue from the auctioning of carbon certificates; the Austrian programs were a mechanism to reimburse consumers for previously collected environmental fees that were no longer compatible with EU law. All programs, therefore, served solely environmental objectives and were not intended as a fiscal stimulus. Table 1 summarizes the programs focusing on main design characteristics such as consumer and product eligibility, timing, rebate amount, and any recycling requirements i.e. whether participation is contingent on scrappage of an existing device. All subsidies were administered within the EU's legislative framework for energy-related products, whose key elements are described in Appendix A. All but one program defined product eligibility by setting a minimum threshold of energy efficiency in terms of the EU energy label, which rates appliances on a scale from A+++ (most efficient) to G (least efficient).

Table 1: Appliance Replacement Programs: Design and Reported Outcome

Country	Austria			Hungary		Croatia	
Implementation	2009	2010	2010	2015	2016	June 2015	Oct. 2015
Eligibility							
Category	REF, FRZ		WM[a]	WM	REF,FRZ	WM. REF, FRZ[b]	
Energy label	A++		$0.15\frac{\text{KWh}}{\text{kg}}$	A+, A++, A+++		A+++	
Product list			yes	yes	yes		
Subsidization							
Budget (Euro, mm.)	2.9	2.2	3.1	5.4	4.3	2.1	
Amount (Euro)	50 or 100[c]		100	50% or max 80-150[d]		40% or max 100	
Period[e]	Sep.-Dec.	Sep.-Nov.	Apr.-Jun.	Oct.-Jan.	Sep.-Dec.	June	Oct.
Administration							
Scrappage	required			required		recommended	
Eligible consumers	residents			residents[f]		residents	
Disbursement	consumers			retailers		consumers	
Reported outcomes							
№ subsidized	32,816[g]	25,537[h]	29,603	40,522	41,196	10,000	10,000
of this WM			25,459			9,000	8,300
№ recycled	-	16,960	25,892	40,522	41,196	-	-
Median age recycled[i]	-	14	18	-	23	-	-
Δ CO_2 (t/year)	-1,350	-	-	-2,907	-17,803	-235	-220

Notes: [a] Tumble driers of energy label A or above were also eligible, but are not observed in the data.
[b] In addition to the listed categories, tumble driers and dishwashers were also eligible for subsidies.
[c] For refrigerators, the subsidy is 50 euros for height up to 90 cm, and 100 euros – above 90cm. All freezers were subsidized by 100€.
[d] Subsidy is 50% of the retail price up to a maximum of 80 euros for energy class A+, 110 euros for A++, and 150 euros for A+++.
[e] These are statutory purchase periods. In Croatia, budgets were exhausted after 9 days in June, and in a single day in October. In Austria, the budget for the WM program was spent in May, while, to meet demand, the budget in 2009 had to be increased from 2.5 to 2.9 million euros. In Hungary, application and purchase periods were separate. Budgets in the application periods were spent within days. Application periods for the 2015/2016 Hungarian programs are July-Sept. 2015, and July-Sept. 2016, respectively.
[f] Pensioners and large families were allowed to apply for subsidies a few days earlier than other applicants.
[g] № subsidized refrigerators $\leq$ 90 cm: 6,952;$>$ 90 cm: 21,332; Freezers: 4,532.
[h] № subsidized refrigerators $\leq$ 90 cm: 4,605;$>$ 90 cm: 14,687; Freezers: 3,428.
[i] Panels B of Figures E.2 and E.3 show cumulative distributions of the age of recycled appliances for the frige/freezer and washing-machine programs in Austria in 2010, respectively. Panels A of the same figures provide information on subsidized purchases per day and subsidy disbursement.
Sources: Croatia: Croatian Fund for Environmental Protection and Energy Efficiency (Republika Hrvatska Fond Za Zaštitu Okoliša I Energetsku Učinkovitost). Austria: Umweltforum Haushalt GmbH & Co KG as well as from Dehmel (2010). Information on the age and number of recycled appliances, as well as composition by size and type of newly purchased appliances are provided by Karl Tröstl at UFH. Hungary: All information on Hungarian subsidies retrieved from the Applicant Guidelines issued by the Hungarian Ministry of National Development in Nemzeti Fejlesztési Minisztérium. Source of information for the number of replaced appliances for the 2015 and 2016 programs, their CO_2 savings and age composition is the Hungarian Ministry for Innovation and Technology/NFSI through APPLiA Hungary. An earlier subsidy program for refrigerators and freezers in Hungary in 2015 is not analyzed in this paper as it was administered by a different tender agency under a different system. To obtain the list of treated products would have necessitated asking permission from every producer that participated in the program, which was unfeasible.

Austria carried out three rebate programs – two for refrigerators/freezers in 2009 and 2010, and one for washing machines/washer-dryers in 2010.[5] Programs were promoted via commercials and a campaign web site launched at the start of the first rebate program.[6] Consumers who bought an appliance of the highest energy class at the time (A++) could claim a rebate after filling in an application and confirming that they had recycled an old device. Since the EU energy label for washing machines was undergoing reforms in 2010, for this product category, eligibility was defined in terms of minimum KWh/kg consumption. Austrian subsidies were lump-sum and constituted close to 13% of the average purchase price of eligible appliances: Refrigerators higher than 90 cm were supported with 100 euros, and those below 90 cm – with 50 euros. The amount was set at 100 euros for freezers and washing machines. The administrative agency reported CO_2 savings of 1,350 tons per year for the 2009 program. No estimates were provided for the programs implemented in 2010.

We also analyze two Hungarian subsidies, one for washing machines in 2015 and one for refrigerators/freezers in 2016 that were part of the wide-ranging "*Otthon Melege*" or "Warmth of Home" policy.[7] In both instances, individuals wishing to obtain a subsidy had to register through an online government portal, and provide detailed information on the freezer/refrigerator/washing machine that they wanted to replace. They could then make a new selection from a list of qualifying products. A product became eligible only if the manufacturer registered it through the same government portal following a separate procedure. A consumer's selection was valid provided that the newly

[5] Subsidies were financed with revenues from environmental levies. Under regulations implemented in 1993, consumers buying a cooling unit had to pay in advance for its future disposal by purchasing adhesive labels (so-called "*Kühlschrank Pickerl*"). After adjustments in Austrian legalisation aligning it with EU law in 2003, the voucher system ended and remaining funds had to be repaid to consumers, which was accomplished via the three rebate programs. See Dehmel (2010) for a detailed exposition of the political and economic background of the Austrian subsidies.

[6] Exploring internet search activity in Austria using google trends with the key word "Trennungsprämie" shows a first peak in searches in September 2009 and no earlier activity.

[7] Funding came from surplus allowances for greenhouse gas (GHG) emissions under the Kyoto Protocol of the UN Framework Convention on Climate Change. Under the Kyoto Protocol, parties, whose GHG emissions do not exhaust their quotas, can sell any surplus allowances to other parties. The income from the sale of Kyoto units must be used under the Green Investment Scheme/Green Economy Financing Scheme for projects leading to the direct reduction of emissions, or activities supporting this process. Having considerable quota surplus, the Hungarian government, in accordance with the Kyoto Protocol, has implemented programs subsidising households' purchases of more energy efficient appliances. "*Otthon Melege*" incorporates a variety of GHG-reducing initiatives including the replacement of boilers, doors, windows, and complex energy renovation of apartment houses. It is set to continue until 2020 with a total budget of 94 mm. Euro.

chosen appliance yielded 10% energy savings or an annual reduction of at least 20 kg of CO_2 compared to the old device.[8] Programs were promoted via information campaigns launched at the start of application periods.[9]

All permanent residents of Hungary were eligible for the washing machine rebate in 2015. Regarding the refrigerator/freezer replacement program, priority was given to pensioners and large families by allowing them to participate a few days earlier than other applicants.[10] Hungary subsidized energy classes A+++, A++, and A+. Consumers could purchase their pre-selected appliance up to 50% below the retail price. The maximum rebate amounts were significant and covered about 22%(33%) of the average purchase price of a cooling appliance (washing machine) within a given label. Altogether, 81,718 appliances were replaced resulting in annual savings of 2,907 tons of CO_2 for the washing machine subsidy, and 17,803 tons of CO_2 for the frige/freezer program, according to the Hungarian Ministry for Innovation and Technology.

Croatia carried out two programs in June and October 2015 subsidizing a broad range of A+++ household appliances, including refrigerators, freezers, and washing machines. Administrative data on the outcomes of the two Croatian programs indicate that the vast majority of subsidized purchases were washing machines, so this product category is the focus of the analysis below.[11,12] The subsidy amount was a fraction of the price with an upper limit: Consumers received 40% off the retail price, but not more than 100 euros per device, or approximately 20% of the average

[8] The calculation was performed automatically by the government's web site based on the specifications of the old and new appliances. The retailer delivered the device to the household's address, checked that the old appliance was in working condition and its specification corresponded to that reported in the application, and ensured its proper recycling. Only after this obligation was fulfilled, did the retailer obtain the subsidy amount.

[9] Internet search activity in Hungary using google trends and the key word "*Otthon Melege*" shows that the highest search frequency during 2015 is reported for July – within the application period for washing machines.

[10] If these applicants did not exhaust the available budget, everyone else could apply. The funds were allocated to seven regions in Hungary in the same percentage as the population ratios. The application start dates varied by region. The formal application periods listed in Table 1 do not reflect the actual application periods, which in some cases were as short as a few days before the available budget was exhausted. We are grateful to Fanni Mészáros for providing this information.

[11] Despite the (intended) wide scope of the Croatian programs in terms of product categories range, the data covers only a relatively small number of subsidized refrigerators and freezers (see Table 3 in the following section.)

[12] The programs were part of Croatia's Energy Development Strategy and were funded with auctioning revenue within the EU's Emissions Trading System (ETS). According to the EU ETS Directive (2003/87/EC), at least 50% of revenue generated from the auctioning of CO_2 emission allowances should be utilized for the achievement of climate objectives (European Parliament and Council of the European Union, 2003).

purchase price of eligible washing machines. At its announcement in June 2015, the program was advertized by the Croatian Fund for Environmental Protection and Energy Efficiency and the government.[13]

The design of the June and October policies was identical. Conditional on the budget, consumers could receive a subsidy by purchasing an eligible appliance from selected retailers. In the June program, the budget was set up to subsidize 10,000 units and was spent within nine days. In the second program, the same amount of funds was exhausted even faster.[14] There were no restrictions on consumer eligibility and energy savings or a formal requirement for the replacement of an old appliance, although disposal was encouraged. Based on statistics provided by the program administrator, in June (October), 51% (40%) of participants replaced a device older than six years. The officially reported figures on CO_2 savings, measured in tons per year, are 235 and 220, for the first and second initiative, respectively.[15]

4 Data

We use a product-level monthly panel data set of scanner prices and unit sales of white goods sold in eight European countries.[16] The data is provided by the market research company Gesellschaft für Konsumforschung (GfK) Retail and Technology GmbH and is part of the company's Retail Panel on Major Domestic Appliances. Product-level prices are unit sales-weighted averages across retailers within a month within a country inclusive of sales (value-added) taxes, while quantities are the sum of unit sales across retailers in a month in a country. All products fall within two categories: refrigerators & freezers (cold appliances) and washing machines. Identical products sold in multiple countries have the same product identification number (id). Apart from monthly

[13] Exploring internet search activity based on google trends and the key word "Programa A+++ UREĐAJA" in Croatia shows a first spike in searches in the first week of June 2015.

[14] Cf. Croatian Fund for Environmental Protection and Energy Efficiency (Republika Hrvatska Fond Za Zaštitu Okoliša I Energetsku Učinkovitost)

[15] The outcomes of both subsidies are discussed in the news section of the Environmental Protection and Energy Efficiency Fund (the subsidy administrator) at http://www.fzoeu.hr/.

[16] The data covers Austria, the Czech Republic, Croatia, Germany, Hungary, Poland, and Slovenia from January 2004 until January 2017, and Serbia from January 2008 to January 2017.

prices and units sold, each product is characterized in the data by a set of physical attributes described in Table B.1 in the Appendix. Importantly, these include the energy label, and, for products sold in Austria, Croatia, or Hungary, additionally, a model number as designated by the manufacturer.

Panel A of Table 2 reports descriptive statistics of the full sample. The average product in the data sells about 71 units per month-year at a price of 500 euros, is sold in close to 3 countries and is on display in the respective regional segment of the European market a little over two years. Restricting the sample to products sold in at least two countries at the same time, which is an essential requirement for the identification strategy outlined below, yields the estimation sample, summarized in Panel B. This reduced sample remains largely representative of the full data, in terms of both key variables, and country and product-category composition. The largest product category is cold appliances, which accounts for 68% of all observations.

Whether a product qualifies for a subsidy or not is determined by the specific criteria of each program. For the three countries under consideration, Table 3 provides information on the sets of products in the respective subsidy years according to eligibility status. The Croatian programs and Austrian refrigerator & freezer subsidies in 2009-2010 limited participation to a specific energy label: all A+++ products in Croatia and all A++ cold appliances in Austria were eligible. Due to a producer registration requirement, the Hungarian programs are based on administrative lists of qualifying products. Likewise, the KWh/kg participation threshold for washing machines in Austria in 2010 necessitated a product list (See Table 1). In these cases, we match model numbers from the respective administrative lists with model numbers in the GfK data in order to determine the eligibility status.

Based on the programs determining eligibility with administrative lists, the coverage of the data is extensive – 97% of all eligible washing machines in Austria and Hungary, and 85% of eligible cold appliances in Hungary are present in the data. Table 3 also demonstrates a substantial heterogeneity in program scale: only 13-17% of products in Austria qualified for subsidies as opposed to 43-58% in Hungary. These differences are driven not only by participation criteria, but also by country,

Table 2: Descriptive Statistics

	Mean	Std. Dev.	Min	Max	N
	A. Full sample				
№ Units sold	70.8	208.2	2	24,965	1,951,851
Price (Euro)	498.7	355.4	0.01	11,538	2,339,489
Market age (months)	27.4	22.5	1	157	4,188,094
Annual energy (KWh)	255.3	131.8	14	3,285	3,319,827
№ countries	2.9	1.9	1	8	4,188,094
	B. Estimation sample				
№ Units sold	74.2	211.5	2	19,062	1,294,233
Price (Euro)	523.4	371.4	0.4	11,538	1,535,039
Market age (months)	26.3	20.3	1	157	2,513,361
Annual energy (KWh)	251.9	136.0	51	1,768	2,124,153
№ countries	3.8	1.7	2	8	2,513,361

Notes: The table shows summary statistics per product (model) per month averaged across time, countries, and products. "Market age" is the average number of months a product is sold in a given European country. "№ countries" is the average number of countries in which a product is sold. The only transformations done to the data in Panel A are the following: products without id are dropped (2009 obs.); negative values for units sold and prices are replaced with missing observations (151 obs.); zero prices and unit sales smaller than 2 are replaced with missing observations (946,476 obs.); outliers in annual energy consumption (reported consumption of 0,1,2, 8500 and 9999 KWh) are replaced with missing observations. Number of observations associated with a specific country as a percent of all observations are – AT: Austria (17.37); HR: Croatia (6.27); CZ: the Czech Republic (13.92); DE: Germany (27.42); HU: Hungary (10.39); PL: Poland (14.32); RS: Serbia (4.09); SI: Slovenia (6.23)–or associated with specific product category are – FRZ: Freezers (11.62); REF: Refrigerators (56.36); WM: Washing machines (32.02). In Panel B, the data is reduced to products sold in at least two countries over their life cycle and within a product-date cell. In Panel B: AT (19.49); HR (7.25); CZ (15.48); DE (21.03); HU (12.45); PL (11.50); RS (4.43); SI (8.36). FRZ (11.93); REF (57.34); WM (30.73). Table B.3 in the Appendix presents more detailed statistics on the full data by product category and by energy label.

category-, and label-specific developments over time.[17]

A comparison of subsidized products with all products in a given country-subsidy year points to substantial energy efficiency gains from subsidized cold appliances. Specifically, the energy consumption of refrigerators & freezers in the top energy efficiency class is only 70-85% of the median annual energy use of all products. These savings are considerably smaller for the top label of subsidized washing machines, whose median consumption ranges from 86 to 94% of the market

[17] Figure E.4 in the Appendix shows diffusion curves (market shares) of different energy labels in Austria, Croatia, Germany and Hungary, separately for refrigerators/freezers and washing machines. Note the small penetration rate of higher energy efficiency cold appliances (A++ and A+++) in Central and Eastern Europe (CEE) relative to Germany and Austria. The 20% market share of A++ refrigerators & freezers in Croatia and Hungary in 2017 is comparable to that in Germany in 2010, pointing to a lag of close to seven years before technology supporting the top labels in cold appliances becomes available in CEE.

Table 3: SUBSIDY ELIGIBILITY

	Austria			Hungary		Croatia	
Subsidy Year	2009	2010	2010	2015	2016	2015	2015
Product Category	REF FRZ	REF FRZ	WM	WM	REF FRZ	REF FRZ	WM
Identification of subsidized products by	Energy Label		Administrative List			Energy Label	
№ products in GfK data in subsidy year	3,337	3,165	1,151	1,077	1,905	1,082	774
№ subsidized in administrative list	–	–	154	468	1,122	–	–
№ subsidized in GfK data	–	–	149	456	955	–	–
№ subsidized in GfK data in subsidy year	408	565	134	390	913	33	310
№ subsidized in GfK data sold concurrently in min. two countries,	395	540	134	413	861	33	278
of which:							
in subsidy year	381	525	119*	338	811	33	268
Energy Class A+	–	–	2	37	351	–	–
Energy Class A++	381	525	26	75	367	–	–
Energy Class A+++	–	–	57	225	93	33	268
№ non-subsidized in GfK data in subsidy year,	2,929	2,600	1,017	687	992	1,049	464
of which:							
sold concurrently in min. two countries	2,167	1,925	742	499	674	811	283

Notes: The table reports information on the cross-section of products in a given country in a given subsidy year by subsidy eligibility status. Administrative eligibility lists exist for the two Hungarian programs and the Austrian washing machine subsidy in 2010. For these three programs, assignment into treatment is done by merging manufacturer's model numbers in administrative lists to the GfK data. For the remaining four programs, product eligibility is defined solely via the energy label. Hungary subsidized three energy labels (A+, A++, A+++), Austria–A++ for refrigerators and freezers, and Croatia–A+++. The Austrian washing machine subsidy defined eligibility in KWh/kg energy consumption, which cut across four labels. Croatia had two programs, one in July and one in October 2015. Since the number of products does not change within a year and to preserve consistency with the category-specific programs in Hungary and Austria, the table reports separately for washing machines and refrigerators/freezers in Croatia, although both categories were subsidized at the same time. *The remaining 34 products are of energy class A.
Sources: The official list of eligible washing machines for the 2010 Austrian subsidy is provided by Karl Tröstl at UFH. For the 2015 and 2016 Hungarian programs, official government lists of products registered by manufacturers, and thus eligible for subsidies, were downloaded from the respective programs' web sites, are on file with the authors, and are available upon request.

median. In addition, with few exceptions, subsidized models are more expensive and younger.[18]

[18]For more details of this comparison, refer to Table B.2 in the Appendix.

5 Methodology

We explore the effects of subsidies on unit sales using the following baseline regression specification:

$$\begin{aligned}
\Delta\log(\text{UNITS})_{idc} &= \left(\beta_B \mathsf{L}^{-1}\mathsf{I}_{cd} + \beta_P \mathsf{I}_{cd} + \beta_A \mathsf{L}^{+1}\mathsf{I}_{cd}\right) \cdot \mathsf{S}_i \\
&+ \left(\delta_B \mathsf{L}^{-1}\mathsf{I}_{cd} + \delta_P \mathsf{I}_{cd} + \delta_A \mathsf{L}^{+1}\mathsf{I}_{cd}\right) \cdot (1 - \mathsf{S}_i) \\
&+ \gamma X_{icd} + \alpha_{id} + \mathsf{S}_i \cdot \sigma_{cd} + (1 - \mathsf{S}_i) \cdot \Sigma_{cd} + \epsilon_{icd}.
\end{aligned} \tag{1}$$

$\Delta\log(\text{UNITS})_{icd}$ is the log change of unit sales of product (model) i in country c at date d, where the date varies by month and year. S_i is a product-specific indicator of eligibility, which is equal to one for subsidized products, while $(1 - \mathsf{S}_i)$ denotes non-subsidized products; I_{cd} is a binary country-date specific variable that equals one for all program months in a country. A one-month ahead indicator ($\mathsf{L}^{-1}\mathsf{I}_{cd}$) as well as a lagged indicator ($\mathsf{L}^{+1}\mathsf{I}_{cd}$) account for intertemporal shifting as consumers postpone or accelerate their purchases to the period of a subsidy. Hence, β_B, δ_B capture changes in unit sales of subsidized and non-subsidized products respectively before a program starts, β_P, δ_P measure effects during the program time, and β_A, δ_A pick up any after-program effects.

To control for possibly different product-specific time trends in sales across countries, X_{idc} incorporates the number of months since a product is on display in a given country c, which is referred to as "market age" ($mage$), as well as its squared term. The specification further includes country-specific seasonal patterns in sales, σ_{cd} and Σ_{cd}, that are allowed to differ between the groups of subsidized and non-subsidized products in light of their different characteristics. α_{id} is a product-date specific fixed effect, which nests product dummies, and thus controls for all time-invariant unobservable product characteristics such as attributes and brand. Importantly, α_{id} ensures that the program effect captures the response in the unit sales of a product relative to the contemporaneous change in the unit sales of the identical product sold in countries without a subsidy. Identification in this framework, therefore, comes from differences in the growth rates of sales between a country that offers a subsidy and all other countries within the same product-date cell.

Note that this identification method circumvents an important problem in program evaluation analysis stemming from potential externalities of treatment for non-participants. In particular, developments in the sales of non-subsidized products within a given program country do not constitute a valid counterfactual for subsidized products. As discussed in Section 2, on the one hand, an increased demand for qualifying products may occur at the expense of their ineligible counterparts as consumers revise their decisions and upgrade (or downgrade). On the other hand, sales of non-subsidized products may exhibit a positive response as a result of behavioral spillover effects arising from improved information on and heightened public attention to energy cost and CO_2 emissions. Irrespective of the direction of the effect, attempts to base counterfactuals on market performance of non-subsidized products would violate the "stable unit treatment value assumption" (e.g., Lechner, 2011).

To check for effects on non-subsidized products, the specification uses interactions with S_i and $1 - \mathsf{S}_i$ to produce separate, jointly estimated "average treatment effects on the treated" (ATET) for the two sub-groups of products after removing the growth rate of unit sales of each individual product. Since subsidies are implemented in different time periods and regions of the European Common Market, individual programs are analyzed separately without loss of efficiency. In each case, the sample is adjusted to ensure that developments of sales in other regions, used to derive counterfactuals, do not capture any contemporaneous rebate programs.

The estimates of the above specification can be used to quantify the changes in unit sales of subsidized and non-subsidized products that are driven by the rebates. Given that the dependent variable is the log-change of unit sales, the average program effect is the total increase in the sales of subsidized models during the program relative to the counterfactual, and is computed as $e^{\widehat{\beta_B}+\widehat{\beta_P}} - 1$. The average pre-program effect, driven by consumers postponing purchases, is $e^{\widehat{\beta_B}} - 1$, while the post-program response, reflecting purchases brought forward, is defined as $e^{\widehat{\beta_B}+\widehat{\beta_P}+\widehat{\beta_A}} - 1$. Adding the program, pre-program and post-program responses yields the net-program outcome, determining the effect on subsidized products net of intertemporal shifting.[19]

[19] For a program with a duration of n months and considering two pre- and two post-program months, the average pre-program response relative to the counterfactual is calculated as $\frac{1}{2}\left[\left(e^{\widehat{\beta_{B_1}}} + e^{\widehat{\beta_{B_1}}+\widehat{\beta_{B_2}}}\right) - 2\right]$. The average program

Upgrading effects associated with consumers switching away from their intention to buy non-subsidized products would be reflected in a decline of their sales relative to the number of counterfactual unit sales. In the above specification, these effects on unit sales of non-subsidized models are captured by the coefficients δ_B, δ_P and δ_A. A point estimate of switching within the program time is then given by $e^{\widehat{\delta_B}+\widehat{\delta_P}} - 1$.[20] As noted above, this effect is not necessarily negative since dissemination of energy-efficiency-related information may also induce replacement outside of the set of qualifying products.

For ease of exposition, equation (1) uses only first-order forward and lag operators. The estimation below typically employs second-order operators, which capture effects two months before or after a rebate program. Since a basic inspection of media trends did not reveal much consumer interest outside the program timing (see Section 3), suggesting short or no pre-announcements, the baseline specification does not consider longer windows. However, note that results are robust to the inclusion of higher-order forward and lag operators.

To evaluate the price effects of a program we use a specification similar to that for unit sales, formally

$$\begin{aligned}\Delta\log(\text{PRICE})_{idc} &= \left(b_B \mathsf{L}^{-1}\mathsf{I}_{cd} + b_P \mathsf{I}_{cd} + b_A \mathsf{L}^{+1}\mathsf{I}_{cd}\right)\cdot \mathsf{S}_i \\ &+ \left(d_B \mathsf{L}^{-1}\mathsf{I}_{cd} + d_P \mathsf{I}_{cd} + d_A \mathsf{L}^{+1}\mathsf{I}_{cd}\right)\cdot (1-\mathsf{S}_i) \\ &+ cX_{icd} + a_{id} + \mathsf{S}_i \cdot s_{cd} + (1-\mathsf{S}_i)\cdot S_{cd} + e_{idc}.\end{aligned} \tag{2}$$

$\Delta\log(\text{PRICE})_{idc}$ is the percentage change of the average retail price of model i at date d in country c. Note that in all cases, the retail price is not inclusive of a rebate. Hence, if a subsidy is fully passed on to consumers, price effects should be absent. Any price increases during the program

effect relative to the counterfactual is given by $\frac{1}{n}\left[e^{\sum_{j=1}^{2}\widehat{\beta_{B_j}}+\widehat{\beta_{P_1}}} + e^{\sum_{j=1}^{2}\widehat{\beta_{B_j}}+\widehat{\beta_{P_1}}+\widehat{\beta_{P_2}}} + \ldots + e^{\sum_{j=1}^{2}\widehat{\beta_{B_j}}+\widehat{\beta_{P_1}}+\ldots+\widehat{\beta_{P_n}}} - n\right]$. The average post-program response is $\frac{1}{2}\left[e^{\sum_{j=1}^{2}\widehat{\beta_{B_k}}+\sum_{j=1}^{n}\widehat{\beta_{P_j}}+\widehat{\beta_{A_1}}} + e^{\sum_{j=1}^{2}\widehat{\beta_{B_k}}+\sum_{j=1}^{n}\widehat{\beta_{P_j}}+\widehat{\beta_{A_1}}+\widehat{\beta_{A_2}}} - 2\right]$. The net program effect is obtained as Program + $\frac{2}{n}$Pre-program + $\frac{2}{n}$Post-program.

[20] Since consumers' switching may take place across time, losses in unit sales may also be found before and after the program time. The magnitude of these effects can be computed analogously to the analysis of pre- and post-program responses. Given adjustment costs, contemporaneous switching should be strongest.

or decreases before or after its start could compromise program effectiveness, especially if such price effects are stronger for products with higher energy efficiency. As in the analysis of sales, the inclusion of product-specific date effects a_{id} ensures that the program effect captures the response in the price of a product relative to the contemporaneous price of the identical product sold in countries without a subsidy.

The baseline specifications (1) and (2) assume that program effects on non-subsidized products are homogenous within a country. This may not be the case if substitution effects are stronger for products, which are similar to eligible products. As a robustness check, we explore response heterogeneity for a subset of "close substitutes." To identify these products, we apply the "coarsened exact matching" (CEM) procedure developed by Blackwell et al. (2009). In particular, subsidized and non-subsidized products are exactly matched on several categorical/binary product attributes and on a mean price coarsened into bins.[21] We consider matched strata consisting of both subsidized and non-subsidized products within the same price interval and with identical product characteristics to be close substitutes.

Equations (1) and (2) explore effects of subsidy programs on groups of observations as unit sales and prices are grouped by product, country and date. If unaccounted for, group effects may lead to biased inference. Based on extensive testing, we cluster standard errors at the product level. The discussion below explains our reasoning.

Since programs are country-specific, over-rejection of the null hypothesis of the absence of program effects may be a concern due to within-country correlation among subsidized and non-subsidized products. For each product in the data, however, unit sales and prices are observed in at most eight countries, which strongly differ is size. With a small number of clusters that are unbalanced in

[21] For refrigerators and freezers, the CEM procedure matches exactly on type, construction, and the presence of a no-frost system, and for washing machines – on type and capacity in kg. See Table B.1 for an overview of available product characteristics. Additionally, for all three product categories, prices averaged over five months, three months prior to the start of a subsidy, are coarsened into 16 bins with the first bin set at (0,200), the last bin at (1600+), and 14 100 euros intermediate bins. For example, all Austrian, 2-door freezer bottom, built-in refrigerators with a no-frost function, sold in 2009 and worth between 200 and 300 euros belong to a single stratum. To avoid unbalanced strata with many non-subsidized products matched to a few subsidized, the procedure randomly drops observations to ensure an equal number.

terms of number of observations, a robust variance-matrix estimator clustered by country would be biased downwards as demonstrated, for example, in Conley and Taber (2011). In addition, since all estimations entail only a single treated cluster, the wild cluster bootstrap (WCB) procedure of Cameron, Gelbach, and Miller (2008) would also fail to provide valid statistical inference.[22] To achieve reliable finite-sample inference, we employ the sub-cluster wild bootstrap approach proposed by MacKinnon and Webb (2018), which allows us to cluster below country level.

According to MacKinnon and Webb (2018), a clustering method is reliable when differences between the p-values of restricted and unrestricted estimates are minimal, so that inferences are the same. We implemented this procedure by bootstrapping at the intersection of country and product. As reported in the Appendix, p-values and confidence intervals from a restricted ordinary wild bootstrap (null hypothesis of the absence of program effects imposed) and from an unrestricted ordinary wild bootstrap are very similar. Likewise, restricted and unrestricted WCB clustering at the product level yield largely equivalent p-values and 95% CIs.[23] Based on these tests, in all subsequent estimations, we choose to cluster standard errors by product.[24]

6 Results

The goal of the empirical analysis is to study the effects of local rebate programs on unit sales and prices by comparing the market performance before, during and after a subsidy's implementation with the concurrent performance of the same product in other regions of the EU common market. A

[22] In particular, MacKinnon and Webb (2018) and Roodman et al. (2019) show that tests using the restricted WCB would tend to under-reject, whereas those based on the unrestricted WCB would over-reject the null hypothesis. In the context of eq. (1), this is confirmed by Table D.2 in the Appendix, which shows that for unit sales effects of subsidized products there are large discrepancies between the p-values from a restricted and an unrestricted WCB that clusters by country. The differences do not disappear, if clustering is at the intersection of country and date (country∩date) instead, which increases the number of clusters, but treats observations in a given country at different dates as independent. The problem is especially pronounced for the Austrian programs due to cluster imbalance. In the case of the Croatian and Hungarian subsidies, observations are more evenly distributed across a larger number of Central and Eastern European controls. Clustering at a finer level by country∩date leads to a larger convergence of p-values for these two countries compared to Austria.

[23] See Table D.3 in the Appendix.

[24] Alternative p-values and standard errors are reported in the Appendix.

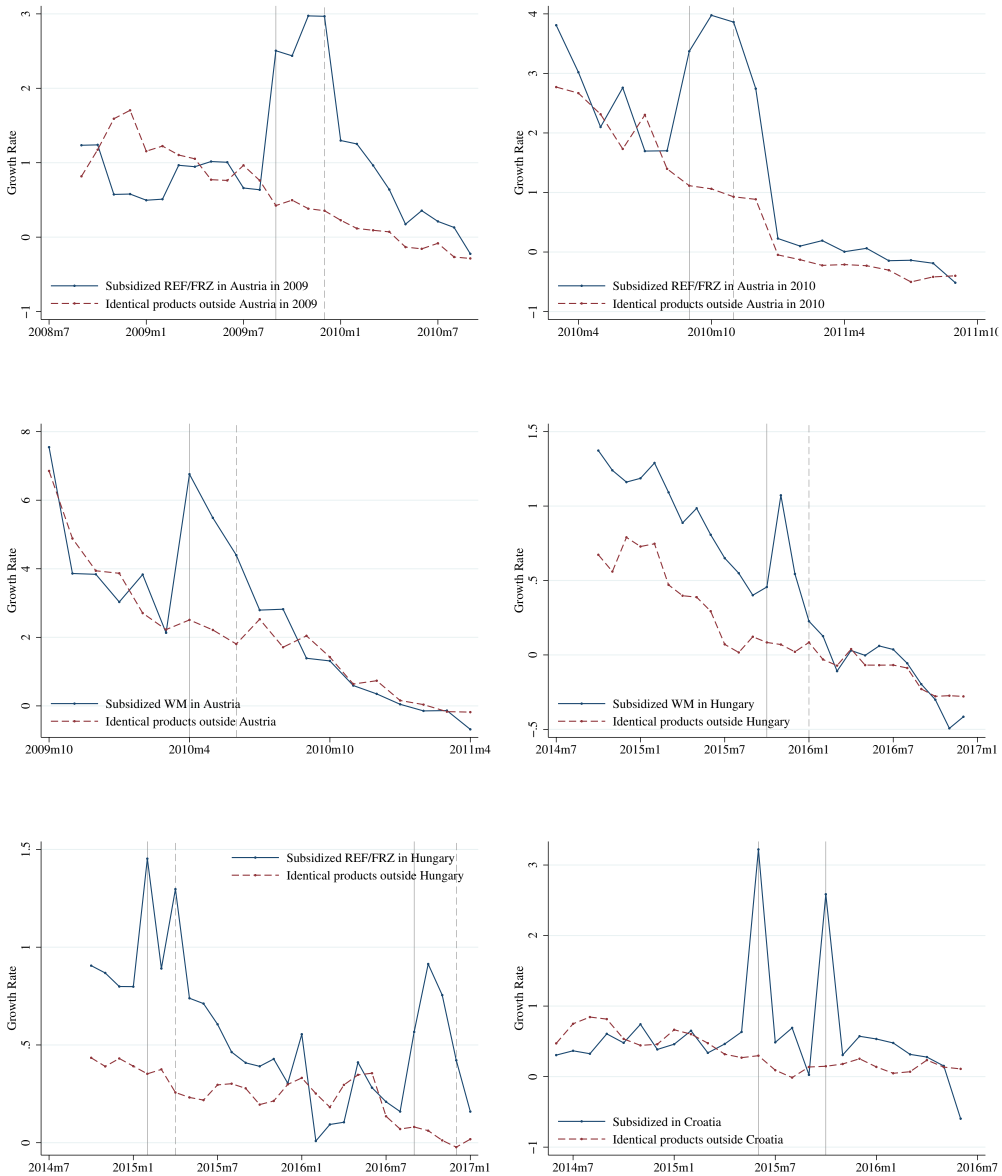
first impression of the effects on unit sales based on the raw data is provided by Figure 1. It displays year-over-year growth rates of purchases of subsidized products in the respective program's country and the average growth rates of contemporaneously sold identical products in other countries. All figures show a strong increase in growth rates in the first implementation month (marked by a solid vertical line) followed by a drop at the end of a program (vertical dashed line). Note that the last two plots (Croatia and refrigerators/freezers in Hungary) depict two programs each. In all cases, sales in other countries do not exhibit spikes around the start or end of a program. Although unadjusted for any composition effects or product-specific trends, this simple comparison nevertheless points to largely similar pre-subsidy patterns.

6.1 Regression Analysis

Table 4 reports estimates of the effects on unit sales and prices of both subsidized and non-subsidized refrigerators & freezers for the earliest program implemented in Austria in 2009. Starting with subsidized products, Column (1) shows that their unit sales decline by 11 and 12 log points in the two months before the program (cf. coefficients with subindices B_2 and B_1), followed by a rise of 82 log points in the first month of the program (cf. coefficient with subindex P_1). Another 34-log-points increase in sales is observed in the third month of the subsidy. Purchases drop by 27 log points after the program ends (cf. coefficient with subindex A_1), but show a rebound in the second month (subindex A_2). All, but three coefficients are statistically significant at the 1% level.[25] Column (2) reports corresponding estimates for non-subsidized products: There is no evidence of consumers switching away from non-subsidized appliances. Rather, their sales actually increased slightly. With respect to price effects, Column (3) reveals a cumulative increase of 2.4% for subsidized products in the two months prior to implementation, with prices remaining unchanged throughout the program, and growing again by 2.1% in the second month after the program ended. In Column (4), a statistically significant decline in the prices of non-subsidized products by 1.2% in the first

[25]The standard errors reported in Table 4 are clustered at the level of the individual product. Table D.1 in the Appendix shows standard errors clustered by country or by the intersection of country and date, which, given the discussion in Section 5, are biased downwards.

Figure 1: Growth Rates of Unit Sales in Raw Data



Notes: The plots are based on a sample reduced to the products sold in Hungary, Austria, or Croatia in the relevant program years. Thus, all devices exiting (entering) the data set prior to (after) a program year are excluded, and so are any products in Germany, the Czech Republic, Poland, Slovenia, and Serbia, which are not contemporaneously sold in a subsidy year in Hungary, Austria, or Croatia. The solid lines depict year-over-year growth rates of the total number of units sold of subsidized products. The dashed lines are the year-over-year growth rates of the total number of units sold of the identical products averaged across all other countries, in which they are sold contemporaneously. The beginning of each subsidy program is marked with a solid vertical line and the end – with a dashed line. These two lines overlap for the Croatian programs due to their implementation in a single month. The two Croatian programs are depicted in a single plot. The growth rates of the 2010 Austrian fridge/freezer program are calculated relative to 2008, since the 2009 program also started in September. The graph for the Hungarian refrigerator/freezer programs captures an earlier subsidy in 2015, which is not studied in this paper (see note to Table 1).

Table 4: Austria: Unit Sales and Price Response to 2009 Program

	(1)	(2)	(3)	(4)
	REF/FRZ Program 2009			
	Unit Sales		Prices	
	Sub.	Non-sub.	Sub.	Non-sub.
$\beta_{B_2}, \delta_{B_2}, b_{B_2}, d_{B_2}$	-0.105	0.039	0.010	-0.000
	(0.086)	(0.039)	(0.008)	(0.004)
$\beta_{B_1}, \delta_{B_1}, b_{B_1}, d_{B_1}$	-0.121	-0.040	0.014	0.006
	(0.042)	(0.024)	(0.004)	(0.002)
$\beta_{P_1}, \delta_{P_1}, b_{P_1}, d_{P_1}$	0.824	0.081	0.001	-0.012
	(0.088)	(0.041)	(0.007)	(0.004)
$\beta_{P_2}, \delta_{P_2}, b_{P_2}, d_{P_2}$	-0.186	-0.034	-0.000	0.000
	(0.057)	(0.029)	(0.005)	(0.003)
$\beta_{P_3}, \delta_{P_3}, b_{P_3}, d_{P_3}$	0.338	0.114	-0.001	0.013
	(0.090)	(0.053)	(0.010)	(0.005)
$\beta_{P_4}, \delta_{P_4}, b_{P_4}, d_{P_4}$	-0.018	-0.039	0.001	0.002
	(0.057)	(0.032)	(0.005)	(0.003)
$\beta_{A_1}, \delta_{A_1}, b_{A_1}, d_{A_1}$	-0.272	0.023	-0.007	0.001
	(0.076)	(0.045)	(0.007)	(0.004)
$\beta_{A_2}, \delta_{A_2}, b_{A_2}, d_{A_2}$	0.176	0.006	0.021	0.008
	(0.076)	(0.051)	(0.008)	(0.005)
N	537,385			
Product-date	211,609			
Products	11,692			

Notes: The table reports results for the refrigerator/freezer program implemented in Austria in 2009 and summarized in Table 1. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding washing machines. The dependent variable is either the log change in unit sales in Columns (1)-(2), or the log change in price in Columns (3)-(4). All specifications are based on interactions of country-specific date dummies with a product-specific subsidy eligibility indicator, and include country-month-eligibility fixed effects as per Eqs. (1) and (2). All columns report only the specified reference category's coefficients (subsidized or non-subsidized products), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. For effects on subsidized refrigerators/freezers by height, see the first part of Table C.2. Standard errors in parentheses are robust in all specifications and clustered by product. Wild cluster bootstrapped standard errors clustering by product and ordinary wild bootstrapped standard errors clustering at the intersection of country and product (country ∩ product) are shown in Table D.3.

program month is offset by a 1.3% increase in the third month.[26]

Rather than going through detailed estimates for the other six rebate programs, henceforth we focus on graphical representations of the predicted time paths of unit sales and prices based on the cumulative sums of coefficient estimates for each program.[27] Figure 2 depicts the time paths of the levels of unit sales and prices relative to the baseline as well as 95% confidence bounds for the three refrigerator & freezer rebates.

The Austrian program in 2009 is described visually in the first panel of Figure 2 (Panel A). Some postponement of purchases to the time of the program is clearly visible, as well as the lack of decline in sales, post-program. During the program, units sales climb up to 53 log points above the baseline in the third month (November), while the decrease in the earlier month may be due to the quick use-up of allocated funds, and the subsequent decision to extend the budget (see Table 1). The sales of non-subsidized products show a small increase during the program time, which persists after the program's end. The plot of the price paths indicates small increases for subsidized products before and after the program, which do not differ much from price developments for non-subsidized products.[28]

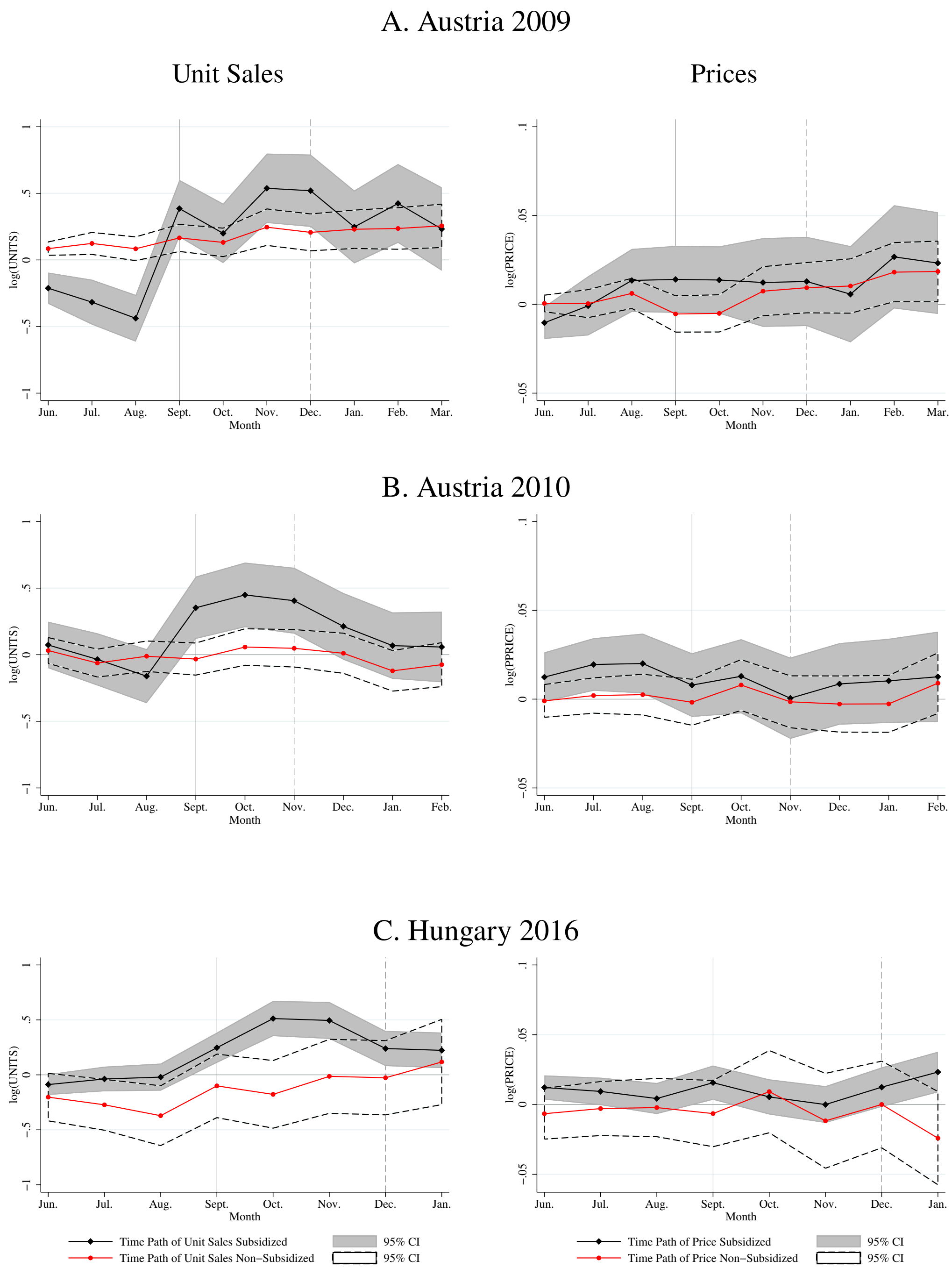
Panel B of Figure 2 shows the implied developments in unit sales and prices of the second (repeated) subsidy program for refrigerators & freezers carried out in Austria in 2010. There is a small drop in unit sales prior to implementation, followed by a growth of 45 log points above the baseline in the second month of the program (October) before sales revert back to the pre-subsidy level in January next year. Statistically significant responses are not detected for the sales of non-eligible products. Similarly, prices show little program effects.

[26]A specialty of the Austrian 2009 program is that subsidy amounts vary by the size of the appliance. Table C.2 shows that effects for unit sales are quite similar for small and large appliances, although the timing of price responses differs.

[27]The Appendix contains a full set of tables (Table C.1-C.5) of coefficient estimates for the remaining programs structured analogously to Table 4. In particular, Tables C.1, C.3 and C.5 report estimated effects on the unit sales and prices of subsidized and non-subsidized products. For those programs where the rebate amount varies by a given product characteristic (appliance's height or energy label), Tables C.2 and C.4 provide estimates by height and label, respectively.

[28]Note that the confidence bands in the figures are based on joint statistics of the estimation parameters reported in Tables 4, C.1 or C.5 in the Appendix.

Figure 2: Refrigerators and Freezers: Time Path of Unit Sales and Prices



Notes: The figures depict the predicted time paths of unit sales (left) and prices (right) of both subsidized (black solid line) and non-subsidized (red solid line) refrigerators/freezers for each program based on cumulative sums of coefficient estimates from Eqs. (1) and (2) using three-month windows around each program. Note that since our data ends in January 2017, plots pertaining to the Hungarian rebate in 2016 show only one month after the subsidy's end. The beginning of each program is marked with a solid vertical line and the end – with a dashed line. 95% confidence intervals based on clustered standard errors by product are displayed in gray for subsidized, and marked with dashed lines for non-subsidized products. Refer to Tables C.1 and C.3 for details on coefficient estimates.

The third part of Figure 2, Panel C, pertains to the rebate program in Hungary in 2016. For simplicity, the plots outline the average unit sales and price effects across all subsidized products.[29] Sales pick up in the program time and reach a maximum of 51 log points above the baseline in the second month (October). There is no evidence of intertemporal shifting. Unit sales of non-subsidized appliances remain below the baseline until January 2017. A modest price increase (1.6%) is observed for subsidized products in the beginning and a stronger one (2.3%) shortly after the end of the program.

Figure 3 summarizes the estimates for the four subsidy programs targeting washing machines. Panel A describes results for the Austrian rebate program in 2010. Probably due to the small number of subsidized appliances (Table 3), effects for this program are estimated rather imprecisely as demonstrated by the relatively large confidence bands for both unit sales and prices. The 55-75% surge in subsidized purchases in April and May is accompanied by a small and statistically insignificant reduction in the sales of non-subsidized washing machines. The prices of subsidized products display an increase after the program, but this estimate is also quite imprecise.

Panel B of Figure 3 depicts the effects of the two Croatian programs. In response to the rebate, in June (first program) sales increase by 78 log points, and in October (second program) by 56 log points relative to the baseline. Given the limited funds, programs end quickly resulting in a strong decline back to the baseline in the next month. While consumers do not appear to have postponed purchases to take advantage of the June program, the second program exhibits a pronounced dip in sales prior to its implementation comparable in absolute magnitude to the subsequent subsidy effect. The results indicate no upgrading: On the contrary, in June the sales of non-subsidized washing machines rise as much as 40%, but do not respond in October. Price patterns for subsidized and non-subsidized products are similar, increasing at the start of the first program and then settling at a higher level (4-5% above the baseline) from July onwards.

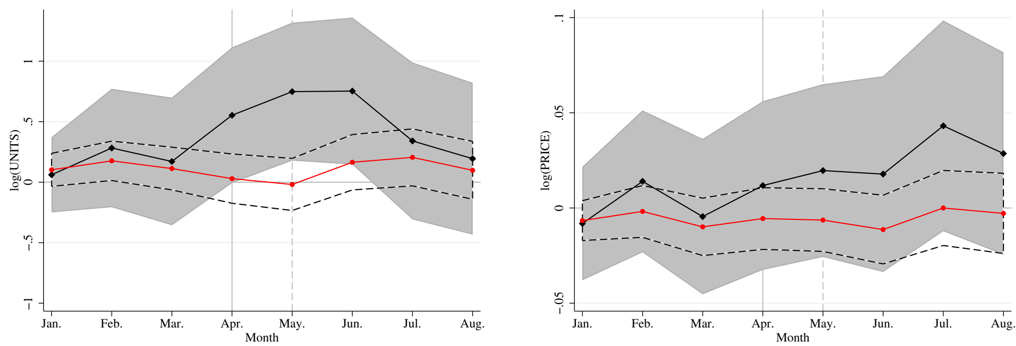
Results for the washing machine subsidy in Hungary in 2015 are displayed in Panel C of Figure 3.

[29] Since the subsidy rate varies with the energy class, we also provide separate estimates by label. See Columns (7)-(12) in Table C.4 for coefficient estimates. For visual representation of the time paths by label, refer to Panel B of Figure E.1 in the Appendix.

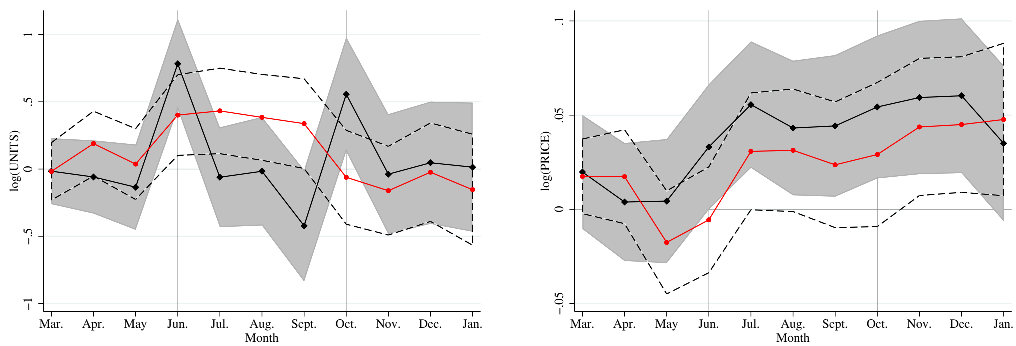
Figure 3: Washing Machines: Time Path of Unit Sales and Prices

A. Austria 2010

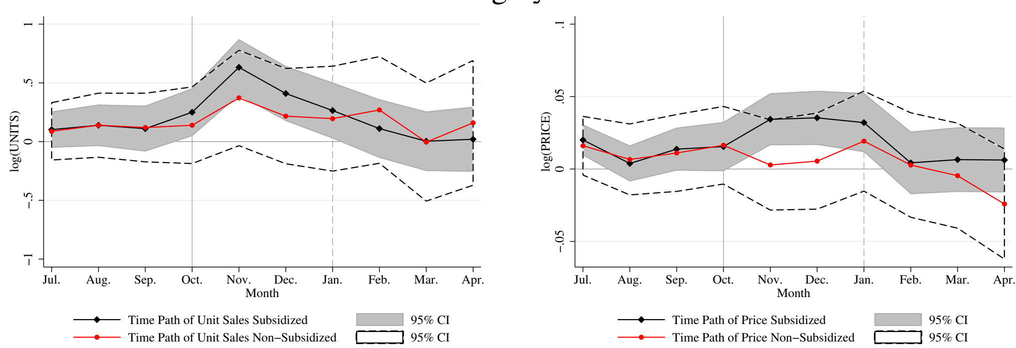
Unit Sales | Prices



B. Croatia 2015



C. Hungary 2015



Notes: The figures depict the predicted time paths of unit sales (left) and prices (right) of both subsidized (black solid line) and non-subsidized (red solid line) washing machines for each program based on cumulative sums of coefficient estimates from Eqs. (1) and (2) using three-month window around each program. The beginning of each program is marked with a solid vertical line and the end – with a dashed line. These lines overlap for the Croatian programs due to their implementation in a single month. The two Croatian programs are depicted in a single plot. 95% confidence intervals based on clustered standard errors by product are displayed in gray for subsidized, and marked with dashed lines for non-subsidized products. Refer to Tables C.1, C.3, and C.5 for details on coefficient estimates.

Unit sales rise up to 63 log points over the baseline in the second month of the program (November) and revert back to the baseline in April next year.[30] An increase in the sales of non-subsidized products is found for November, but is estimated imprecisely. Prices of subsidized models grow by up to 3.5% in the second month of the program and return to their pre-subsidy level in February, whereas no statistically significant price response is found for non-subsidized products.

Table 5 summarizes the outcomes of all rebate programs. Column (1) shows the program duration in months. The other columns present monthly averages of the program, pre-, post-, and net-program effects for unit sales and prices. Columns (6) and (8) outline program effects for unit sales and prices of non-subsidized appliances. As reported in Column (2), in the implementation period, all programs led to economically and statistically significant increases in unit sales relative to counterfactuals, ranging from as high as 122 log points for washing machines in Croatia in June 2015 to 35 log points in Hungary in the same year. The two Hungarian rebate programs exhibit considerable heterogeneity in the program effect by energy label. Columns (3) and (4) demonstrate that the sizable program effects are not driven by consumers delaying or accelerating purchases. For all subsidy programs the pre-program responses are much smaller than the program effects. With the exception of the Austrian refrigerator/freezer programs in 2009/2010, the null hypothesis of the absence of pre-program effects cannot be rejected. In most cases, the post-program effects are also small. In three instances (cooling appliances in Austria and Hungary in 2009 and 2016), these effects are in fact positive, indicating that sales are higher after the programs ended. In a number of cases, therefore, the net-program effects in Column (5) are even larger than the respective program effects. Note that extending the window to 5 months before and after a program does not change the finding that pre- and post-rebate shifting is largely absent in the programs under consideration.[31]

Column (6) summarizes results on unit sales of non-subsidized products. In most cases, estimated effects on the sales of these products are negligible, indicating that rebate responses in Column (2)

[30] As in the 2016 Hungarian program, rebate amounts depended on the energy label. Separate estimates by label are shown in Columns (1)-(6) in Table C.4 in the Appendix. For visual representation of the time paths by label, refer to Panel A of Figure E.1 in the Appendix.

[31] Results using longer windows are available upon request. Extension of the window after the program is impossible for the Hungarian 2016 program, as the data ends in January 2017. Likewise, the three-month separation between the two Croatian programs constrains the post-rebate time for June and the pre-rebate time for October.

Table 5: Summary of Programs' Outcomes

		Unit Sales					Prices	
		Subs.				Non-subs.	Subs.	Non-subs.
	Duration (months) (1)	Program Effect (2)	Pre-Program (3)	Post-Program (4)	Net Program Effect (5)	Program Effect (6)	Program Effect (7)	Program Effect (8)
		Refrigerators and Freezers						
Austria 2009	4	0.881	-0.158	0.737	1.170	0.109	0.024	0.001
		(0.209)	(0.043)	(0.240)	(0.327)	(0.058)	(0.010)	(0.005)
Austria 2010	3	0.391	-0.164	0.072	0.330	-0.006	-0.005	0.003
		(0.149)	(0.068)	(0.128)	(0.253)	(0.055)	(0.009)	(0.006)
Hungary 2016	4	0.601	0.044	0.366	0.714	0.134	-0.004	0.004
		(0.109)	(0.047)	(0.105)	(0.144)	(0.155)	(0.005)	(0.012)
A+++		3.257	0.069	0.891	3.514	2.834	-0.016	-0.085
		(1.440)	(0.240)	(0.695)	(1.652)	(2.988)	(0.027)	(0.041)
A++		1.645	0.172	0.842	1.941	0.100	0.008	0.043
		(0.327)	(0.085)	(0.269)	(0.407)	(0.282)	(0.011)	(0.023)
A+		0.057	-0.034	0.123	0.071	0.121	-0.010	0.009
		(0.081)	(0.056)	(0.101)	(0.119)	(0.176)	(0.006)	(0.014)
		Washing Machines						
Austria 2010	2	0.812	0.005	0.660	1.477	-0.092	0.024	-0.001
		(0.425)	(0.173)	(0.440)	(0.920)	(0.086)	(0.017)	(0.007)
Croatia, 6.2015	1	1.223	-0.093	-0.044	0.993	0.520	0.013	-0.023
		(0.324)	(0.098)	(0.157)	(0.609)	(0.227)	(0.012)	(0.014)
Croatia, 10.2015	1	0.772	-0.167	0.021	0.480	-0.043	0.035	0.012
		(0.341)	(0.146)	(0.203)	(0.983)	(0.166)	(0.015)	(0.020)
Hungary, 2015	4	0.349	-0.010	-0.043	0.323	0.158	0.009	-0.005
		(0.143)	(0.077)	(0.119)	(0.218)	(0.193)	(0.008)	(0.013)
A+++		0.672	0.064	0.180	0.793	-0.332	0.014	0.058
		(0.211)	(0.103)	(0.175)	(0.318)	(0.197)	(0.009)	(0.032)
A++		-0.034	-0.014	-0.267	-0.175	0.213	-0.009	0.025
		(0.212)	(0.143)	(0.209)	(0.353)	(0.818)	(0.021)	(0.039)
A+		-0.313	-0.190	-0.322	-0.569	1.030	0.018	-0.010
		(0.207)	(0.226)	(0.250)	(0.395)	(0.801)	(0.023)	(0.032)

Notes: Estimates are calculated based on non-linear transformations of point estimates as reported in Tables 4, C.1, C.5, and C.3 (see discussion on page 16 and footnote 19). Program effects are computed as averages over the program duration denoted in Column (1). Pre- and post-program effects are computed as averages over two months, except for the Hungarian 2016 and Croatian June programs, for which the post-program period is restricted to one month due to data or program-specific reasons (see footnote 31 below.) Standard errors (in parentheses) are obtained from linear or non-linear post-estimation combinations of the parameter estimates in the tables referenced above based on the "delta method".

are not driven by consumers substituting away from non-subsidized models. In fact, for the Austrian and Croatian subsidies in 2009 and June 2015, respectively, the program effects for non-subsidized products point to an expansion of sales.

A possible explanation for this result is an information spillover of campaigns advertising the subsidies and promulgating the monetary and environmental advantages of replacing old with more energy efficient appliances. This explanation is supported by the finding that significant effects are detected for the first rebate programs implemented in Austria and Croatia, but are absent when these programs are repeated. The lack of positive effects on the sales of non-subsidized products for the Hungarian programs may stem from the fact that information campaigns in this case started several months before implementation. Another possibility is that significant negative program effects on non-subsidized models exist, but for subgroups, and are thus concealed as the baseline specification assumes that these responses are homogenous within a country. In fact, strongest upgrading responses can be expected to arise for appliances that are most similar to subsidized products. To explore this in more detail, we identify close substitutes using "coarsened exact matching" (see Section 5). The estimates for close substitutes also do not show negative effects. In contrast to the estimates for all non-subsidized products, the positive effects of the first rebate programs in Austria and Croatia are not confirmed. Hence, if there are upgrading effects, they are probably masked by effects of an increased attention to energy consumption in general.[32]

Columns (7) and (8) of Table 5 show program effects on prices of subsidized and non-subsidized products. Statistically significant increases of 2.4% and 3.5% in the prices of subsidized products are observed for the Austrian 2009 and Croatian October 2015 programs, respectively. A small price decrease of 2.2% is found for non-subsidized models in the first Croatian subsidy. Although, as a whole, prices do not appear to be affected by the Hungarian programs, some price responses are observed within individual energy labels.

Table 5 suggests that repeating programs are less effective than their predecessors. The Austrian cooling appliances rebate in 2010, exactly one year after the equivalent program in 2009, yields a

[32]Estimates for non-subsidized close substitutes are provided in Table C.6 in the Appendix.

net-program effect only one-quarter of that of the earlier program. Likewise, the Croatian subsidy in October is half as effective as the first initiative in June. The table also shows that in the case of Hungary, average net-program effects mask substantial response heterogeneity across subsidized labels. In particular, for the refrigerator/freezer campaign in 2016, the net response is entirely driven by the top energy labels A+++ and A++, whereas A+ models, which constitute 43% of all eligible appliances, are unaffected. The Hungarian washing machine subsidy in 2015 reveals a significant 80 log points rise in the sales of subsidized A+++ devices, but negative, albeit imprecisely estimated, outcomes for subsidized A++ and especially for A+ products, implying upgrading *within* the set of subsidized appliances. This is also the only program that exhibits substitution from non-subsidized to subsidized models – the loss in sales of non-eligible A+++ washing machines amounts to 33 log points of the counterfactual, indicating that a substantial part of the estimated net-program effect simply reflects a shift within the group of most energy efficient appliances.

6.2 Cost Effectiveness

To assess the cost effectiveness of the programs, we compute their implied energy savings. The computations are based on two assumptions. First, we assume that all households are already equipped with an appliance, and are thus not first-time buyers at the point of replacement. Second, we abstract from any changes in the usage of new or existing devices. Given these assumptions, two factors determine the energy savings: Earlier replacement and replacement at a higher level of energy efficiency. As households are expected to replace oldest devices first, which are likely to be scrapped soon anyway, the first effect is a one-time acceleration of diffusion of technology by one to two periods and, hence, is most likely very small. The second effect is more important, since the energy savings associated with replacement at higher energy efficiency are generated over the entire lifetime of the product. Hence, our computations focus solely on this second effect.[33]

Table 6 provides the results of these computations. The annual energy savings are computed based

[33] Allowing for the possibility that, in the absence of a subsidy, an old appliance would not have been replaced at all, and would have remained functioning within a household indefinitely, would have resulted in considerably larger energy savings than the ones reported below.

Table 6: Estimated Energy Savings and Programs' Cost

	Energy savings			Budget	Share	Cost per MWh	
	MWh (1)	90% CI (2)		in 1000 euros (3)	% (4)	euros (5)	s.e. (6)
	Refrigerators and Freezers						
Austria 2009	20,894	[11, 278	30, 510]	3,000	90	129	36.2
Austria 2010	4,382	[−1, 153	9, 916]	2,200	75	375	287.7
Hungary 2016	9,522	[−344	19, 389]	4,259	100	447	281.8
	Washing Machines						
Austria 2010	6,085	[−150	12, 320]	3,100	61	153	95.4
Croatia 6.2015	3,187	[−29	6, 404]	1,052	57	188	115
Croatia 10.2015	1,879	[−5, 670	9, 430]	1,052	60	337	692
Hungary 2015	2,269	[−25, 337	29, 876]	5,394	100	2,377	14,753

Notes: Column (1) reports estimated energy savings calculated as the product of the change in units sales relative to a counterfactual estimate of the number of units sales of subsidy-eligible products in the absence of a subsidy, the difference in KWh (ΔKWh) between the average annual energy consumption of subsidized products and the average of the entire stock of a given product category on the market in a given subsidy year, and the average number of years over which a household will use the appliance. The change in unit sales is calculated as the product of the net program effect as reported in Column (5) of Table 5 and the counterfactual. The counterfactual estimates are: AT 2009: 15,705; AT 2010 REF/FRZ program: 13,697; HU 2016: 941 (A+++), 13,037 (A++), 66,286 (A+); AT 2010 WM: 4,239; HR 06.2015: 2,314; HR 10.2015: 2,826; HU 2015: 20,230 (A+++), 16,093 (A++), 24,013 (A+), 944 (A+++, non-subsidized). ΔKWh for each program is: AT 2009: 63.1; AT 2010 REF/FRZ program: 53.9; HU 2016: 77.8 (A+++), 11.4 (A++), -28.3 (A+); AT 2010 WM: 69.41; HR 2015 June and Oct.: 99.1; HU 2015: 89.7 (A+++), 77.9 (A++), 73.2 (A+). Based on administrative data on appliance age at point of recycling (see Table 1 and Figure E.2 in the Appendix), we take the average number of years, in which a washing machine remains in a household to be 14 years, for refrigeratros/freezers in Austria–18 years, and for refrigerators and freezers in Hungary–23 years.
Column (2) reports the 90% confidence interval based on the estimate of the standard error of the net-program effect.
Column (3) exhibits the official program budget.
Column (4) reports the ratio of the maximum estimated number of unit sales in a program period and the number of subsidized purchases observed in the administrative data. The maximum estimated unit sales in a program period is obtained as a product of (1+Program Effect), as shown in Column (2) of Table 5 and the counterfactual estimate. The budget reported in Column (3) is then adjusted based on this share.
Column (5) states the cost per unit of energy savings obtained as the ratio of the product of (3) and (4) and the energy savings reported in column (1).
Column (6) reports the standard error of the cost estimate.

on the estimated net-program effects for units sales of subsidized appliances reported in Column (5) of Table 5. We do not take account of upgrading from non-subsidized products since we find little evidence of negative switching effects. Only in the case of Hungary 2015, where there is a clear indication of switching within the group of subsidized products and from non-subsidized to subsidized models within the A+++ label, substitution effects are taken into consideration. We employ information on the annual energy consumption of subsidized products relative to all products sold in the respective country and year to calculate energy efficiency gains due to replacement. We also use country specific information on the average number of years an appliance is used within a household.[34]

The largest energy savings are associated with the first program implemented in Austria in 2009. The figure in Column (1) points to annual savings of 20,894 MWh. The 90 % confidence interval, calculated using the standard error for the net-program effect is relatively small. To put the energy savings into perspective, Column (3) lists the total budget of the respective subsidy program. Since not all sales of subsidized products in the data can be matched with the official number of subsidized units, the cost effectiveness is calculated only based on a share of the total funds as reported in Column (4). Column (5) states the cost of energy savings per MWh based on the point estimate for energy savings in Column (1). In the case of Austria's 2009 program, the cost is estimated to be 129 euros per MWh with a standard error of 36 €. The repetition of the refrigerator/freezer subsidy in Austria in 2010 delivers only one-fifth of the energy savings of the first program and the cost of saving one MWh is tripled. Likewise, energy savings are smaller and costs higher for the second Croatian subsidy in October relative to the earlier program in June.

The two programs in Hungary come with the highest price tag per saved MWh. Despite leading to the replacement of more than 40,000 appliances, the washing machine subsidy is estimated to have saved only 2,269 MWh at the cost of 2,377€/MWh. Two factors explain this high cost estimate: consumer substitution within the set of subsidized products and the weakness of the European energy label for washing machines. Had there been no substitution within subsidized appliances,

[34] This is based on administrative data on the average age of replaced appliances at the point of their disposal.

the cost of the program would have been around 11% of the actual cost. The properties of the label play an important role as well: In particular, there is virtually no energy-use differentiation across washing machines belonging to a different energy classes.[35] Had the corresponding average KWh-differences between energy labels of subsidized washing machines been comparable to that of cooling appliances in Hungary, the estimated cost of energy savings would have been 5 times lower.

Although much more successful than the washing machine program, the Hungarian refrigerator & freezer subsidy in 2016 is nevertheless more expensive compared to the Austrian and Croatian subsidy programs. This is partly due to the high prevalence of refrigerators & freezers with medium level of energy efficiency in the list of subsidized products. To see why this is the case, one needs to look at the specific market composition for cooling appliances in Hungary and how this composition plays out within the energy label. Despite the 351 log points increase in the sales of subsidized A+++ models (cf. Column (5) of Table 5), the very low penetration of the most efficient refrigerating technology in Hungary at the time means that these sales account for only a small fraction of replaced appliances, with the majority of purchases being A++ devices. Relative to the average for the market, subsidized A++ refrigerators and freezers in Hungary are only 12 KWh more efficient as opposed to 78 KWh for subsidized A+++. The low cost effectiveness of both Hungarian rebate programs, thus, highlights the risk of setting a too low eligibility threshold, and draws attention to the drawbacks of tying eligibility to an institutional label.

Even the program with the lowest cost estimate of 129€ per MWh turns out to be a relatively expensive way of lowering energy consumption. Gillingham, Keyes, and Palmer (2018) provide figures based on a survey of the U.S. Energy Information Administration. According to this survey, the cost of saving 1 MWh of energy by means of utility energy efficiency programs is about 28 US dollars in 2016, or, about 25€ per MWh.[36] Gillingham, Keyes, and Palmer (2018) are careful to note, however, that ex-post evaluations tend to result in substantially higher estimates. Davis, Fuchs,

[35]The difference between the average yearly energy consumption of subsidized A+ and A++ washing machines in Hungary in 2015 is 5 KWh, and that between A++ and A+++ only 12 KWh.

[36]Based on the official ECB reference exchange rate.

and Gertler (2014), for example, find that subsidies for refrigerators in Mexico's *Cash for Coolers* program cost 272 US dollars per saved MWh. In their analysis of the US *Cash for Appliances* program, which had a dual purpose of incentivizing purchases of energy efficient appliances and stimulating the economy, Houde and Aldy (2017) provide estimates of 210 US dollars per MWh for washing machines and as much as 1,100 US dollars per MWh for refrigerators. An alternative way to assess the cost effectiveness of the programs is to combine information on their energy savings with the CO_2 emission intensity of electricity in Europe in the time period under consideration. Based on the lowest cost estimate from our analysis, the cost of saving a ton of CO_2 emissions is around 385€.[37] For comparison, in the same time period, EU's CO_2 emission allowances always traded below 20€.

7 Conclusion

This paper provides an in-depth analysis and evaluation of seven rebate programs aiming at the replacement of energy-intensive household appliances. We pursue an identification strategy relying on the temporary nature of the rebate programs carried out in regional segments of the EU Common Market. Our results indicate that programs can induce substantial replacement. In contrast to existing empirical evidence based mainly on experience with programs that are part of fiscal stimulus packages, estimated program effects are, in most cases, not simply offset by intertemporal substitution: Even when considering developments in unit sales before and after a rebate, the net program effects are positive. Abstracting from program heterogeneity, with subsidies amounting to 10 to 30% of the average price of an appliance, the median program effect is an increase in the unit sales of subsidized products by about 72 log points during the program. Accounting for pre- and post program effects, the median net-effect is about the same size.

Our research design enables us to further explore effects on non-subsidized products. This is

[37] Based on data provided by the European Environment Agency, the average CO_2 emission intensity in Europe was 335 g per KWh in the years from 2009 to 2016. Using this figure, the implied cost of saving a ton of CO_2 for the Austrian 2009 program is 385€= 129/ 0.335.

important, since the increase in unit sales might be driven by consumers who had an intention to replace even without a subsidy, and who, due to the program, upgrade in order to meet product-eligibility requirements. With one exception, where consumers switched between non-subsidized to subsidized products in the highest efficiency class, we do not find such switching away from non-subsidized products. Instead, in some cases, sales of non-subsidized units increase during the program. Upgrading effects are only found among subsidized products, when the subsidy rate differs.

Our analysis indicates that some of the subsidy programs are associated with price increases amounting to between 1% and 3.5%. Compared with the subsidy rates, these increases are rather modest indicating that the subsidies are mostly passed through to the consumer. As the programs are tiny in relation to the total EU common market, the price effects are unlikely to be associated with changes in producer prices. A possible explanation is a decline in consumer effort to search for best offers during a program. An alternative explanation points to retailers, which are running out of stock. This view is supported by some positive price effects on non-subsidized products and by the finding that in some programs prices stay at a higher level after the programs ended.

Abstracting from the cost of implementation, the point estimates for the cost of saving 1 MWh of energy consumption through rebate programs are 129 euros or higher. Although this finding supports concerns that rebate programs are an expensive way to improve energy efficiency in private households, our results suggest that this is not due to ineffectiveness of the programs. Programs result in substantial increases in sales and hence replacement, and we find little evidence of offsetting intertemporal effects. However, the energy savings of the rebate programs are constrained by the actual differences in energy consumption between the high end of energy efficiency and the market average. Hence, the available technology is a strong limiting factor.

The large differences in the cost effectiveness of programs illustrate the importance of a careful program design. A key issue is to set an appropriate eligibility threshold. Our results indicate that focusing the subsidy on the efficient frontier in the market results in much better performance than attempts to distribute subsidies more broadly across different segments of the market. The results also indicate that subsidy programs are a singular policy instrument – repeating a program tends to be associated with weaker outcomes. Since the rebate programs under consideration are funded with small budgets, it is unlikely that the full potential for replacement is exhausted after a single program. Our findings suggest an alternative explanation for the worse performance of repeating programs, namely the fact that the increased public awareness of the potential for energy savings by the replacement of household appliances is no longer a significant factor once a program is repeated. Taking this into account, the weaker effects on subsidized products found for repeated programs provide more reliable estimates of the effectiveness of the monetary incentive of rebate programs.

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Appendix

Promoting Sales of Energy Efficient Household Appliances: Outcomes and Cost Effectiveness of Rebate Programs

April 23, 2021

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Contents

A EU Legislative Framework on Energy-related Products

The European Energy Efficiency Directive (2012/27/EU) lays out the EU's long-term commitments and targets pertaining to energy savings and reductions in greenhouse gas emissions. It sets the stage for the various programs implemented by the EU Member States, establishes goals that engage all actors along the energy chain, and aligns EU legislation towards a common energy union. Regarding energy-related products, the Energy Efficiency Directive builds on two legal acts: the European Energy Labelling Directive (European Commission, 2010) and the Ecodesign Directive (European Commission, 2009).

Since 1994, the Energy Labelling Directive requires that household appliances sold within the common market have an energy label. Currently, the EU label rates appliances on a scale from A+++ (best) to G (worst) based on their energy efficiency, and reports annual electricity consumption in KWh, storage volume, water consumption, noise level, and other product-category specific

Table A.1: Energy Label Assignment Based on EEI

Refrigerator/Freezer		Washing Machines	
B	55≤EEI<75	B	68≤EEI<77
A	42/44≤EEI<55	A	59≤EEI<68
A+	33≤EEI<42/44	A+	52≤EEI<59
A++	22≤EEI<33	A++	46≤EEI<52
A+++	EEI<22	A+++	EEI<46

Notes: The table depicts the assignment of labels based on (Energy Efficiency Index) EEI intervals for cold appliances and washing machines. In general, the EEI is computed as follows: $EEI = \frac{AE_c}{SAE_c} * 100$, where AE_c is the annual energy consumption of the household appliance, and SAE_c is the standard annual energy consumption of the appliance. For refrigerators/freezers, AE_c is calculated by multiplying the 24-hour KWh consumption by 365 days of the year. $SEA_c = V_{eq} * M + N + CH$, where V_{eq} is an equivalent volume (function of number of compartments and their storage volume, the nominal temperature of the compartment(s), and volume correcting factors for frost-free, climate class, and build-in characteristics), M, and N are values that vary with the category of the appliance (e.g., refrigerator-freezer, upright freezer, chest freezer, refrigerator-cellar, etc.), and CH equals 50KWh/year for cold appliances with a chill compartment with a storage volume of at least 15 litres. For exact calculations, refer to Annex VIII of European Commission (2010a) for refrigerating appliances and Annex VII of European Commission (2010b) for washing machines. Numbers in bold are the new threshold values for cold appliances classes A and A+ as of 2010 set by Regulation N1060/2010.

characteristics (European Commission, 2010a, 2010b). The efficiency grade of a model is assigned using the so-called Energy Efficiency Index (EEI), which is the ratio of the annual energy consumption of the unit and the average energy consumption of an appliance with the same adjusted volume. Table A.1 lists label assignments in terms of ranges of the EEI for cold appliances and washing machines and provides some details on the calculation of the EEI. The adjustment allows for numerous product features unrelated to electricity usage to enter the EEI's formula.[1] With one exception, the eligibility of all subsidized models in the programs studied in this paper is defined in terms of the EU energy label.

While the Energy Labelling Directive enables consumers to base purchase decisions on energy efficiency considerations, the Ecodesign Directive directly restricts consumers' choice. Targeting the most inefficient and obsolete technology, it bans products from the market through the establishment of minimum energy performance standards (MEPS), which are defined in terms of the EEI. Thus, even though labels from A+++ to G/D exist for cold appliances/washing machines, presently

[1] The EEI index for washing machines, for example, is adjusted for loading capacity. In the space of a decade, the average capacity of new washing machines has increased by 2.5 kg, from 5 kg to 7.5 kg. In fact, the share of 5-6 kg machines, which is 77% in class A+, declines to 48% in A++ and to 30% in A+++.

the Ecodesign Directive prevents models rated below A+ from entering the EU market. MEPS therefore predominantly target the low-efficiency end of the market, whereas labels and incentive programs such as subsidies affect the middle- to high-efficiency segment.

Table A.2: EU Legislation and Standards for Energy Efficiency and Eco-Design for Cold Appliances and Washing Machines

Energy Label Directive 2010/30/EU		Eco-Design Directive 2009/125/EC	
Cold Appliances			
Regulation N1060/2010	New threshold values for energy classes A and A+ Introduces new energy class A+++	Regulation N643/2009	Introduces new minimum performance standards (MEPS) July 2010: EEI<55 effectively banning energy classes B and C July 2012: EEI<44 effectively banning energy class A (in two steps) July 2014: EEI<42
Washing Machines			
Regulation N1061/2010	Adds energy classes A+ to A+++	Regulation N1015/2010	December 2011: EEI<68 effectively banning energy classes B-D December 2013 EEI<59 effectively banning energy class A

Notes: The table lists the relevant major EU legislation and regulations affecting cold appliances and washing machines in the time period of the studied programs. Refrigerators and freezers: Energy labels A-G introduced in 1995. Classes D, E, and F banned in 1999. In 2004, classes A+ and A++ introduced. Washing machines: Energy labels A-D introduced in 1996 based on KWh/kg capacity efficiency definition. In 2011, labels A+ to A+++ are added, but efficiency is measured in terms of the EEI. Sources: European Commission (2009a), (2010a), (2010b), (2010c) and Attali *et al.* (2015).

References

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B Additional Data Tables

Table B.1: Product Characteristics by Category

Category	Features
Coolers/Refrigerators	Brand*; Model number*; No-frost system (Y/N); Construction (built-in/ under, freestanding); Energy label; Annual energy consumption (KWh); Type (1 door (dr) 81-90 cm, 1 dr>90 cm, 1 dr up to 80 cm, 2 drs freezer bottom, 2 drs freezer top, 3+ doors, side-by-side.
Freezers	Brand*; Model number*; Construction (built-in/ under, freestanding); No-frost system (Y/N); Type (chest, upright); height (cm); Energy label; Annual energy consumption (KWh).
Washing Machines	Brand*; Model number*; Type (front-, top-loading, wash-dry); Spin speed; Loading capacity (kg); Energy label; Annual energy consumption (KWh).

Notes: The table lists the product characteristics in the data pertaining to each product category. Characteristics marked with an asterisk are not available for all products, but only for those sold in Austria, Hungary, or Croatia.

Table B.2: COMPARING SUBSIDIZED MODELS WITH ALL PRODUCTS

	Austria			Hungary						Croatia
Time	6.2008-5.2009	1-5.2010	2009		6.2015-5.2016			7.2014-6.2015		3.2014-2.2015
Program	2009	2010	2010		2016			2015		2015
Category	REF/FRZ	REF/FRZ	WM		REF/FRZ			WM		WM
Subsidized Label	A++	A++	-	A+++	A++	A+	A+++	A++	A+	A+++
KWh	0.80	0.85	0.86	0.70	1.01	1.14	0.91	1.08	1.26	0.94
Units	0.88	1.07	0.82	0.45	0.90	2.2	1.33	3.94	7.50	0.90
Price	1.29	1.27	1.55	1.85	1.28	0.82	1.12	0.85	0.70	1.11
Age	0.59	0.70	0.58	0.81	1.23	1.160	0.81	0.95	1.26	0.74
Market share (%)	9.5	19.9	6.9	1.0	17.7	68.6	23.3	24.8	30.6	34.9

Notes: KWh/Units/Price/Age is the ratio of the median KWh/Units/Price/Age of subsidized models to the median KWh/Units/Price/Age of the full cross-section of products within the year of the program in the respective country. Market share is the sum of unit sales of subsidized models over total units sales in the respective country. Since KWh is time-invariant, comparison is performed within the subsidy year to ensure that entry and exit do not affect the composition of products. Age is also computed in the year of a subsidy. For units, price, and market share the comparison period starts one year prior to the year of a subsidy and ends 3 months before the start of a program to avoid capturing announcement effects. Composition effects will be present as some models that enter in the year of a program have not yet entered, and likewise for exit.

Table B.3: Descriptive Statistics: Full Data by Product Category and Energy Label

	Mean	Std. Dev.	Min	Max	N
Refrigerators and Freezers					
№ Units sold	59.2	151.8	2	11,086	1,299,194
Price (Euro)	522.4	395.1	0.01	11,538	1,577,530
Annual energy (KWh)	258.9	102.8	14	3,285	2,753,340
A+++					
№ Units sold	76.3	171.1	2	5,304	43,349
Price (Euro)	789.8	322.4	50	3,200	50,866
Annual energy (KWh)	149.9	36.6	51	360	86,813
A++					
№ Units sold	59.8	134.6	2	4,291	252,600
Price (Euro)	629.3	381.6	40	6,919	297,520
Annual energy (KWh)	198.1	62.3	62	542	506,977
A+					
№ Units sold	60.2	153.3	2	8,384	501,711
Price (Euro)	514.6	412.6	2	9,433	602,177
Annual energy (KWh)	252.3	85.7	41	1,257	1,051,175
A-D or No Label					
№ Units sold	56.5	156.6	2	11,086	501,534
Price (Euro)	457.5	369.2	0.01	11,538	626,967
Annual energy (KWh)	301.5	113.6	14	3,285	1,108,375
Washing Machines					
№ Units sold	93.9	288.1	2	24,965	652,657
Price (Euro)	449.7	247.0	0.4	3,504	761,959
Annual energy (KWh/kg)	237.8	224.0	58	1,797	566,487
A+++					
№ Units sold	118.0	359.8	2	11,041	142,988
Price (Euro)	541.0	280.5	50	3,504	161,814
Annual energy (KWh/kg)	168.4	28.0	58	381	241,607
A++					
№ Units sold	100.1	291.5	2	8,751	58,574
Price (Euro)	378.3	143.2	92.5	1,881	66,870
Annual energy (KWh/kg)	184.9	27.9	105	434	100,994
A+					
№ Units sold	97.9	238.7	2	7,581	97,049
Price (Euro)	369.7	199.3	48.2	2,102	110,520
Annual energy (KWh/kg)	190.1	29.2	109	485	137,493
A-D or No Label					
№ Units sold	82.0	265.9	2	24,965	354,046
Price (Euro)	447.0	246.2	0.4	3,472	422,755
Annual energy (KWh/kg)	569.4	440.6	99.8	1,797	86,393

Notes: The table shows summary statistics of the full sample by product category, and by energy label within a category. For descriptive statistics of the full and estimation samples, refer to Table 2 in the main text.

C Estimation Results

Table C.1: Austria: Unit Sales and Price Effects of Further Programs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	REF/FRZ Program 2010				WM Program 2010			
	Unit Sales		Prices		Unit Sales		Prices	
	Sub.	Non-sub.	Sub.	Non-sub.	Sub.	Non-sub.	Sub.	Non-sub.
$\beta_{B_2}, \delta_{B_2}, b_{B_2}, d_{B_2}$	-0.109	-0.094	0.007	0.003	0.221	0.074	0.022	0.005
	(0.079)	(0.040)	(0.007)	(0.004)	(0.176)	(0.071)	(0.014)	(0.006)
$\beta_{B_1}, \delta_{B_1}, b_{B_1}, d_{B_1}$	-0.126	0.051	0.001	0.001	-0.111	-0.064	-0.019	-0.006
	(0.085)	(0.044)	(0.006)	(0.004)	(0.164)	(0.060)	(0.015)	(0.006)
$\beta_{P_1}, \delta_{P_1}, b_{P_1}, d_{P_1}$	0.514	-0.021	-0.012	-0.004	0.382	-0.083	0.016	0.003
	(0.078)	(0.040)	(0.006)	(0.004)	(0.208)	(0.066)	(0.013)	(0.005)
$\beta_{P_2}, \delta_{P_2}, b_{P_2}, d_{P_2}$	0.097	0.090	0.005	0.010	0.195	-0.048	0.008	-0.005
	(0.076)	(0.049)	(0.007)	(0.004)	(0.149)	(0.061)	(0.013)	(0.005)
$\beta_{P_3}, \delta_{P_3}, b_{P_3}, d_{P_3}$	-0.044	-0.010	-0.012	-0.009				
	(0.066)	(0.042)	(0.006)	(0.004)				
$\beta_{A_1}, \delta_{A_1}, b_{A_1}, d_{A_1}$	-0.193	-0.037	0.008	-0.001	0.005	0.183	-0.002	-0.004
	(0.070)	(0.049)	(0.006)	(0.005)	(0.150)	(0.064)	(0.016)	(0.006)
$\beta_{A_2}, \delta_{A_2}, b_{A_2}, d_{A_2}$	-0.145	-0.132	0.002	0.000	-0.412	0.040	0.025	0.008
	(0.059)	(0.044)	(0.006)	(0.004)	(0.173)	(0.066)	(0.015)	(0.005)
N	537,385				267,502			
Product-date	211,609				108,619			
Products	11,692				6,419			

Notes: The table reports results for the refrigerator/freezer program implemented in Austria in 2010 and the washing machine program in Austria in 2010. Both programs are summarized in Table 1. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding washing machines in Columns (1)-(4), and excluding refrigerators/freezers in Columns (5)-(8). The dependent variable is either the log change in unit sales, or the log change in price. All specifications are based on interactions of country and program-specific date dummies with a product-specific subsidy eligibility indicator, and include country-month-eligibility fixed effects as per Eqs. (1) and (2). All columns report only the specified reference category's coefficients (subsidized or non-subsidized products), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. For effects on subsidized refrigerators/freezers by height, see the second part of Table C.2. Standard errors in parentheses are robust in all specifications and clustered by product. Wild cluster bootstrapped standard errors clustering by product and ordinary wild bootstrapped standard errors clustering at the intersection of country and product (country ∩ product) are shown in Table D.3.

Table C.2: Austria. Unit Sales and Price Effects on Subsidized Products by Height

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	REF/FRZ Program 2009				REF/FRZ Program 2010			
	Unit Sales		Prices		Unit Sales		Prices	
Category	> 90cm	≤ 90cm	> 90cm	≤ 90cm	> 90cm	≤ 90cm	> 90cm	≤ 90cm
β_{B_2}, b_{B_2}	-0.131	-0.003	0.008	0.017	-0.079	-0.253	0.013	-0.020
	(0.093)	(0.218)	(0.009)	(0.014)	(0.090)	(0.156)	(0.007)	(0.021)
β_{B_1}, b_{B_1}	-0.130	-0.077	0.015	0.009	-0.178	0.121	0.002	-0.007
	(0.048)	(0.091)	(0.005)	(0.009)	(0.097)	(0.161)	(0.007)	(0.014)
β_{P_1}, b_{P_1}	0.803	0.915	0.002	-0.006	0.517	0.505	-0.008	-0.032
	(0.102)	(0.155)	(0.008)	(0.015)	(0.091)	(0.121)	(0.007)	(0.011)
β_{P_2}, b_{P_2}	-0.181	-0.214	0.001	-0.007	0.100	0.082	-0.001	0.035
	(0.063)	(0.130)	(0.005)	(0.012)	(0.086)	(0.159)	(0.007)	(0.020)
β_{P_3}, b_{P_3}	0.277	0.636	-0.004	0.014	-0.012	-0.200	-0.012	-0.017
	(0.098)	(0.208)	(0.011)	(0.025)	(0.074)	(0.130)	(0.006)	(0.015)
β_{P_4}, b_{P_4}	0.016	-0.171	-0.008	0.040				
	(0.061)	(0.144)	(0.005)	(0.010)				
β_{A_1}, b_{A_1}	-0.327	0.010	-0.010	0.007	-0.224	-0.015	0.009	0.003
	(0.084)	(0.155)	(0.008)	(0.012)	(0.075)	(0.181)	(0.007)	(0.015)
β_{A_2}, b_{A_2}	0.228	-0.068	0.023	0.014	-0.166	-0.039	0.001	0.001
	(0.085)	(0.163)	(0.009)	(0.018)	(0.065)	(0.144)	(0.006)	(0.017)
N	537,381				537,381			
α_{id}	211,609				211,609			
Products	11,692				11,692			

Notes: The table reports unit sales and price effects on subsidized products for the two Austrian refrigerator/freezer programs in 2009 and 2010, respectively. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding washing machines. The dependent variable is either the log change in unit sales, or the log change in price. The specification distinguishes between cold appliances higher or lower than 90 cm, as the subsidy amount varies based on this threshold as indicated in Table 1. All specifications use triple-interactions of country and program-specific date dummies, product-specific subsidy eligibility indicator, and a height dummy, and include country-month-eligibility-height fixed effects. All columns report only the specified reference category's coefficients (below or above 90cm), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. Standard errors in parentheses are robust in all specifications and clustered by product.

Table C.3: Hungary: Unit Sales and Price Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	WM Program 2015				REF/FRZ Program 2016			
	Unit Sales		Prices		Unit Sales		Prices	
	Sub.	Non.-sub.	Sub.	Non.-sub.	Sub.	Non.-sub.	Sub.	Non.-sub.
$\beta_{B_2}, \delta_{B_2}, b_{B_2}, d_{B_2}$	0.037	0.052	-0.016	-0.009	0.051	-0.070	-0.003	0.004
	(0.080)	(0.112)	(0.005)	(0.009)	(0.047)	(0.095)	(0.004)	(0.008)
$\beta_{B_1}, \delta_{B_1}, b_{B_1}, d_{B_1}$	-0.029	-0.020	0.010	0.004	0.017	-0.099	-0.005	0.001
	(0.076)	(0.117)	(0.005)	(0.009)	(0.048)	(0.109)	(0.004)	(0.007)
$\beta_{P_1}, \delta_{P_1}, b_{P_1}, d_{P_1}$	0.139	0.020	0.002	0.005	0.267	0.271	0.011	-0.004
	(0.070)	(0.119)	(0.006)	(0.009)	(0.048)	(0.098)	(0.004)	(0.008)
$\beta_{P_2}, \delta_{P_2}, b_{P_2}, d_{P_2}$	0.382	0.232	0.019	-0.014	0.265	-0.077	-0.010	0.016
	(0.070)	(0.130)	(0.005)	(0.010)	(0.047)	(0.080)	(0.004)	(0.011)
$\beta_{P_3}, \delta_{P_3}, b_{P_3}, d_{P_3}$	-0.223	-0.155	0.001	0.003	-0.017	0.164	-0.005	-0.021
	(0.068)	(0.090)	(0.006)	(0.009)	(0.046)	(0.139)	(0.004)	(0.012)
$\beta_{P_4}, \delta_{P_4}, b_{P_4}, d_{P_4}$	-0.145	-0.022	-0.003	0.014	-0.256	-0.013	0.012	0.012
	(0.067)	(0.102)	(0.006)	(0.010)	(0.046)	(0.098)	(0.004)	(0.012)
$\beta_{A_1}, \delta_{A_1}, b_{A_1}, d_{A_1}$	-0.154	0.074	-0.028	-0.017	-0.016	0.144	0.011	-0.024
	(0.086)	(0.110)	(0.006)	(0.008)	(0.046)	(0.131)	(0.004)	(0.009)
$\beta_{A_2}, \delta_{A_2}, b_{A_2}, d_{A_2}$	-0.108	-0.274	0.002	-0.007				
	(0.074)	(0.124)	(0.006)	(0.009)				
N	238,267				537,385			
Product-date	100,336				211,609			
Products	703				11,692			

Notes: The table reports results for the Hungarian washing machine program in 2015, and the Hungarian refrigerator/freezer program in 2016. Both programs are summarized in Table 1. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding refrigerators/freezers in Columns (1)-(4), and excluding washing machines in Columns (5)-(8). The dependent variable is either the log change in unit sales, or the log change in price. All specifications are based on interactions of country and program-specific date dummies with a product-specific subsidy eligibility indicator, and include country-month-eligibility fixed effects as per Eqs. (1) and (2). For the 2015 washing machine program, Croatian unit sales and prices are excluded as controls due to a contemporaneous subsidy. All columns report only the specified reference category's coefficients (subsidized or non-subsidized products), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. For effects on subsidized refrigerators/freezers/washing machines by energy label, see Table C.4. Standard errors in parentheses are robust in all specifications and clustered by product. Wild cluster bootstrapped standard errors clustering by product and ordinary wild bootstrapped standard errors clustering at the intersection of country and product (country ∩ product) are shown in Table D.3.

Table C.4: Hungary: Unit Sales and Price Effects on Subsidized Products by Energy Label

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	WM Program 2015						REF/FRZ Program 2016					
	Unit Sales			Prices			Unit Sales			Prices		
	A+++	A++	A+	A+++	A++	A+	A+++	A++	A+	A+++	A++	A+
β_{B_2}, b_{B_2}	0.035	-0.069	0.301	-0.019	-0.011	-0.006	0.477	0.251	-0.100	-0.013	0.007	-0.008
	(0.105)	(0.138)	(0.230)	(0.006)	(0.010)	(0.010)	(0.221)	(0.089)	(0.055)	(0.021)	(0.008)	(0.005)
β_{B_1}, b_{B_1}	0.044	0.020	-0.372	0.009	0.007	0.018	-0.200	0.025	0.014	0.002	-0.009	-0.002
	(0.095)	(0.137)	(0.271)	(0.006)	(0.010)	(0.017)	(0.206)	(0.078)	(0.063)	(0.021)	(0.007)	(0.005)
β_{P_1}, b_{P_1}	0.209	0.182	-0.463	0.007	-0.018	0.006	0.917	0.482	0.072	-0.009	0.016	0.009
	(0.079)	(0.135)	(0.226)	(0.007)	(0.015)	(0.015)	(0.255)	(0.084)	(0.058)	(0.011)	(0.008)	(0.005)
β_{P_2}, b_{P_2}	0.488	-0.018	0.195	0.020	0.024	0.011	0.534	0.426	0.117	-0.004	-0.008	-0.011
	(0.083)	(0.157)	(0.135)	(0.007)	(0.013)	(0.010)	(0.200)	(0.083)	(0.057)	(0.018)	(0.007)	(0.005)
β_{P_3}, b_{P_3}	-0.204	-0.313	-0.094	0.004	-0.003	-0.014	-0.201	-0.062	0.038	0.015	-0.007	-0.007
	(0.080)	(0.158)	(0.206)	(0.007)	(0.015)	(0.018)	(0.186)	(0.080)	(0.060)	(0.021)	(0.008)	(0.005)
β_{P_4}, b_{P_4}	-0.232	-0.049	0.209	0.001	-0.013	-0.004	-0.277	-0.379	-0.160	-0.006	0.012	0.014
	(0.077)	(0.141)	(0.227)	(0.008)	(0.012)	(0.016)	(0.222)	(0.076)	(0.060)	(0.021)	(0.007)	(0.006)
β_{A_1}, b_{A_1}	-0.181	0.149	-0.150	-0.034	-0.007	-0.039	-0.613	-0.132	0.135	0.014	0.025	0.003
	(0.097)	(0.177)	(0.311)	(0.007)	(0.011)	(0.018)	(0.195)	(0.082)	(0.058)	(0.019)	(0.008)	(0.005)
β_{A_2}, b_{A_2}	0.012	-0.483	-0.029	0.007	-0.010	-0.006						
	(0.090)	(0.150)	(0.225)	(0.007)	(0.013)	(0.015)						
N	238,125						537,260					
α_{id}	100,279						211,551					
Products	6,053						11,684					

Notes: The table reports unit sales and price effects on subsidized products for the two Hungarian programs in 2015 and 2016, respectively. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding refrigerators/freezers in Columns (1)-(6), and excluding washing machines in Columns (7)-(12). The dependent variable is either the log change in unit sales, or the log change in price. The specification distinguishes between appliances based on their energy label, as the subsidy amount varies with the energy class as indicated in Table 1. All specifications use triple-interactions of country and program-specific date dummies, product-specific subsidy eligibility indicator, and a label dummy, and include country-month-eligibility-label fixed effects. For the 2015 washing machine program, Croatian unit sales and prices are excluded as controls due to a contemporaneous subsidy. All columns report only the specified reference category's coefficients (label A+++, A++, A+), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. Standard errors in parentheses are robust in all specifications and clustered by product.

Table C.5: Croatia: Unit Sales and Price Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	WM Program June 2015				WM Program Oct. 2015			
	Unit Sales		Prices		Unit Sales		Prices	
	Sub.	Non-sub.	Sub.	Non-sub.	Sub.	Non-sub.	Sub.	Non-sub.
$\beta_{B_2}, \delta_{B_2}, b_{B_2}, d_{B_2}$	-0.043	0.207	-0.016	-0.000	0.044	-0.048	-0.012	0.001
	(0.114)	(0.112)	(0.011)	(0.009)	(0.102)	(0.092)	(0.009)	(0.010)
$\beta_{B_1}, \delta_{B_1}, b_{B_1}, d_{B_1}$	-0.076	-0.152	0.000	-0.035	-0.405	-0.047	0.001	-0.008
	(0.113)	(0.098)	(0.011)	(0.012)	(0.110)	(0.105)	(0.010)	(0.010)
$\beta_{P_1}, \delta_{P_1}, b_{P_1}, d_{P_1}$	0.918	0.364	0.029	0.012	0.978	-0.399	0.010	0.005
	(0.094)	(0.126)	(0.010)	(0.012)	(0.112)	(0.120)	(0.007)	(0.013)
$\beta_{A_1}, \delta_{A_1}, b_{A_1}, d_{A_1}$	-0.844	0.031	0.022	0.036	-0.594	-0.100	0.005	0.015
	(0.096)	(0.117)	(0.008)	(0.011)	(0.107)	(0.097)	(0.009)	(0.012)
$\beta_{A_2}, \delta_{A_2}, b_{A_2}, d_{A_2}$					0.085	0.138	0.001	0.001
					(0.111)	(0.105)	(0.009)	(0.009)
N	213,351							
Product-date	92,035							
Products	5,681							

Notes: The table reports results for the Croatian programs in June and October in 2015, focusing on washing machines only. Both programs are summarized in Table 1. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding refrigerators/freezers. The dependent variable is either the log change in unit sales, or the log change in price. All specifications are based on interactions of country and program-specific date dummies with a product-specific subsidy eligibility indicator, and include country-month-eligibility fixed effects as per Eqs. (1) and (2). Hungarian unit sales and prices are excluded as controls due to a contemporaneous washing machine subsidy in Hungary. All columns report only the specified reference category's coefficients (subsidized or non-subsidized products), and do not report interaction terms or remaining controls, herein market age and its square term. 'B', 'P', and 'A' coefficient subscripts refer to months before, during, and after the program, respectively. Standard errors in parentheses are robust in all specifications and clustered by product. Wild cluster bootstrapped standard errors clustering by product and ordinary wild bootstrapped standard errors clustering at the intersection of country and product (country ∩ product) are shown in Table D.3.

Table C.6: UNIT SALES RESPONSES OF NON-SUBSIDIZED: CLOSE SUBSTITUTES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Category		Austria		Hungary		Croatia	
	2009	2010	2010, WM	2015	2016	June	Oct.
δ_{B_2}	-0.107	-0.155	0.292	0.184	0.007	0.436	-0.049
	(0.096)	(0.094)	(0.206)	(0.230)	(0.144)	(0.213)	(0.196)
δ_{B_1}	-0.024	0.172	-0.156	-0.300	-0.284	-0.228	-0.309
	(0.055)	(0.097)	(0.265)	(0.203)	(0.132)	(0.171)	(0.240)
δ_{P_1}	0.024	0.022	0.165	0.047	0.246	0.178	-0.300
	(0.093)	(0.092)	(0.211)	(0.246)	(0.127)	(0.224)	(0.234)
δ_{P_2}	-0.052	-0.022	-0.190	0.224	-0.057		
	(0.069)	(0.112)	(0.177)	(0.658)	(0.110)		
δ_{P_3}	-0.110	-0.058		-0.281	0.169		
	(0.114)	(0.104)		(0.262)	(0.200)		
δ_{P_4}	-0.089			0.342	-0.089		
	(0.067)			(0.189)	(0.152)		
δ_{A_1}	0.056	-0.009	0.005	-0.216	0.321	0.063	0.125
	(0.094)	(0.106)	(0.260)	(0.341)	(0.198)	(0.270)	(0.211)
δ_{A_2}	0.058	-0.130	-0.259	-0.160			-0.034
	(0.117)	(0.102)	(0.280)	(0.218)			(0.208)
N	385,476	385,476	191,982	168,734	385,476	153,131	153,131
α_{id}	48,860	46,450	16,891	8,731	14,180	6,560	6,560
Products	1,911	1,652	665	394	548	252	252
Close. substit.	274	343	74	209	425	90	90

Notes: The table reports results of the response of unit sales of non-subsidized close substitutes to subsidy programs. The dependent variable is the percentage change in unit sales. The sample refers to the estimation sample summarized in Panel B of Table 2, excluding all subsidy-eligible products. Close substitutes are determined via Coarsened Exact Matching between subsidized products in Austria, Hungary, and Croatia, and the non-subsidized set of products on the market in these countries in the subsidy year, performed by keeping the number of treated and control products the same within a matched stratum. For refrigerators and freezers, matching is exact on no-frost, type and construction features, and for washing machines–on loading capacity and type. See Table B.1 for exact description of product characteristics. For all product categories, category- and program-country-specific average prices obtained from periods prior to subsidies are coarsened into 16 bins, 14 100-bins, initial interval (0,200) and final interval of (1,600+), and are included in the CEM procedure in addition to the features above. Identification is identical to that in Section 5, but non-subsidized close substitutes are considered as 'treated' in this estimation. Standard errors in parentheses are robust in all specifications and clustered by product.

D Clustering Level

Table D.1: STANDARD ERRORS: SENSITIVITY TO CLUSTERING LEVEL

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Austria		Hungary		Croatia	
	2009	2010, FF	2010, WM	2015	2016	6.2015	10.2015
β_{B_2}	-0.105	-0.109	0.221	0.037	0.051	-0.072	0.063
Product	(0.086)	(0.079)	(0.176)	(0.081)	(0.047)	(0.113)	(0.104)
Country	(0.027)	(0.049)	(0.113)	(0.052)	(0.030)	(0.061)	(0.081)
Country∩Date	(0.032)	(0.050)	(0.074)	(0.061)	(0.041)	(0.080)	(0.074)
β_{B_1}	-0.121	-0.126	-0.111	-0.029	0.017	-0.073	-0.451
Product	(0.043)	(0.086)	(0.164)	(0.077)	(0.048)	(0.108)	(0.106)
Country	(0.012)	(0.017)	(0.038)	(0.075)	(0.020)	(0.114)	(0.077)
Country∩Date	(0.022)	(0.021)	(0.087)	(0.103)	(0.027)	(0.100)	(0.074)
β_{P_1}	0.824	0.514	0.382	0.139	0.267	0.919	1.029
Product	(0.088)	(0.078)	(0.208)	(0.070)	(0.049)	(0.092)	(0.109)
Country	(0.031)	(0.021)	(0.056)	(0.065)	(0.055)	(0.086)	(0.076)
Country∩Date	(0.044)	(0.042)	(0.056)	(0.060)	(0.049)	(0.074)	(0.077)
β_{P_2}	-0.186	0.097	0.195	0.382	0.265		
Product	(0.057)	(0.076)	(0.149)	(0.070)	(0.047)		
Country	(0.032)	(0.020)	(0.052)	(0.044)	(0.046)		
Country∩Date	(0.032)	(0.032)	(0.124)	(0.049)	(0.039)		
β_{P_3}	0.338	-0.044		-0.223	-0.017		
Product	(0.090)	(0.066)		(0.068)	(0.046)		
Country	(0.032)	(0.028)		(0.052)	(0.031)		
Country∩Date	(0.035)	(0.031)		(0.056)	(0.039)		
β_{P_4}	-0.018			-0.145	-0.256		
Product	(0.057)			(0.067)	(0.046)		
Country	(0.019)			(0.028)	(0.036)		
Country∩Date	(0.028)			(0.051)	(0.048)		
β_{A_1}	-0.272	-0.193	0.005	-0.154	-0.017	-0.854	-0.668
Product	(0.076)	(0.070)	(0.150)	(0.086)	(0.046)	(0.099)	(0.108)
Country	(0.022)	(0.049)	(0.044)	(0.049)	(0.044)	(0.079)	(0.049)
Country∩Date	(0.031)	(0.047)	(0.082)	(0.065)	(0.050)	(0.084)	(0.058)
β_{A_2}	0.176	-0.145	-0.412	-0.108			0.109
Product	(0.076)	(0.059)	(0.173)	(0.074)			(0.107)
Country	(0.057)	(0.024)	(0.108)	(0.068)			(0.063)
Country∩Date	(0.057)	(0.032)	(0.083)	(0.048)			(0.067)

Notes: The table reports coefficient estimates for unit sales of subsidized products for all programs based on Eq. (1), and robust standard errors in parentheses clustered in three different ways: by product, by country, or by the intersection of country and date.

Table D.2: Wild Cluster Bootstrap: *P*-values

	(1)	(2)	(3)	(4)	(5)
	Coeff.	WCBR	WCBU	WCBR	WCBU
H_0		$\beta = 0$	$\beta = \hat{\beta}$	$\beta = 0$	$\beta = \hat{\beta}$
Clustering		Country		Country-date	
		Austria, 2009			
β_{B_2}	-0.105	[0.436]	[0.006]	[0.359]	[0.006]
β_{B_1}	-0.121	[0.162]	[0.000]	[0.348]	[0.000]
β_{P_1}	0.824	[0.107]	[0.000]	[0.197]	[0.000]
β_{P_2}	-0.186	[0.307]	[0.000]	[0.256]	[0.000]
β_{P_3}	0.338	[0.107]	[0.000]	[0.137]	[0.000]
β_{P_4}	-0.018	[0.392]	[0.178]	[0.571]	[0.518]
β_{A_1}	-0.272	[0.206]	[0.000]	[0.263]	[0.000]
β_{A_2}	0.176	[0.493]	[0.035]	[0.456]	[0.006]
№ clusters		8	8	1,200	1,200
		Austria, REF/FRZ 2010			
β_{B_2}	-0.109	[0.515]	[0.255]	[0.521]	[0.252]
β_{B_1}	-0.126	[0.231]	[0.000]	[0.261]	[0.000]
β_{P_1}	0.514	[0.095]	[0.000]	[0.213]	[0.000]
β_{P_2}	0.097	[0.175]	[0.000]	[0.252]	[0.023]
β_{P_3}	-0.044	[0.347]	[0.055]	[0.380]	[0.143]
β_{A_1}	-0.193	[0.461]	[0.101]	[0.407]	[0.033]
β_{A_2}	-0.145	[0.193]	[0.000]	[0.272]	[0.000]
№ clusters		8	8	1,200	1,200
		Austria, WM 2010			
β_{B_2}	0.221	[0.508]	[0.180]	[0.088]	[0.001]
β_{B_1}	-0.111	[0.119]	[0.000]	[0.355]	[0.286]
β_{P_1}	0.382	[0.163]	[0.000]	[0.014]	[0.000]
β_{P_2}	0.195	[0.303]	[0.002]	[0.335]	[0.189]
β_{A_1}	0.005	[0.925]	[0.923]	[0.960]	[0.960]
β_{A_2}	-0.412	[0.410]	[0.086]	[0.073]	[0.000]
№ clusters		8	8	1,200	1,200
		Hungary, 2015			
β_{B_2}	0.037	[0.581]	[0.496]	[0.582]	[0.529]
β_{B_1}	-0.029	[0.765]	[0.743]	[0.836]	[0.838]
β_{P_1}	0.139	[0.300]	[0.123]	[0.189]	[0.020]
β_{P_2}	0.382	[0.069]	[0.000]	[0.008]	[0.000]
β_{P_3}	-0.223	[0.187]	[0.000]	[0.021]	[0.001]
β_{P_4}	-0.145	[0.138]	[0.000]	[0.137]	[0.010]
β_{A_1}	-0.154	[0.249]	[0.023]	[0.141]	[0.062]
β_{A_2}	-0.108	[0.354]	[0.145]	[0.125]	[0.009]
№ clusters		7	7	1,044	1,044

Table D.2: Wild Cluster Bootstrap: *P*-values (Contd.)

	(1)	(2)	(3)	(4)	(5)
	Coeff.	WCBR	WCBU	WCBR	WCBU
H_0		$\beta = 0$	$\beta = \hat{\beta}$	$\beta = 0$	$\beta = \hat{\beta}$
Clustering		Country		Country∩date	
		Hungary, 2016			
β_{B_2}	0.051	[0.385]	[0.027]	[0.393]	[0.248]
β_{B_1}	0.017	[0.461]	[0.388]	[0.532]	[0.500]
β_{P_1}	0.267	[0.182]	[0.013]	[0.020]	[0.000]
β_{P_2}	0.265	[0.161]	[0.001]	[0.011]	[0.000]
β_{P_3}	-0.017	[0.586]	[0.529]	[0.622]	[0.622]
β_{P_4}	-0.256	[0.064]	[0.001]	[0.028]	[0.000]
β_{A_1}	-0.017	[0.795]	[0.761]	[0.792]	[0.773]
№ clusters		8	8	1,200	1,200
		Croatia, June 2015			
β_{B_2}	-0.072	[0.479]	[0.428]	[0.494]	[0.355]
β_{B_1}	-0.073	[0.634]	[0.576]	[0.551]	[0.529]
β_{P_1}	0.919	[0.028]	[0.000]	[0.000]	[0.000]
β_{A_1}	-0.854	[0.019]	[0.000]	[0.004]	[0.000]
№ clusters		7	7	1,044	1,044
		Croatia, October 2015			
β_{B_2}	0.063	[0.525]	[0.472]	[0.466]	[0.410]
β_{B_1}	-0.451	[0.049]	[0.000]	[0.008]	[0.000]
β_{P_1}	1.029	[0.013]	[0.000]	[0.001]	[0.000]
β_{A_1}	-0.668	[0.021]	[0.000]	[0.004]	[0.000]
β_{A_2}	0.109	[0.512]	[0.199]	[0.368]	[0.202]
№ clusters		7	7	1,044	1,044

Notes: Column (1) reports coefficient estimates for unit sales of subsidized products for all programs based on Eq. (1). Columns (2)-(3) report *p*-values from a restricted (WCBR) and unrestricted wild cluster bootstrap (WCBU), respectively, clustering by country. Columns (4)-(5) report *p*-values from a restricted and unrestricted wild cluster bootstrap, respectively, clustering by the intersection of country and date. The table uses the wild bootstrap post-estimation procedure `boottest` described in Roodman et. al. (2019). Given the small number of clusters in Columns (2)-(3), the bootstrap is based on 999,999 replications and Webb (6-point) weights. Columns (4)-(5) are based on 999 bootstrap samples and Rademacher weights.

Table D.3: Wild Cluster and Ordinary Wild Bootstrap

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		WCBR		WCBU		WBR	WBU
H_0		$\beta = 0$		$\beta = \hat{\beta}$		$\beta = 0$	$\beta = \hat{\beta}$
Cluster		Product				Country∩product	
	Coeff.	p-value	95% CI	p-value	95% CI	p-value	p-value
				Austria, 2009			
β_{B_2}	-0.105	[0.243]	[-0.286, 0.074]	[0.219]	[-0.277, 0.067]	[0.228]	[0.241]
β_{B_1}	-0.121	[0.006]	[-0.210, -0.035]	[0.005]	[-0.211, -0.031]	[0.004]	[0.002]
β_{P_1}	0.824	[0.000]	[0.654, 0.998]	[0.000]	[0.641, 1.006]	[0.000]	[0.000]
β_{P_2}	-0.186	[0.000]	[-0.297, -0.072]	[0.002]	[-0.299, -0.073]	[0.000]	[0.001]
β_{P_3}	0.338	[0.000]	[0.162, 0.514]	[0.000]	[0.160, 0.517]	[0.000]	[0.001]
β_{P_4}	-0.018	[0.765]	[-0.126, 0.091]	[0.764]	[-0.130, 0.094]	[0.740]	[0.733]
β_{A_1}	-0.272	[0.000]	[-0.424, -0.120]	[0.001]	[-0.418, -0.126]	[0.000]	[0.000]
β_{A_2}	0.176	[0.013]	[0.030, 0.323]	[0.019]	[0.022, 0.330]	[0.014]	[0.022]
№ clusters		15,689		15,689		37,895	37,895
				Austria, REF/FRZ 2010			
β_{B_2}	-0.109	[0.181]	[-0.270, 0.050]	[0.163]	[-0.272, 0.055]	[0.170]	[0.165]
β_{B_1}	-0.126	[0.144]	[-0.290, 0.043]	[0.154]	[-0.292, 0.040]	[0.134]	[0.124]
β_{P_1}	0.514	[0.000]	[0.360, 0.669]	[0.000]	[0.356, 0.671]	[0.000]	[0.000]
β_{P_2}	0.097	[0.221]	[-0.054, 0.245]	[0.186]	[-0.051, 0.244]	[0.181]	[0.190]
β_{P_3}	-0.044	[0.523]	[-0.172, 0.079]	[0.508]	[-0.174, 0.087]	[0.508]	[0.498]
β_{A_1}	-0.193	[0.003]	[-0.327, -0.054]	[0.008]	[-0.333, -0.053]	[0.008]	[0.007]
β_{A_2}	-0.145	[0.013]	[-0.258, -0.032]	[0.014]	[-0.259, -0.031]	[0.013]	[0.012]
№ clusters		15,689		15,689		37,895	37,895
				Austria, WM 2010			
β_{B_2}	0.221	[0.225]	[-0.154, 0.576]	[0.218]	[-0.118, 0.561]	[0.204]	[0.207]
β_{B_1}	-0.111	[0.505]	[-0.458, 0.241]	[0.507]	[-0.424, 0.201]	[0.497]	[0.481]
β_{P_1}	0.382	[0.090]	[-0.070, 0.831]	[0.084]	[-0.052, 0.816]	[0.078]	[0.071]
β_{P_2}	0.195	[0.199]	[-0.104, 0.504]	[0.191]	[-0.109, 0.498]	[0.218]	[0.207]
β_{A_1}	0.005	[0.977]	[-0.312, 0.308]	[0.973]	[-0.300, 0.309]	[0.970]	[0.969]
β_{A_2}	-0.412	[0.021]	[-0.764, -0.059]	[0.031]	[-0.774, -0.051]	[0.016]	[0.017]
№ clusters		8,032		8,032		19,485	19,485
				Hungary, 2015			
β_{B_2}	0.037	[0.681]	[-0.117, 0.191]	[0.659]	[-0.113, 0.187]	[0.639]	[0.632]
β_{B_1}	-0.029	[0.699]	[-0.185, 0.134]	[0.713]	[-0.187, 0.130]	[0.700]	[0.704]
β_{P_1}	0.139	[0.038]	[0.008, 0.278]	[0.039]	[0.005, 0.274]	[0.043]	[0.023]
β_{P_2}	0.382	[0.000]	[0.246, 0.517]	[0.000]	[0.244, 0.520]	[0.000]	[0.000]
β_{P_3}	-0.223	[0.001]	[-0.359, -0.082]	[0.001]	[-0.359, -0.086]	[0.003]	[0.000]
β_{P_4}	-0.145	[0.029]	[-0.268, -0.019]	[0.028]	[-0.280, -0.010]	[0.034]	[0.026]
β_{A_1}	-0.154	[0.065]	[-0.316, 0.011]	[0.073]	[-0.321, 0.014]	[0.072]	[0.061]
β_{A_2}	-0.108	[0.132]	[-0.250, 0.031]	[0.164]	[-0.259, 0.043]	[0.124]	[0.144]
№ clusters		7,957		7,957		17,792	17,792

Table D.3: Wild Cluster and Ordinary Wild Bootstrap (Contd.)

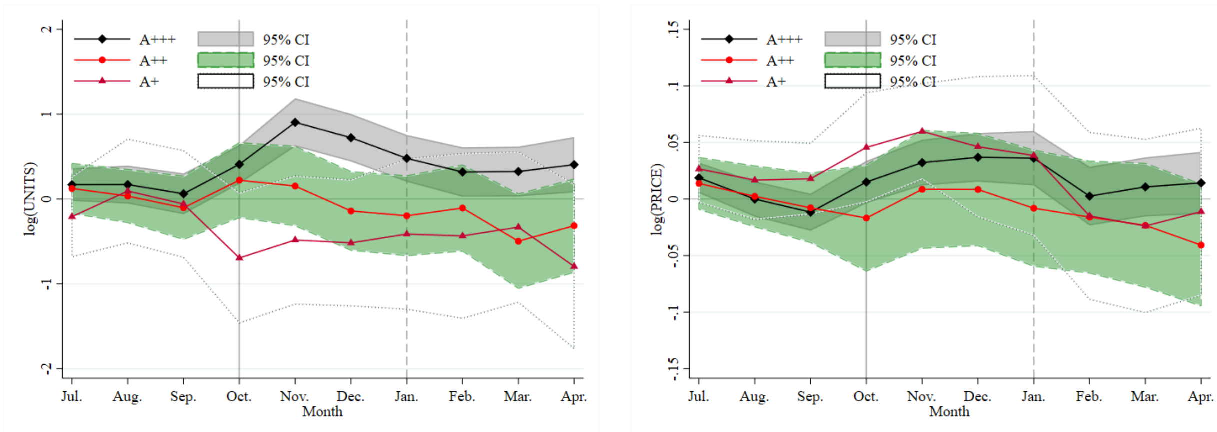
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		WCBR		WCBU		WBR	WBU
H_0		$\beta = 0$		$\beta = \hat{\beta}$		$\beta = 0$	$\beta = \hat{\beta}$
Cluster		Product				Country∩product	
	Coeff.	p-value	95% CI	p-value	95% CI	p-value	p-value
				Hungary, 2016			
β_{B_2}	0.051	[0.286]	[-0.039, 0.142]	[0.265]	[-0.038, 0.140]	[0.258]	[0.275]
β_{B_1}	0.017	[0.726]	[-0.071, 0.106]	[0.723]	[-0.078, 0.112]	[0.741]	[0.711]
β_{P_1}	0.267	[0.000]	[0.172, 0.365]	[0.000]	[0.171, 0.364]	[0.000]	[0.000]
β_{P_2}	0.265	[0.000]	[0.175, 0.356]	[0.000]	[0.173, 0.358]	[0.000]	[0.000]
β_{P_3}	-0.017	[0.715]	[-0.111, 0.077]	[0.717]	[-0.114, 0.079]	[0.712]	[0.701]
β_{P_4}	-0.256	[0.000]	[-0.347, -0.160]	[0.000]	[-0.346, -0.165]	[0.000]	[0.000]
β_{A_1}	-0.017	[0.727]	[-0.106, 0.075]	[0.726]	[-0.109, 0.076]	[0.711]	[0.723]
№ clusters		15,689		15,689		37,895	37,895
				Croatia, June 2015			
β_{B_2}	-0.072	[0.536]	[-0.305, 0.151]	[0.525]	[-0.295, 0.150]	[0.540]	[0.535]
β_{B_1}	-0.073	[0.520]	[-0.288, 0.141]	[0.487]	[-0.282, 0.136]	[0.516]	[0.475]
β_{P_1}	0.919	[0.000]	[0.734, 1.100]	[0.000]	[0.745, 1.093]	[0.000]	[0.000]
β_{A_1}	-0.854	[0.000]	[-1.061, -0.655]	[0.000]	[-1.048, -0.660]	[0.000]	[0.000]
№ clusters		23,527		23,527		50,875	50,875
				Croatia, October 2015			
β_{B_2}	0.063	[0.529]	[-0.129, 0.258]	[0.524]	[-0.144, 0.270]	[0.520]	[0.536]
β_{B_1}	-0.451	[0.000]	[-0.657, -0.245]	[0.000]	[-0.655, -0.247]	[0.000]	[0.000]
β_{P_1}	1.029	[0.000]	[0.809, 1.242]	[0.000]	[0.822, 1.236]	[0.000]	[0.000]
β_{A_1}	-0.668	[0.000]	[-0.875, -0.454]	[0.000]	[-0.881, -0.456]	[0.000]	[0.000]
β_{A_2}	0.109	[0.332]	[-0.115, 0.332]	[0.303]	[-0.101, 0.319]	[0.297]	[0.277]
№ clusters		23,527		23,527		50,875	50,875

Notes: Column (1) reports coefficient estimates for unit sales of subsidized products for all programs based on Eq. (1). Columns (2)-(3) report p-values and 95% confidence intervals from a restricted wild cluster bootstrap clustering by product, and Columns (4)-(5)–from unrestricted wild cluster bootstrap at the same level of clustering. Columns (6) and (7) show p-values from a restricted and unrestricted ordinary wild bootstrap, respectively, clustering at the intersection of country and product. The table uses the wild bootstrap post-estimation procedure `boottest` described in Roodman et. al. (2019) and is based on 999 bootstrap samples.

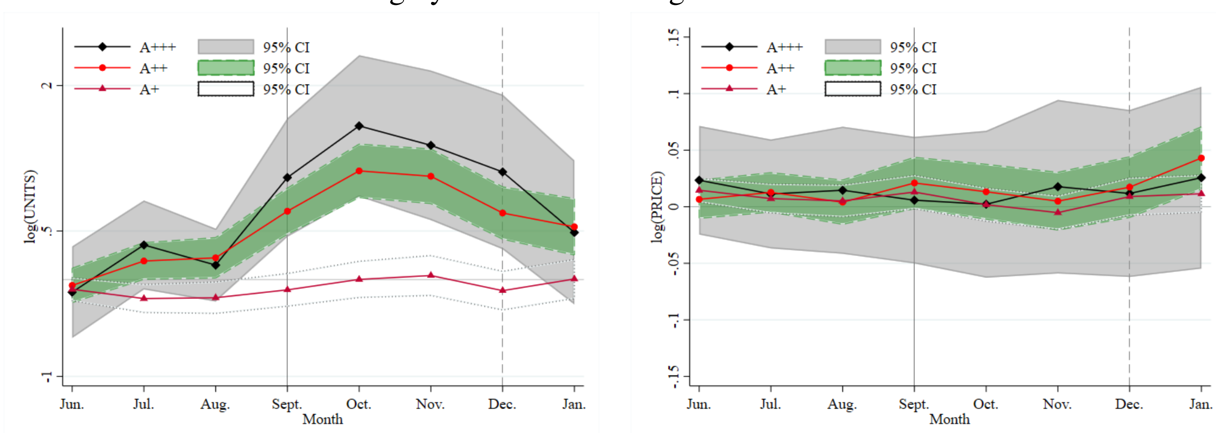
E Additional Figures

Figure E.1: Time Path of Unit Sales and Prices by Label

A: Hungary: Subsidized washing machines



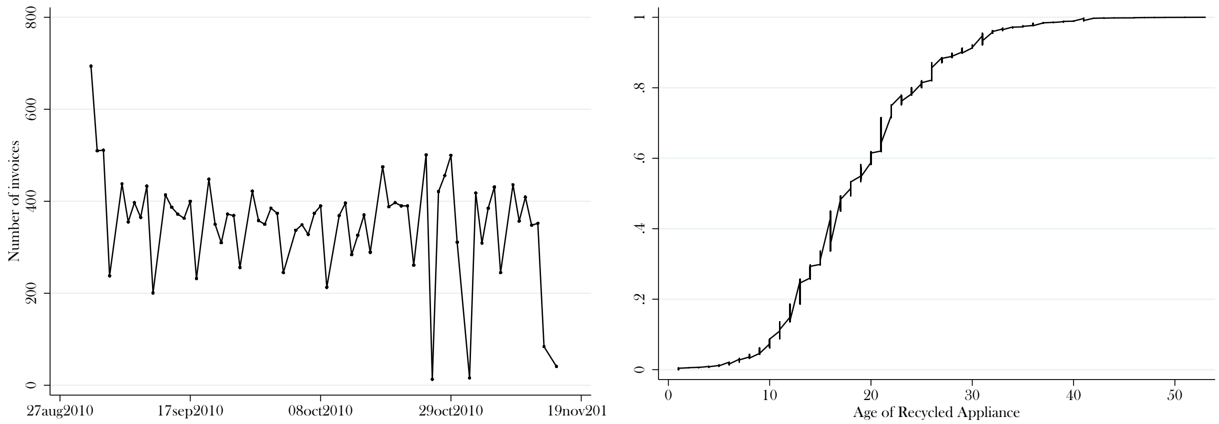
B: Hungary: Subsidized refrigerators and freezers



Notes: The figures depict the predicted time paths of unit sales (left) and prices (right) by energy label of subsidized washing machines in Panel A and subsidized refrigerators/freezers in Panel B for the 2015 and 2016 Hungarian programs. The time paths are based on cumulative sums of coefficient estimates from Eqs. (1) and (2) using three-month window around each subsidy. The beginning of each program is marked with a solid vertical line and the end – with a dashed line. Refer to Tables C.4 for details on coefficient estimates.

Figure E.2: Austria Refrigerators/Freezers Program 2010

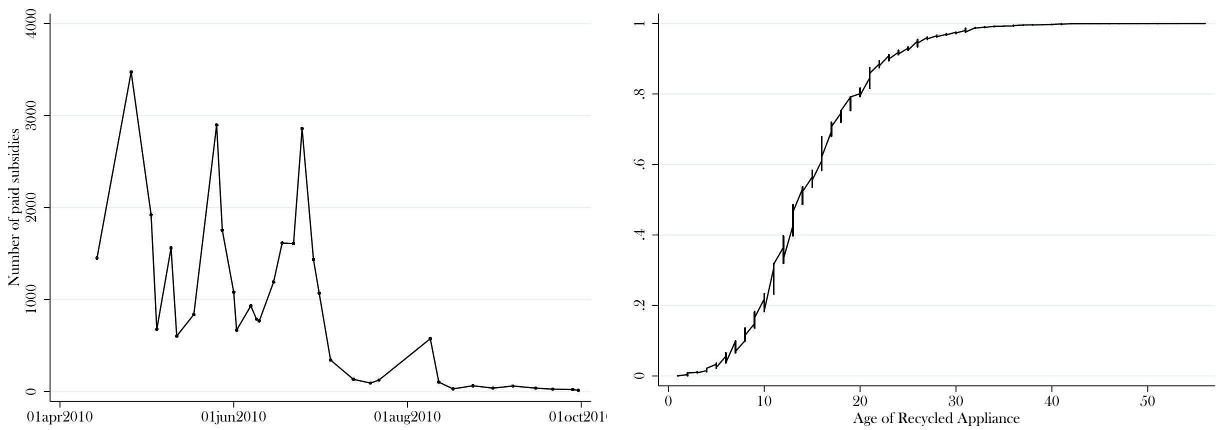
A. № of Invoices per Subsidy Day | B. CDF: Age of Recycled Appliances



Notes: The figure uses an administrative data set for the Austrian 2010 refrigerator & freezer program on the total number of applications, granted and non-granted, reason if non-granted, postcode of applicant, the date of invoice, with which a subsidy is applied for, dummy for recycle status of the old appliance (if any), year of manufacture of the old appliance (if any). Panel A plots the total number of invoices issued per subsidy day from 1st September until 15th November 2010 (20,655 observations), excluding Sundays when shops are closed in Austria. Panel B shows the cumulative distribution function of the age of recycled appliances based on 15,465 applications reporting the year of production of the old device. Both panels exclude non-successful applications. Source: UFH (Karl Tröstl).

Figure E.3: Austria Washing Machines Program 2010

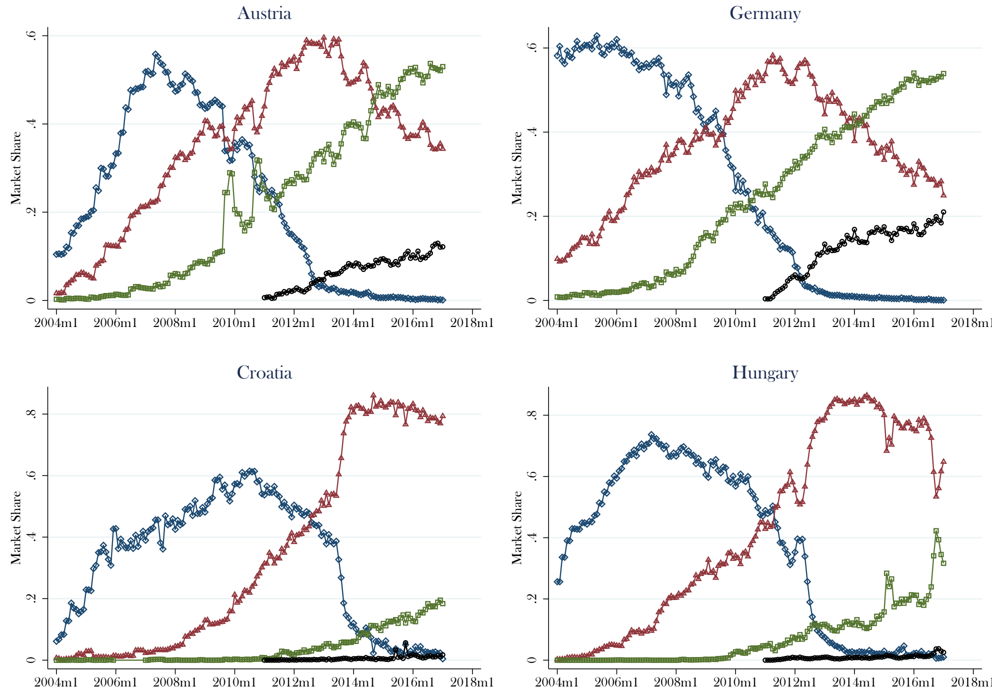
A. № of Paid Out Subsidies | B. CDF: Age of Recycled Appliances



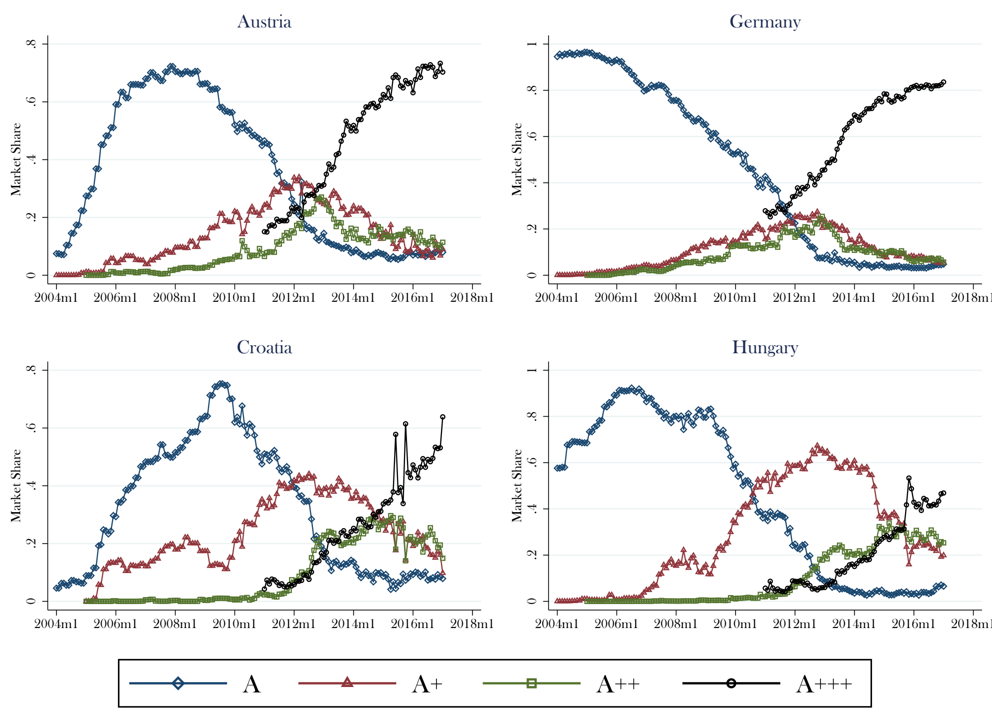
Notes: The figure is based on an administrative data set for the Austrian 2010 washing machine program on the total number of applications, granted and non-granted, reason if non-granted, the date a subsidy is paid out to an applicant, dummy for recycle status of the old appliance (if any), year of manufacture of the old appliance (if any). Panel A plots the disbursement of subsidies from 1st April until 31st September 2010 (30,922 observations). Panel B shows the cumulative distribution function of the age of recycled appliances based on 25,750 applications reporting the year of production of the old device. Both panels exclude non-successful applications. Source: UFH (Karl Tröstl).

Figure E.4: Market Share (Diffusion Rate) by Energy Label and Product Category

A. Cold Appliances



B. Washing Machines



Note: The figures depict the evolution of market shares (units sold of a given energy class over total volume of sales) for refrigerators/freezers and washing machines of energy label A, A+, A++, and A+++ in Austria, Croatia, Germany, and Hungary.