CER-ETH – Center of Economic Research at ETH Zurich

Bunching with the Stars: How Firms Respond to Environmental Certification

S. Houde

Working Paper 18/292
July 2018

Economics Working Paper Series

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Bunching with the Stars: How Firms Respond to Environmental Certification

Sébastien Houde*

July 5, 2018

Abstract

This paper shows that firms respond strategically to ENERGY STAR, a voluntary certification program for energy-efficient products. Firms offer products that bunch at the certification requirement, differentiate certified products in energy and non-energy dimensions, and charge a price premium on certified products. In the US refrigerator market, the magnitude of the price premium corresponds exactly to the average willingness to pay consumers have for certified products. This suggests that firms have the ability to extract most of the consumer surplus associated with certified products. If firms had to pay a fee to use the certification, a policy recently suggested, most of the cost should then be borne by consumers. I illustrate how such policy would impact the adoption of energy-efficient appliances.

JEL Codes: L13, L15, Q48, Q58
Keywords: environmental certification, firm behavior, energy efficiency, imperfect competition.

*ETH Zürich, E2e Project, e-mail: shoude@ethz.ch. I would like to thank Ginger Jin, Lucas Davis, James Sallee, Anna Spurlock, David Rapson, Katrina Jessoe, Kyle Meng, and Antonio Bento, in addition to numerous seminar participants, for helpful suggestions. Daniel Werner and Yuandong Qi provided excellent research assistance. Funding was provided in part by the Precourt Energy Efficiency Center at Stanford University and the Social Sciences and Humanities Research Council of Canada. This research is also part of the activities of SCCER CREST, which is financially supported by the Swiss Commission for Technology and Innovation (CTI)/Innosuisse.

1. Introduction

In recent years, consumer markets have been inundated with eco-labels and environmental certifications. These programs are sometimes managed by governmental entities or non-profit groups to nudge consumers toward more environment-friendly products. Other times, they are offered by business entities or trade organizations as part of corporate social responsibility initiatives. In either cases, a certification program that succeeds in raising environmental awareness among consumers can become an important determinant of market outcomes.

If firms believe that consumers value a certification highly, they will make product line and pricing decisions accordingly. When firms can exercise market power, an environmental certification then facilitates second-degree price discrimination. As a result, firms may benefit by extracting part of the consumer surplus associated with the high willingness to pay for certified products. This result is a standard prediction of product differentiation. It has been discussed, implicitly or explicitly, in the theoretical literature on eco-labels and environmental certifications (Bonroy and Constantatos 2014), and the literature has investigated issues pertaining to market power and its interaction with competing labels (Heyes and Martin 2016; Fischer and Lyon 2014), imperfect information signals (Harbaugh, Maxwell, and Roussillon 2011; Mason 2011), label credibility (Murali, Lim, and Petruzzi 2018), and market structure (Amacher, Koskela, and Ollikainen 2004).

Although imperfect competition and product differentiation are the basic ingredients of these theoretical studies, the empirical importance of these phenomena has not been well documented. The goal of this paper is to bridge the gap between the theory and the real-world applications of environmental certifications. Using the ENERGY STAR (ES) program—a voluntary certification for energy-efficient products—as a case study, I show the different ways by which firms respond strategically to such program.

I investigate firms' product line and pricing decisions and how they respond to the key features of the ES program. Using data from the US refrigerator market, I first show that manufacturers differentiate ES-certified models in both the energy and non-energy dimensions. Although I do not precisely quantify the exact channels giving rise to these strategies, I provide evidence that the nature of the certification requirement, the underlying supply technology to deliver energy efficiency improvements, and demand characteristics all play a role.

I then show that firms, refrigerator manufacturers, and retailers, subject to the ES program also respond strategically through their pricing strategies. I use three different natural experiments to estimate the price premium associated with ES-certified refrigerators. All three strategies allow me to rule out various unobservables correlated with the certification. The estimates are highly consistent with each other, and also with previous estimates of consumers' willingness to pay (WTP) for the ES label that I have estimated elsewhere (Houde 2017). Across three income groups and different specifications, I previously found that the WTP for the ES label ranges from \$16 to \$75 (Table 11, Appendix 9.2). This corresponds to 1.2% to 5.7% of the average price of a refrigerator. Focusing on the behavior of the firms, I now find that ES-certified refrigerators command a price premium that ranges from 1% to 6%, which exactly matches consumers' WTP. Moreover, I extend the analysis to other appliance categories (dishwashers, clothes washers, and air conditioners) and find a price premium of similar magnitude.

This paper is the first to document firms' strategic response to ES,[1] and among a few to consider the broader context of environmental certifications. To date, empirical studies on ES and more generally environmental certifications have focused on consumers' responses using in large part stated preferences data (Ward, Clark, Jensen, Yen, and Russell 2011; Newell and Siikamäki 2014; Davis and Metcalf 2016) or have documented the diffusion of such certification (Kok, McGraw, and Quigley 2011). A few studies have used market-level data combined with hedonic approaches to study the impact of a particular certification on equilibrium prices (Bjorner, Hansen, and Russell 2004; Eichholtz, Kok, and Quigley 2010; Reichardt, Fuerst, Rottke, and Zietz 2012). One example of an empirical study looking into firms' behavior in this context is Rysman, Simcoe, and Wang (2018), which focuses on the Leadership in Environmental and Energy Design (LEED) program for buildings. The study shows that builders use the certification as a device to vertically differentiate new buildings from existing buildings in the same local markets. I also show that ES clearly acts as a mechanism to differentiate in the environmental (energy efficiency, in this case) dimension. In addition, I show that an environmental certification induces vertical differentiation in other dimensions, and that pricing decisions are consistent with these differentiation strategies.

Beyond validating the basic tenets of the theoretical models used to study environmental certifications, my analysis also informs about the incidence of environmental certification

[1] Allcott and Sweeney (2016) investigate how sales agents promote the ES certification, but do not study product line and pricing decisions. They find that sales agents are more likely to selectively mention the certification to consumers prone to purchase ES-certified products.

in imperfectly competitive markets and contributes to the debate on how such program should be funded. This analysis complements my previous work on the ES program, where I focused on consumer response (Houde 2017) and the welfare effects of the program among different market participants (Houde 2018). In this latter work, imperfect competition is an important ingredient that determines what would happen in a market with and without certification. In the present paper, I provide stylized facts that motivate the assumption that firms are well aware of the program, respond strategically with medium-run product line decisions, and make sophisticated pricing decisions that are consistent with second-degree price discrimination and consumer preferences.[2]

I further contribute to the debate on the ES program by investigating the impact of costly certification on various market outcomes. Recently, it has been proposed that the federal administration should stop funding the program and should instead rely on a certification fee that firms would pay to use the ES label. Motivated by my results showing that appliance manufacturers and retailers are able to systemically maintain a price premium on certified products, I argue that a certification fee should be borne almost entirely by consumers. A costly certification would increase the prices of certified products, which would then lower their adoption and lead to an increase in externality costs associated with energy consumption. Under various scenarios regarding the magnitude of the certification fee, I show that the market and environmental impacts of such a fee could be minimal, while it could easily cover the cost associated with running the ES program.

The remainder of this paper is organized as follows. In the next section, I discuss the institutional features of the ES program. In Section 3, I investigate firms' product line decisions in response to ES for the US refrigerator market. In Section 4, I focus on the pricing decisions for the same market. In Section 5, I extend the analysis to US dishwasher, clothes washer, and air conditioner markets. In Section 6, I investigate the impact of costly certification, and conclusions follow in Section 7.

2. The ENERGY STAR Certification Program

The ES program is administered by the US Environmental Protection Agency (EPA) and it covers more than 60 different product categories, ranging from large appliances, to consumer electronics, to residential and commercial buildings. The main feature of the program is

[2]Spurlock (2013) also provides evidence that firms use second-degree price discrimination in the US clothes washer market and focuses on the price impact of ES and minimum standards.

the ES labeling scheme that firms can use in marketing their certified products. Since its establishment, however, the program has grown from a pure product certification scheme into one that also recognizes businesses' and organizations' efforts to promote and achieve energy efficiency. For instance, the EPA now rewards program participants, such as retailers, builders, utilities, and non-profits, with "Partner of the Year" awards. Under this initiative, the program has become an important part of the corporate social responsibility strategies of many businesses. Nonetheless, the core of the program remains the certification of specific technologies with the goal of achieving market transformation (Horowitz 2001).

Under the ES program, the product certification scheme works as follows. The EPA first targets technologies for which it considers energy efficiency improvements to be possible although they have not been adopted in their respective markets. It then establishes a technology-specific certification requirement. For several technologies, such as large appliances, the ES requirement is established relative to the existing federal minimum energy efficiency standard. In the United States, minimum standards consist of a mandatory upper level of energy consumption (and sometimes water) that each product offered on the market must meet, and they usually vary along key product attributes such as size and other dimensions of product design. These are attribute-based regulations (Ito and Sallee 2017), which allow manufacturers to meet energy efficiency requirements by making product design decisions along several dimensions. The ES requirement is usually defined as a simple percentage reduction relative to the corresponding minimum standard for a given technology and is thus also attribute-based.

Given the voluntary nature of the program and the EPA's desire to maximize participation among providers of energy-intensive technologies, the ES certification process has been designed to impose very little cost on program participants. For most of its history, manufacturers could certify their products by simply submitting a list of products that met the requirement to the EPA. Under this process, the certification has been essentially costless. This is especially true in the appliance sector, where manufacturers are required to test and measure the energy consumption of each model they offer to comply with the EnergyGuide mandatory labeling scheme and the federal minimum energy efficiency standards. Given that the ES certification uses the same information, no additional testing and measurement are required.

In 2010, however, the EPA changed its certification process. Following an investigation by the US Government Accountability Office (GAO), which found that the program was too lenient in certifying technologies,[3] the EPA favored a third-party certification process with independent testing. Currently, this certification is a hybrid process, whereby some technologies or manufacturers have to undergo third-party certification, while others can simply submit a list of products that meet the appropriate requirements.

Once a technology is subject to the ES program and the requirement is established, the EPA monitors the market and proposes more stringent requirements over time. The EPA relies on several criteria to revise and set new requirements, such as the share of models offered on the market that are currently certified and the availability of new technologies that can deliver cost-effective improvements in energy efficiency (McWhinney, Fanara, Clark, Hershberg, Schmeltz, and Roberson 2005). A more stringent requirement must be cost-effective based on a life-cycle cost analysis of future energy costs. To carry out this analysis, the EPA estimates the increase in purchase price for a given improvement in energy efficiency and compares this increase with the discounted sum of energy savings over the lifetime of the technology. Observed market prices for certified and non-certified models play an important role in determining the cost increase associated with energy efficiency improvements. Under the EPA methodology, an implicit assumption is that ES-certified models are priced close to their marginal cost, which allows the EPA to accurately infer the marginal cost of providing energy efficiency.

The EPA usually announces a new requirement exactly one year in advance of the effective date. Once a requirement becomes more stringent, the EPA then requires that models that were certified under the previous requirement but do not meet the more stringent one be decertified. Finally, once the EPA deems that a market transformation has been successfully achieved, a technology is no longer subject to the ES program.[4]

3. **Product Line Decisions**

In this section, I first show that refrigerator manufacturers strategically choose the energy efficiency levels of their products to exactly meet the ES certification requirement. I then show that the certification impacts product design decisions along several dimensions. Because of

[3]In its investigation, the GAO illustrated the leniency of the ES certification process by showing that it had certified a gas-powered alarm clock, one among other arguably non-energy-efficient technologies (GAO 2010).

[4]Over the years, the EPA has considered that several markets covered by the ES program achieved a complete market transformation. Examples of such technologies are exit signs and external power adapters.

the nature of the certification requirement, which is akin to an attribute-based regulation (Ito and Sallee 2017), both supply characteristics and demand characteristics play a role in determining how manufacturers meet the ES certification and bundle energy efficiency with different dimensions of quality. For instance, refrigerator overall volume and freezer location, the two main attributes used to define the ES requirement, are strongly correlated with ES-certified models. However, non-energy-related attributes, such as stainless steel finish and the quality of the door handle, are also strongly correlated with ES, which suggests that ES induces manufacturers to vertically differentiate their products not only with respect to energy efficiency, but also along other dimensions of quality.

The data I use for this analysis come from multiple sources and focus on the US full-size refrigerator market. I collected data from the Federal Trade Commission (FTC) to determine the refrigerator models offered on the market during the 2003-2011 period.[5] I matched the FTC data with data from the California Energy Commission (CEC) and from the EPA to recover additional attribute information and to determine the energy efficiency level of each model relative to the minimum federal standard. I use these three datasets to show the evolution of the choice set in the US refrigerator market. I complement these data with transaction-level data from a large appliance retailer, which is active in most US states and has significant market shares. These data cover a large number of refrigerator models offered during the 2008-2012 period. These data also contain additional attribute information that is not available in the FTC, CEC, or EPA data. A unique feature of the transaction data is that a large fraction of transactions ($\approx 44\%$) were matched with household-specific demographic information. In Houde (2017), I use these data to estimate a demand model and to show how consumers respond to the ES certification. In this section, I use the detailed attribute information to show how ES-certified models differ along several dimensions of quality. I also provide additional stylized facts regarding the correlation of household characteristics and the adoption of ES models.

[5]The FTC data contain all refrigerator models that manufacturers offered in a given year in the US market alone and are not sales-weighted. Every calendar year, appliance manufacturers are required to submit to the FTC a list of all models they are planning to stock in retail stores. This information is required by the FTC to comply with the EnergyGuide mandatory labeling program. The actual choice set faced by consumers might differ from what manufacturers are offering due to carry-over inventories. That is, a given refrigerator model can be offered by a manufacturer and can be stocked by retailers in a given year, but not in subsequent years, and still be present in retail stores during the entire period.

3.1. **Bunching at ES**

Figure 1 shows the empirical distribution of energy efficiency for full-size refrigerators from 2003 to 2010. I define energy efficiency as the percentage reduction between the electricity consumption manufacturers reported for each model they offered and the electricity consumption dictated by the federal minimum energy efficiency standard. Note that the minimum standard varies across models because it is set as a function of different attributes. In Figure 1, the ES requirement is identified by the dark vertical line. It was revised on January 2004 and on April 2008. Prior to 2004, the requirement was 10% more stringent than the minimum standard; between 2004 and 2008, the stringency was set at 15%; and after 2008 (until 2014), the stringency was 20%.

Figure 1 clearly shows that manufacturers differentiate their products with respect to energy efficiency. They tend to maintain a bimodal distribution where models either just meet the minimum standard or the ES requirement. The evolution of the distribution over time also shows that firms have the ability to adjust their product lines quickly. When the requirement is revised, which is usually announced exactly one year in advance, not only do they offer new models that meet the revised requirement the same year it is announced, but they also quickly discontinue decertified models after the new requirement becomes effective. As time passes, the share of models that just meet the minimum standard tends to decrease, whereas the bunching at the ES requirement increases. This unraveling toward ES-certified models can be caused by two mechanisms. First, the ES certification might induce technological change facilitating the manufacturing of energy-efficient products. Second, competition effects might induce manufacturers to vertically differentiate by offering more energy-efficient models over time—a phenomenon similar to the one observed by Rysman, Simcoe, and Wang (2018) in the case of the LEED environmental certification for buildings.

Although the share of ES-certified models increases over time, manufacturers offer few highly energy-efficient models that exceed the ES requirement, unless a new requirement is announced. As discussed by Houde (2018), the coarse nature of the ES certification crowds out the offering of highly efficient models if the share of consumers that rely on the ES certification is large enough. It is also possible that manufacturers strategically retain innovation to influence the regulator and to ultimately induce a less stringent certification requirement (Amano 2017).

In the Appendix, I also present the distribution of energy efficiency offered by different manufacturers in the years 2006 and 2010 (Figure 6). The figure shows that firms favored a similar set of strategies, with each firm tending to offer both certified and non-certified models. The bimodal distribution observed for the overall market (Figure 1 is, therefore, not caused by a segmentation of the market where different manufacturers occupy specific portions of the product space. The fact that the strategies are relatively homogeneous across firms also suggests that heterogeneity in the marginal cost of providing energy efficiency may not be a main driver of product differentiation. Instead, the equilibrium outcome is more consistent with a scenario where firms set different energy efficiency levels to screen heterogeneous consumers.

3.2. **Differentiation in the Energy and Non-Energy Dimensions**

The attribute-based nature of the ES requirement enables manufacturers to offer certified products by making design decisions along several dimensions. For full-size refrigerators, the overall volume,[6] the freezer location (top-freezer, bottom-freezer, or side-by-side), and the presence of an ice maker are the three main attributes used in the formula to define the ES requirement. Figure 2 illustrates how manufacturers exploit these dimensions to meet the energy efficiency requirements for the federal minimum standard and ES. Across different types of refrigerators, the joint distribution of volume and electricity consumption corresponds exactly to the requirements for the minimum standard and ES requirement established for each product class.

Figure 2 also shows an important feature of ES. Given that the requirement is based on product characteristics, ES-certified products may not necessarily consume less electricity than non-ES products. In the present market, side-by-side refrigerators with ice makers provide a dramatic example—all ES-certified side-by-side refrigerators consume more electricity than any of the top-freezer refrigerators offered.

In addition to the nature of the certification requirement, supply and demand characteristics can induce a correlation between ES and specific attributes. Supply characteristics correspond to the manufacturing technology used to deliver energy efficiency gains. Demand characteristics are preferences that are correlated across different types of attributes. For instance, higher-income consumers with a high WTP for ES could also prefer larger refrigerators. To investigate the role of the attribute-based requirement, supply characteristics, and demand characteristics, Table 1 presents the correlation between ES and three categories of

[6]A specific formula is used to compute the overall volume of a refrigerator in cubic feet. The volume of the freezing section is scaled by a constant greater than one, and it is added to the volume of the cooling section.

attributes: energy-related attributes used in the definition of the ES requirement, energy-related attributes not used for the requirement, and non-energy-related attributes. This last category corresponds to refrigerator features that should increase quality, in a vertical manner, but should have little impact on energy use from an engineer standpoint. Examples of such features are the stainless steel finish of a refrigerator exterior and a door handle made of metal instead of plastic.

In Table 1, we observe a strong positive correlation between ES and attributes used to define the certification requirement, as expected. Whereas the direction of the correlation with other energy-related attributes tends to be positive, there are a few outliers. For instance, ES models that met the 2004 requirement were less likely to use LED lighting, which is not surprising given that this technology was not as common prior to 2008. The two technology options of advanced cooling and advanced freezing, which mainly refer to the use of sensors to optimize the cooling and freezing processes, are, however, much more predominant among ES-certified models.

In sum, the positive correlation between ES and energy-related attributes is to be expected and suggests that the technology used to deliver energy efficiency gains can exploit several margins. Note that some energy-related attributes could also be correlated with consumer preferences, and the positive correlation found in Table 1 is a result of the combined effect of these various mechanisms. Focusing on the non-energy-related attributes, however, allows us to better isolate the role of demand and vertical product differentiation. Interestingly, there is also a positive correlation between ES and attributes that improve quality but should have little effect on energy use. ES-certified models are more likely to have a stainless steel finish, a metal door handle, more baskets to store food, and a beverage rack. The only exception is the length of the warranty, which is shorter for ES-certified models, although the difference is economically small. Finally, the retailer data also contain a field indicating whether a particular model should have favorable in-store positioning, which is differentiated in four categories (good, better, best, and premium). ES-certified models are 5% to 11% more likely to have a best or premium designation.

As further evidence that demand characteristics play a role in bundling of ES with energy and non-energy attributes, Table 7 (Appendix 9.1) shows the correlation between ES and various demographic information available in the retailer's transaction data. Income level is positively correlated with the adoption of ES-certified models, which is consistent with manufacturers bundling vertical quality, and presumably more expensive features, with ES.

For other demographics, the correlation is weak and not economically significant. Kok, McGraw, and Quigley (2011) also found that income is an important determinant and in fact, one of the main demographic variables explaining the adoption of ES-certified buildings.

4. **Pricing Decisions**

If some consumers value the ES label highly, firms should set prices above marginal costs and extract part of the willingness to pay associated with ES. The challenge in estimating the price premium associated with ES is that several attributes, in addition to energy use, are also correlated with the certification, as just shown above. I exploit three different natural experiments to estimate the price premium associated with the ES certification controlling for unobservables. I first use the revision in the certification requirement that occurred in 2008. Second, I focus on a smaller decertification event that occurred in 2010, when a small number of refrigerator models lost their certification because manufacturers underestimated their energy consumption as a result of a problematic testing procedure. Finally, I consider an institutional feature of the refrigerator market and the fact that manufacturers sometimes offer identical refrigerator models that differ only with respect to their energy consumption. All three estimators show a small price premium for certified models that ranges from 2% to 5%, which is consistent with previous estimates of consumers' WTP for the ES label in this market (Houde 2017).

For this analysis, I rely on the transaction data from the large US appliance retailer. The raw data consist of the transactions for each refrigerator model bought during the 2007-2012 period. I aggregate the data at the model and week levels. For each transaction, I observe three prices: the manufacturer suggested retail price (MSRP), the price actually paid by each consumer (net of sales tax), and the wholesale price paid by the retailer. This last price does not vary over time and effectively consists of the procurement cost to stock a particular refrigerator model. The MSRP is set by the manufacturers and varies over time, but the change in this price is infrequent. The price paid corresponds to the price offered by the retailer and varies widely over time. Note that the retailer has a national pricing policy. Therefore, the variation across stores is minimal, as I have shown elsewhere (Houde 2017).

4.1. **2008 Decertification**

In April 2008, the EPA increased the stringency of the ES requirement for full-size refrigerators, and this new requirement was announced exactly one year in advance. Following such revision, the policy of the EPA is that models that do not meet the more stringent requirement should have their ES labels removed or be clearly identified as not being compliant with the new ES requirement. During the period spanning the effective date of the new requirement, it thus possible to observe the same refrigerator models with and without the ES label. Note that this change in labeling should impact only the information perceived by consumers and not the underlying attributes of the decertified refrigerator models.

I estimate the impact of the change in decertification using a difference-in-differences estimator where I use refrigerator models that were never ES-certified or met the new certification as a counterfactual. The estimator is implemented with the following regression model:

$$log(P_{jt}) = \rho ESTAR_{jt} + \alpha_t + \gamma_j + \beta X_{jt} + \epsilon_{jt} \tag{1}$$

where α_t and γ_j are week-of-sample fixed effects and product fixed effects, respectively. The dependent variable is the log of the weekly price. I report results using both the MSRP and price paid. The variable $ESTAR_{jt}$ is a dummy variable that takes the value of one if product j is certified in week t and zero otherwise. Therefore, the dummy variable $ESTAR_{jt}$ varies only if product j lost its certification in 2008, and the fixed effect γ_j captures all time-invariant product attributes specific to this refrigerator model. X_{jt} is a matrix with additional controls. In one specification, I control for the number of months a product has been on the market, which is a proxy for product age. Controlling for product age allows me to capture dynamic pricing decisions correlated with shelf life. If decertified products tend to be systematically toward the end of their shelf lives, end-of-life sales could be confounded with the effect of decertification. I also consider pre-decertification linear time trends that vary for decertified models and other models. The coefficient ρ is then the quantity of interest and estimates the price impact of removing the ES label.

I estimate the effect of the 2008 decertification with data from January 2007 to December 2008. In 2008, the sample contains 2752 different refrigerator models sold at the retailer, and 1193 lost their ENERGY STAR certification in April 2008 (Table 8, Appendix 9.1).

Figure 3 (panels a and b) provides graphical evidence of the impact of decertification on prices. The average normalized prices (MSRP and promotional) for three efficiency classes are shown: models that lost their certification, models that were not ES-certified as of January 1, 2007, and models that did not lose their certification following the revision in standard. Normalized prices are computed by dividing the price of each refrigerator model by its average price. Figure 3 plots the mean and the standard errors of a flexible regression spline fitted on the normalized price and allows for a discontinuity in the last week of April 2008.

For both the MSRP and the promotional price, there is no clear graphical evidence that the prices of decertified models decreased after the decertification. However, we observe a relative change in prices, especially for the MSRP. The prices of non-ES models, and to a lesser extent ES models that met the new certification requirement, have a strong upward trend following April 2008. In relative terms, decertified models thus became less expensive in the post-revision period. The trends for promotional prices are similar, although they are subject to larger weekly variations. In the pre-revision period, the trends for all three categories of refrigerators tend to be similar, although for the MSRP, non-ES models are trending up as early as January 2008. In the regression model, I show that controlling for linear pre-trends has little impact on the results.

Table 2 presents the estimates of the regression model. Consistent with the graphical evidence, they suggest that the decertification led to a small but significant change in relative prices for decertified models.[7] Controlling for linear pre-trends specific to each of the three product categories (Specification II), product age (Specification IV), or simply omitting non-ES models from the regression model (Specification III) impact the results, but the premium remains small and positive in all cases. For MSRP, the size of the ES premium ranges from 1.7% to 5.9%, and for the transaction price, it ranges from 0.7% to 2.9%.

4.2. **2010 Decertification**

One important caveat in interpreting the results of the 2008 decertification event is that although manufacturers and retailers were required to relabel decertified models, there is no clear evidence that the EPA strongly enforced the policy. This contrasts with the 2010 decertification event.[8] The genesis of this event was the fact that two appliance manufacturers misreported the actual energy usage of a small number of refrigerator models as a result of

[7] A positive coefficient for ρ means that prices are higher when products are certified; i.e., $ES = 1$.

[8] The EPA conducts semiannual assessments to monitor whether products in retail stores are correctly labeled. According to the EPA archives, an assessment for refrigerators was conducted in the spring of 2010. No information is available for the year 2008, though.

a problematic testing procedure. One competitor, aware of this discrepancy, reported the inaccuracy to the EPA and the Department of Energy (DOE) (Plambeck and Taylor 2017), which proceeded to decertify 21 refrigerator models. The EPA and DOE are likely to have enforced this decertification. Not only because there was a small number of refrigerator models affected and but also because one of the manufacturers sought court relief to postpone the decertification, but the U.S. District Court for the District of Columbia upheld the decision on January 18, 2010. On January 20, 2010, the EPA then published a press release announcing the decertification of the 21 refrigerator models.

Figure 4 (panels a and b) shows the average normalized MSRP and promotional prices for refrigerator models that lost their certification and for models that were ES-certified as of January 1, 2009. The figure clearly shows that firms responded by decreasing the prices of decertified models. To estimate the effect on price, I use a difference-in-differences estimator similar to that above with one exception: I restrict the sample to refrigerator models that met the 2008 ES certification only and estimate the decertification effect for the subset of models that lost their certification on January 20 2010. I observe16 models of the 21 models that lost their certification. Given that this decertification event attracted some media attention, I also consider a specification where I interact a dummy for the affected brands with a dummy for the post-decertification period. This control allows me to capture the (potential) negative brand effect that could be correlated with the decertification of a subset of models.

Table 3 presents the results. The magnitude of the estimates is slightly larger than for the 2008 event and robust across specifications. For MSRPs, the ES premium ranges from 5.7% to 6.5%, and for transaction prices, it ranges from 1.4% to 4.1%.

4.3. **Identical Pairs**

One important institutional feature of the US refrigerator market is the large number of products offered by manufacturers at any given moment in time. Although refrigerators are relatively simple technology, manufacturers offer a large number of variants with subtle differences. Above, I showed that the manufacturers rely on the ES certification to differentiate their products in the energy efficiency dimension, as well as in other dimensions that may not be energy-related. Although ES-certified models are systematically correlated with several attributes, in several cases, manufacturers offer product lines where two refrigerator models are identical along all observed dimensions except energy use. These identical pairs usually consist of models offered by the same brand, with the same size, freezer location, overall design, and technology features. However, they have subtle differences in insulation, interior lighting technology, or sensors that allow them to achieve different levels of energy consumption.

In my sample, I use the detailed attribute information to identify such identical pairs. In particular, I match refrigerators by brand, freezer volume, refrigerator volume, height, width, freezer location, door material (stainless or not), ice-maker option, defrost technology, air filtration system, color, and door handle type.[9] Using this matching procedure, I found 50 identical pairs of refrigerator models that differ only with respect to their annual electricity consumption and their ES certification status. For the present analysis, I sought to identify the difference in pricing strategy between these pairs of models that differ with respect to their certification status but are otherwise identical. To do so, I use the wholesale price to compute the markup associated with each model. I then compare the markups for the models within each pair over the period 2008-2012. I use two measures of markup: the percentage markup of the MSRP and the percentage markup of the transaction price.

The regression model that I estimate is a simple fixed model where I regress the percentage markup on an identical pair fixed effects and week-of-sample fixed effects. I also consider an alternative specification where I control for year of entry, as two identical models may not have first entered the market at the same time. The year-of-market-entry fixed effects capture manufacturing cost shocks that may have impacted price (wholesale, MSRP, or transaction) at different points in time. I also consider brand dummies interacted with year-of-market-entry fixed effects to capture firm-specific temporal cost shocks. Table 4 shows that ES-certified models tend to have markups that are 1.6 to 2.6 percentage points higher, on average.

4.4. **Discussion**

Altogether, the stylized facts show that firms operating in the appliance market are aware of the ES certification, believe that consumers value it, and consequently optimize their product lines and prices. Exploiting two decertification events and an institutional feature of the refrigerator market, I obtain three different sets of estimates of the price premium associated

[9] I thank my research assistant Yuandong Qi for painstakingly verifying that the attribute information displayed in various online marketplaces was indeed identical for all the pairs identified by the matching procedure. The identical pairs used for this analysis have all been validated.

with the ES certification that are highly consistent with each other. The premium ranges from 1% to 6%, which also corresponds to the average WTP that consumers have for the ES label in this market (Houde 2017).

By exercising market power, firms can thus extract part of the private benefits associated with the lower energy costs that ES-certified products deliver. To illustrate, consider the difference in electricity consumption between non-ES models and ES models that just met the ES requirement prior to April 2008 (i.e., models that were at least 15% more efficient than the minimum standard). According to Table 1, this difference is 76 kWh/y. Assuming a refrigerator lifetime of 18 years, an average electricity price of 0.11 $/kWh, and a discount rate of 5%,[10] the expected difference in lifetime electricity costs between an ES-certified and a non-ES-certified refrigerator is $98. This corresponds to 5.4% of the MSRP of the ES model in Table 1. Thus, most, if not all, of the private benefits associated with lower electricity consumption is captured by firms, which have the ability to charge higher markups on certified models.

5. **Additional Evidence: Other Markets**

Given that the ES program covers more than 60 product categories, how do the results from the full-size refrigerator market translate to these other markets? Extrapolating the present results to a broader context should be done with caution. The market structure, underlying technologies, and certification requirements vary widely across markets targeted by the ES program, and so should the firms' responses. Thus, it is outside the scope of this paper to investigate firms' responses for all those markets.

In this section, however, I provide additional evidence for a subset of appliance categories that share similar characteristics in terms of market structure and purchase environment to the refrigerator market: dishwashers, clothes washers, and air conditioners. I also revisit the full-size refrigerator market, with a different dataset to assess the external validity of the transaction data provided by the retailer. The data I use in this section consist of point-of-sales data provided by the NPD Group. These data are disaggregated at the model and month levels for the whole US market.[11] Each observation consists of the monthly quantity

[10]These three assumptions are in line with the values used by the DOE to perform cost-benefit analysis of the federal minimum energy efficiency standard program.

[11]The NPD Group collects data from several retail chains and claims that its data cover about 50% of the US market in each appliance category.

of a particular appliance model sold in a large sample of appliance retail stores and the revenue associated with those sales. Using monthly quantities and revenues, I construct an unbalanced panel of monthly average prices at the model level. The panel covers the period 2005 to 2011 and spans several decertification events across appliance categories. Note that the data contain some attribute information, which allows me to identify models that meet more stringent certification requirements. However, detailed attribute information is not available, restricting my ability to conduct an analysis similar to the one carried out for the refrigerator market.

Overall, I find that the results are very consistent across appliance categories. Manufacturers offer products that tend to bunch at the ES certification requirement, and there is a small but noticeable price premium associated with the ES label.

5.1. **Product Lines: Energy Efficiency Offered**

Figure 5 shows the empirical distribution of the energy efficiency offered (non-sales-weighted) for each appliance type. I consider that a particular model was offered on the market in a given year if I observe at least one sale. Under this assumption, the choice set in a given year reflects both manufacturing decisions and retail stores' inventories (i.e., models not offered by manufacturers in a given year but offered in retail stores).[12]

The distributions of energy efficiency for air conditioners follow a similar pattern to those refrigerators. Products bunch at the minimum standard, most products just meet the ES standard, and a few products exceed the certification requirement. There were no revisions in the requirement from 2005 to 2010, except in November 2005, when reverse cycle models, a particular type of air conditioner that can both heat and cool, were allowed to be covered by the ES program. As a result, a small number of models in the sample (N=6, Table 10) earned the ES certification at the end of 2005.

For dishwashers, products tend to bunch around the ES requirement, but the patterns are more idiosyncratic. This can be first explained by the fact that the minimum standard and ES requirement for dishwashers are defined by a combination of energy and water factors, which are inversely correlated. I conjecture that it is thus more difficult for manufacturers to

[12]The FTC data, on the other hand, correspond exactly to what manufacturers aimed to offer in a given year. Even though there is a discrepancy between the two datasets, the distributions for full-size refrigerators in Figure 5 look very similar to those earlier. The effects of inventories in the NPD data are thus likely to be minimal.

make design decisions to achieve a precise level of energy efficiency. This appliance category was also subject to frequent revisions of the ES requirement. It was revised (effective date) in January 2007, August 2009, and July 2011. The minimum standard was revised in January 2010. The revised standard relied on a different approach to compute the energy factor, which explains the important difference in the distribution between 2010 and other years.[13] Prior to 2010, the fact that the minimum standard had been in place for a long time could explain why the minimum standard was not binding. The cumulative effect of small innovations throughout the years may have enabled manufacturers to increase efficiency beyond the minimum required.

For clothes washers, new ES requirements became effective in January 2007, July 2009, and January 2011. The revisions in 2007 and 2011 also coincided with changes in the minimum standard. Figure 5 shows that for all years, a large share of products just met the minimum standard, there was bunching at the ES standard in 2005 and 2006, but then models tended to exceed the ES requirement. In the most recent years, the distribution is bimodal, with a large share of products that just met the minimum and the remaining exceeding the ES standard. It should be noted that the minimum standard and ES requirement for this appliance category are also defined by a combination of energy and water factors. Similarly to dishwashers, the relative lack of bunching at the ES requirement compared with refrigerators and air conditioners could be explained by the fact that the technology required to meet the ES requirement is more complex, as it must optimize in the energy and water dimensions.

5.2. **Pricing: Impact of ES Decertification/Certification**

My empirical strategy to estimate the ES price premium across these various appliance categories is similar to the one I used before. I exploit the changes in the stringency of the certification requirement and the fact that a large number of models lost their ES labels over time. The estimator is implemented with the difference-in-differences estimator of Equation 1 for each appliance category separately. I report two specifications: a first specification with model fixed effects, month-of-sample fixed effects, and a control for product age (measured in months), and a second specification without a control for product age but with linear time trends that can vary in the pre-decertification period.

[13]The previous minimum standard, effective in 1994, relied on an energy factor that was a function of capacity and energy consumption. Since 2010, it is simply set as a function of total energy consumption (kWh/year).

Table 5 reports the regression results. For all three appliance categories subject to at least one decertification event,[14] the decertification led to a decrease in price that is statistically significant (standard errors are clustered at the product level), and is 4.4%-5.0%, 8.2%, and 7.6%-8.7%, for refrigerators, clothes washers, and dishwashers, respectively. Controlling for pre-decertification linear time trends does not impact the results significantly, and I fail to reject that the pre-time trends are the same for decertified and non-decertified models.[15] The effect of product age is negative and significant: as products stay longer on the market, the price tends to decrease. This is consistent with long-term inventory management. As newer models enter the market, manufacturers and retailers may want to liquidate decertified models to free up inventory. The fact that the prices of decertified models decrease even after controlling for product age means that the estimates are not simply capturing end-of-life sales. As I show next, even when the effect of inventories should be expected to have the opposite effect or can be completely ruled out, firms still set different prices for the exact same appliance models with and without the ES label.

In the market for air conditioners. the ES program was expanded in November 2005 to cover a particular type of model that was previously not eligible for certification. In my sample, I thus observe a small number of AC models that earned the ES certification. In 2005-2006, when firms were presumably stocking up on these models, inventories should have been increasing. Using the same strategy as before, I can then compare the prices of these models before and after the certification and use all other AC models as a counterfactual. I find that earning the certification leads to a price increase of 6.0% to 7.3% (Table 5), which closely mirrors the effect of the decertification events. These estimates are, however, marginally significant, which is not surprising given that only six models in the sample earned the certification.

6. **The Impact of Costly Certification**

One important but controversial feature of the ES program is that the certification process is designed to minimize the burden on manufacturers while maximizing participation. From this standpoint, the program has largely succeeded. For technologies subject to the ES program, the certification is widely sought by businesses and organizations, which has resulted

[14]For air conditioners, there was no decertification event during the period 2005-2010.

[15]A pre-decertification linear time trend is specified for each decertification event for the 12 months preceding the revision. The appliance categories subject to three revisions have then 3×2 pre-decertification linear time trends estimated.

in consumers having a high degree of awareness and understanding toward ES (Murray and Mills 2011). Over the years, the program, and especially its certification process, has faced a number of controversies challenging its reputation and trust among consumers. The GAO's 2010 covert testing investigation (GAO 2010) was a turning point that lead the EPA to revisit its certification process. There have also been repeated calls to privatize the ES program—a debate that became very salient recently with the Trump administration's proposal to eliminate public funding for the program. The rationale of the Trump administration is that because firms benefit from the program, a system where the EPA relies on a certification fee should succeed in funding the program.

What would be the impact of costly certification? The incidence of a costly certification and in particular the pass-through of a certification fee, would ultimately depend on the characteristics of each market subject to ES. At one extreme, when demand is relatively inelastic and firms have market power, most of the costs should be passed to consumers. This is turn should reduce the demand for ES-certified models and slow the adoption of energy-efficient products. At the other extreme, in competitive markets where demand is very elastic and competition among firms is high, firms may bear most of the certification costs. In this latter case, a certification fee would have little direct impact on demand, but it would reduce profits and thus firms' incentive to certify products. In equilibrium, this would reduce the market offering of energy-efficient technologies, and ultimately it would also impact demand and realized energy savings.

For the US appliance market, the fact that I find that manufacturers and retailers are able to systematically maintain higher markups for certified products suggests that a costly certification should be borne mostly by consumers. To investigate the market and environmental impact of a costly certification in the appliance market, I consider the extreme case where there is complete pass-through. I then use the full demand system estimated in Houde (2017) to simulate the change in market shares, consumer surplus, and externality costs for different levels of certification fees. The demand model consists of a discrete choice model for full-size refrigerators with two dimensions of heterogeneity: all behavioral parameters vary with three income levels, and within each income group, consumers can be heterogeneous in the way they process energy information. In particular, some consumers might focus on the ES certification, others might prefer more detailed and accurate information about energy costs, and still others might simply dismiss energy information altogether. A theory of information acquisition is used to rationalize each type. In sum, the model accounts for rich patterns of heterogeneity, which makes it particularly well suited to simulate market shares due to a change in price. I model the costly certification as a simple increase in the purchase price where each fee is similar to a small lump-sum tax that must be paid for each ES model sold. To simulate the market, I construct a representative choice set that corresponds to the choice set that was offered in 2011. Further details on the policy simulations can be found in Appendix 9.3.

Table 6 presents the results for three different certification fees: \$10, \$50, and \$100. The first row shows the change in market share for ES-certified products. A fee of \$10 has little to no effect on market shares; a fee of \$50 reduces market share by 2.0%; and a fee of \$100 reduces market share by 4.3%. Considering that the average price (MSRP) of a refrigerator is approximately \$1,700 for an ES-certified model, the certification fee elasticity in this market is on average -0.7.

These changes in market shares translate into small changes in energy consumption. For a fee of \$50, the average increase is 1.59 kWh/y for each refrigerator sold and for \$100, the increase is 3.29 kWh/y. I translate these numbers into change in externality costs using various estimates of the marginal local and global damages associated with electricity generation in the United States, and emission factors (Table 14, Appendix 9.3). I also assume that a refrigerator lifetime is 18 years and sum and discount the externality costs over the lifetime, with a (social) discount rate of 5%. Note that the overall size of the US refrigerator market during that period was approximately 9 million units sold. Focusing on the upper-bound estimate of the externality costs, the overall change in externality costs is \$2.59M, \$13.18M, and \$27.31M for a fee of \$10, \$50, and \$100, respectively. To put this number in perspective, according to the GAO (2011), the EPA and the DOE have spent \$57.4M/year, on average, during the period 2008-2011 to run the ES program. The total amount collected from the certification fees for each of those three scenarios is \$57.81M, \$280.20M, and \$543.48M. In these scenarios, a certification fee of \$10 for the refrigerator market alone could therefore be enough to fund the overall ES program with little impact on energy savings and externality costs.

The above results suggest that a very modest fee targeting a few product categories could be enough to fund the overall ES program. To minimize the impact of the fee on market and environmental outcomes, the EPA should also target markets where imperfect competition appears to be at play. In those markets, a small fee should have a small impact on markups, but it should not change the product offering and should thus be consistent with the EPA's goal of achieving a "market transformation."

7. Conclusions

In this paper, I show three important stylized facts pertaining to environmental certifications. Using the ES program as a case study, I first show that in the imperfectly competitive US appliance market, manufacturers make strategic product line decisions to exactly match the ES certification requirement. Second, I show that the certification enables firms to differentiate products in the energy and non-energy dimensions. This differentiation is due to a combination of three factors: the attribute-based nature of the certification requirement, the underlying technology to provide energy efficiency improvements, and demand characteristics. The observed differentiation is consistent with second-degree price discrimination where ES-certified products are more expensive, more efficient, of higher (vertical) quality in other dimensions, and targeted toward higher-income households. Third, I show that ES-certified models have a systematic price premium, where this premium is attributable to higher markups and the effect of information alone. That is, ES models are more expensive not only because it is costly to design more energy-efficient technologies, they are also more expensive because a significant share of consumers have a high willingness to pay for the ES label, which enables firms to charge higher prices.

The fact that the size of the ES price premium is of the same magnitude as the private benefits associated with the energy savings of ES-certified models has several implications for the design and evaluation of the program. First and foremost, consumers might not benefit as much from the program relative to the firms. Second, a costly certification fee used to fund the program should be borne mostly by consumers and have little impact on firms' profits. I show that such a policy would require setting a very modest fee to collect the necessary public funds to run the program, which would have little impact on market and environmental outcomes.

References

Allcott, H., and R. L. Sweeney (2016): "The Role of Sales Agents in Information Disclosure: Evidence From a Field Experiment," *Management Science*, 63(1), 21–39.

Amacher, G. S., E. Koskela, and M. Ollikainen (2004): "Environmental Quality Competition and Eco-labeling," *Journal of Environmental Economics and Management*, 47(2), 284–306.

Amano, T. (2017): "Ratcheting, Competition, and the Diffusion of Technological Change: The Case of Televisions under an Energy Efficiency Program," Ph.D. thesis, Stanford University.

Bjorner, T. B., L. G. Hansen, and C. S. Russell (2004): "Environmental Labeling and Consumers‘ Choice: An Empirical Analysis of the Effect of the Nordic Swan," *Journal of Environmental Economics and Management*, 47(3), 411–434.

Bonroy, O., and C. Constantatos (2014): "On the Economics of Labels: How their Introduction Affects the Functioning of Markets and the Welfare of all Participants," *American Journal of Agricultural Economics*, 97(1), 239–259.

Davis, L. W., and G. E. Metcalf (2016): "Does Better Information Lead to Better Choices? Evidence From Energy-Efficiency Labels," *Journal of the Association of Environmental and Resource Economists*, 3(3), 589–625.

Eichholtz, P., N. Kok, and J. M. Quigley (2010): "Doing Well by Doing Good? Green Office Buildings," *American Economic Review*, 100(5), 2492–2509.

Fischer, C., and T. P. Lyon (2014): "Competing Environmental Labels," *Journal of Economics & Management Strategy*, 23(3), 692–716.

GAO (2010): "ENERGY STAR PROGRAM: Covert Testing Shows the Energy Star Program Certification Process Is Vulnerable to Fraud and Abuse," Report to congressional requesters, US Government Accountability Office, GAO-10-470.

——— (2011): "ENERGY STAR Providing Opportunities for Additional Review of EPA's Decisions Could Strengthen the Program," Report to congressional requesters, US Government Accountability Office, GAO-11-888.

Greenstone, M., E. Kopits, and A. Wolverton (2011): "Estimating the Social Cost of Carbon for Use in U.S. Federal Rulemakings: A Summary and Interpretation," NBER Working Paper 16913, National Bureau of Economic Research.

Harbaugh, R., J. W. Maxwell, and B. Roussillon (2011): "Label Confusion: The Groucho Effect of Uncertain Standards," *Management Science*, 57(9), 1512–1527.

Heyes, A., and S. Martin (2016): "Social Labeling by Competing NGOs: A Model with Multiple Issues and Entry," *Management Science*, 63(6), 1800–1813.

Horowitz, M. J. (2001): "Economic Indicators of Market Transformation: Energy Efficient Lighting and EPA's Green Lights," *The Energy Journal*, 22(4), 95–122.

Houde, S. (2017): "How Consumers Respond to Environmental Certification and the Value of Energy Information," *The RAND Journal of Economics*, forthcoming.

Houde, S. (2018): "The Incidence of Coarse Certification: Evidence from the ENERGY STAR Program," *Economics Working Paper Series*, 18(290).

Ito, K., and J. M. Sallee (2017): "The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel Economy Standards," *The Review of Economics and Statistics*, forthcoming.

Kok, N., M. McGraw, and J. M. Quigley (2011): "The Diffusion of Energy Efficiency in Building," *American Economic Review*, 101(3), 77–82.

Mason, C. (2011): "Eco-Labeling and Market Equilibria with Noisy Certification Tests," *Environmental and Resource Economics*, 48(4), 537–560.

McWhinney, M., A. Fanara, R. Clark, C. Hershberg, R. Schmeltz, and J. Roberson (2005): "ENERGY STAR Product Specification Development Framework: Using Data and Analysis to Make Program Decisions," *Energy Policy*, 33(12), 1613–1625.

Muller, N. Z., and R. Mendelsohn (2012): "Efficient Pollution Regulation: Getting the Prices Right: Corrigendum (Mortality Rate Update)," *American Economic Review*, 102(1).

Murali, K., M. K. Lim, and N. C. Petruzzi (2018): "The Effects of Ecolabels and Environmental Regulation on Green Product Development," *Manufacturing & Service Operations Management*.

Murray, A. G., and B. F. Mills (2011): "Read the Label! Energy Star Appliance Label Awareness and Uptake Among US Consumers," *Energy Economics*, 33(6), 1103–1110.

Newell, R. G., and J. Siikamäki (2014): "Nudging Energy Efficiency Behavior: The Role of Information Labels," *Journal of the Association of Environmental and Resource Economists*, 1(4), 555–598.

Plambeck, E., and T. A. Taylor (2017): "Testing by Competitors in Enforcement of Product Standards," *Management Science*, Forthcoming.

Reichardt, A., F. Fuerst, N. Rottke, and J. Zietz (2012): "Sustainable Building Certification and the Rent Premium: A Panel Data Approach," *Journal of Real Estate Research*, 34(1), 99–126.

Rysman, M., T. Simcoe, and Y. Wang (2018): "Differentiation Strategies in the Adoption of Environmental Standards: LEED from 2000-2014," Working paper.

Spurlock, C. A. (2013): "Appliance Efficiency Standards and Price Discrimination," Working Paper 6283E, Lawrence Berkeley National Lab.

Ward, D. O., C. D. Clark, K. L. Jensen, S. T. Yen, and C. S. Russell (2011): "Factors Influencing Willingness-to-Pay for the ENERGY STAR Label," *Energy Policy*, 39(3), 1450–1458.

8. **Figures and Tables**

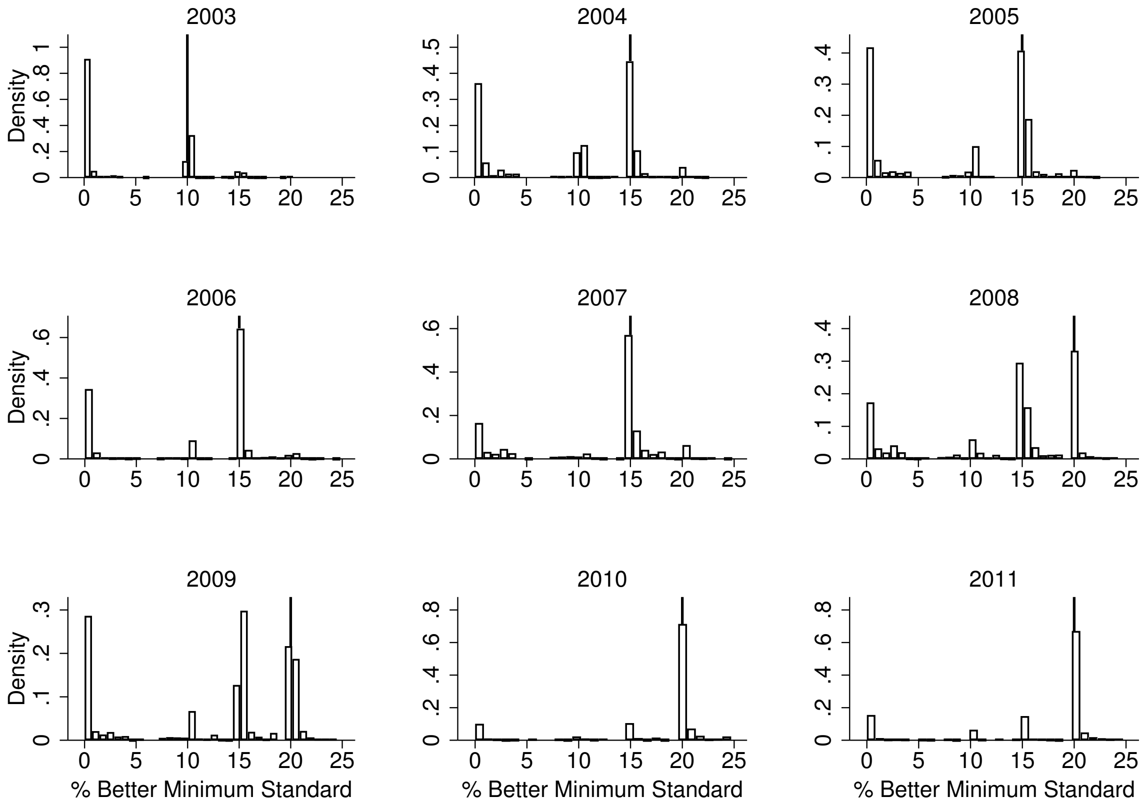


FIGURE 1. Energy Efficiency Offered: Full-Size Refrigerators 2003 to 2011
Notes: Each panel plots the empirical density of the energy efficiency levels offered (non-sales weighted) for full-size refrigerators. The x-axis is the percentage decrease in electricity consumption (kWh/y) relative to the federal minimum energy efficiency standards. The ES certification requirement is identified by the dark line. Sources: Federal Trade Commission and EPA.

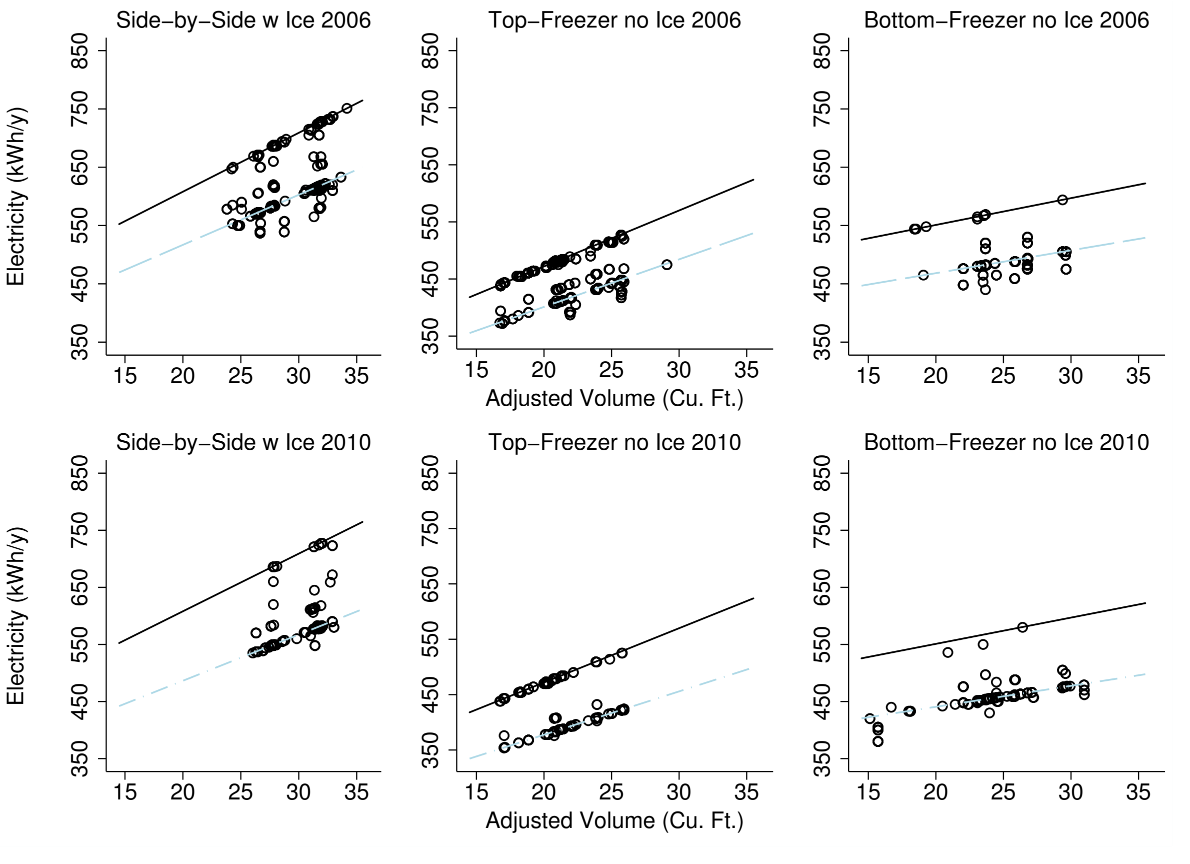
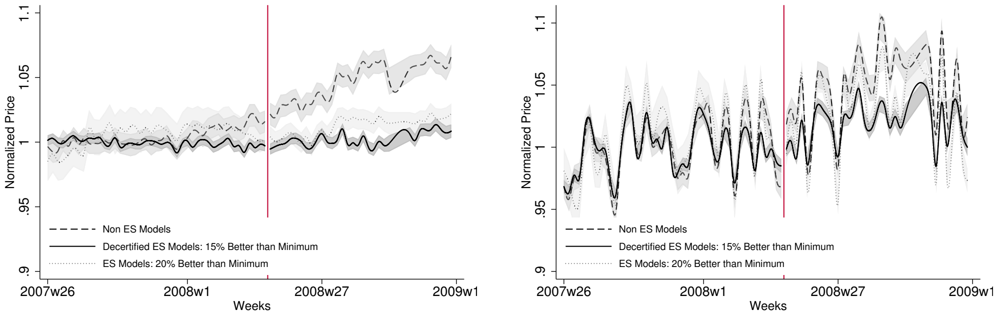


FIGURE 2. Energy Efficiency versus Volume: Full-Size Refrigerators 2006 and 2010

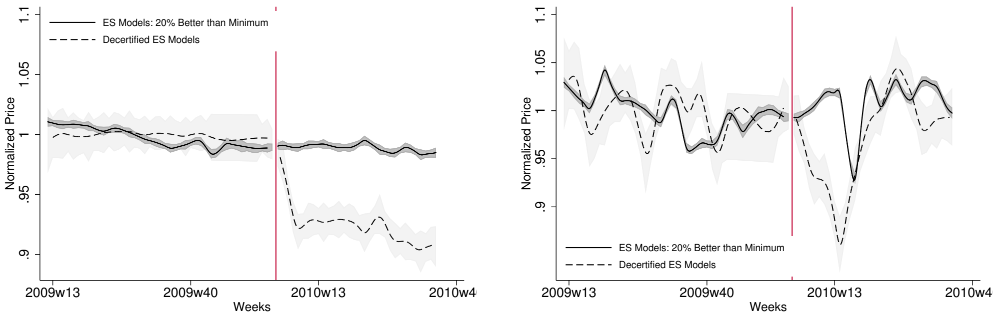
Notes: Each panel plots each model offered in the energy efficiency versus volume dimensions. The x-axis is the adjusted volume, which a weighted average of the refrigerator and freezer volumes measured in cubic feet. The y-axis is electricity consumption measure in kWh/y and reported by the manufacturers. The ES certification requirement is identified by the dark line. Sources: Federal Trade Commission and EPA.



(a) MSRP (b) Price Paid

FIGURE 3. Price Variation: 2008 Decertification Event

Notes: Each panel displays average normalized weekly prices, with 5% confidence intervals, of refrigerators that belong to different efficiency classes. The normalized price for each model is the weekly price (MSRP or transaction price) divided by its average weekly price. The average normalized price and standard errors in each efficiency class are computed by fitting a cubic spline on normalized prices.



(a) MSRP (b) Price Paid

FIGURE 4. Price Variation: 2010 Decertification Event

Notes: Each panel is constructed as in Figure 3. In panels a and b, prices of the 16 models that were decertified are compared with the prices of ES models that did not lose their certification.

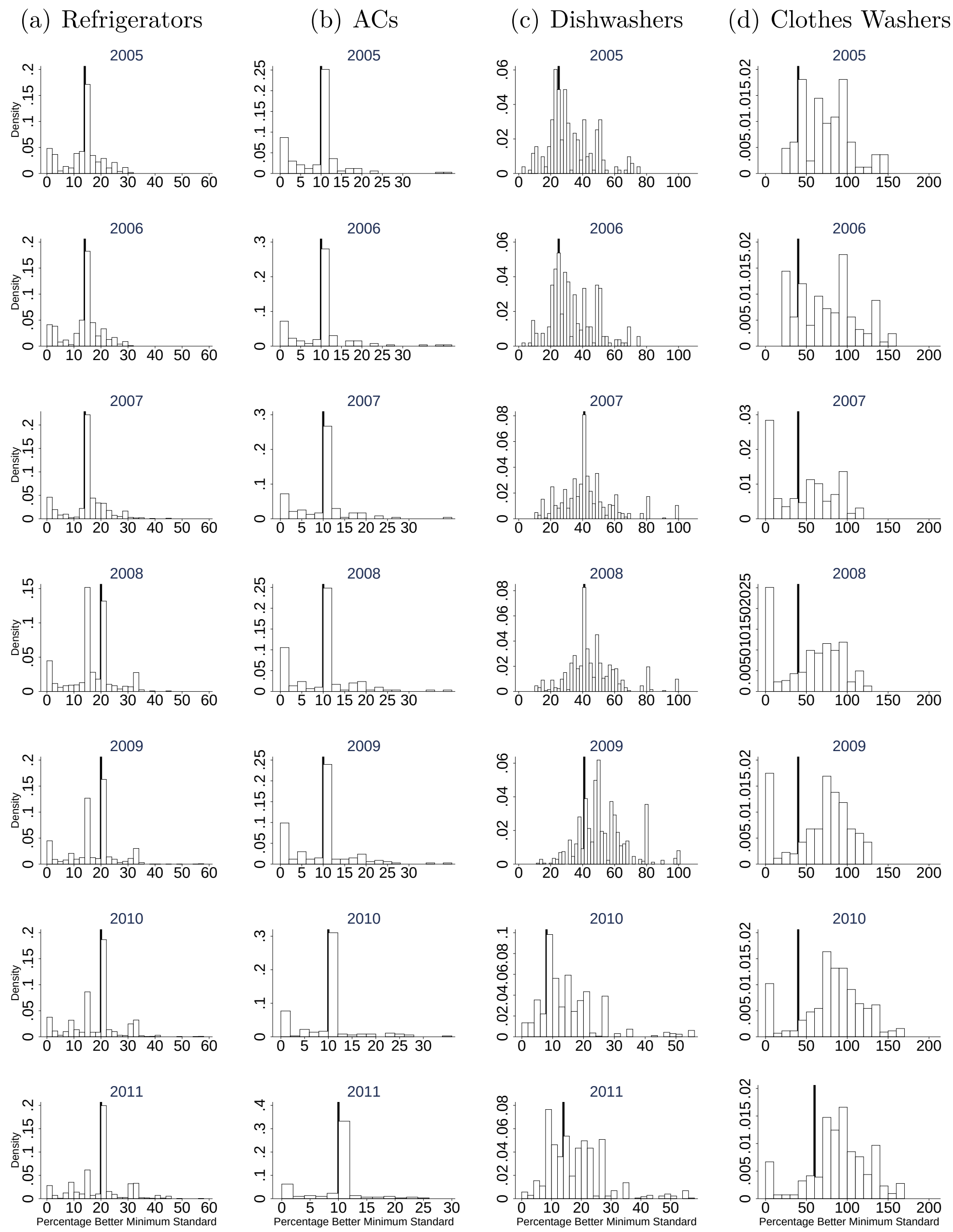


FIGURE 5. Energy Efficiency Offered, 2005-2011

Notes: Each panel plots the empirical density of the energy efficiency levels offered (non-sales weighted) for four appliance types. The x-axis is the percentage decrease in electricity consumption (kWh/y) relative to the federal minimum energy efficiency standards. The ES requirement is identified by the dark vertical line. Source: NPD Group.

Table 1. Correlation Between ES and Product Attributes

	Non-ES	ES 2004 at 15%	ES 2008 at 20%	Non-ES vs. ES at 15%	Non ES vs. ES at 20%
kWh/y	614.72	538.17	503.73	-76.54*	-110.99*
	(2769)	(1903)	(1908)		
MSRP	1539.65	1792.52	1719.10	252.88*	179.45*
	(2750)	(1894)	(1894)		
Energy-related attributes used for the ES requirement					
Adjusted Volume	26.20	27.32	27.64	1.11*	1.44*
	(2769)	(1903)	(1908)		
Freezer Volume	6.57	7.61	7.73	1.04*	1.15*
	(604)	(868)	(1394)		
Ice Maker	0.40	0.61	0.71	0.21*	0.31*
	(2769)	(1903)	(1908)		
Share Side-by-Side	0.44	0.48	0.43	0.04*	-0.01
	(2769)	(1903)	(1908)		
Share Bottom-Freezer	0.20	0.26	0.37	0.06*	0.16*
	(2769)	(1903)	(1908)		
Energy-related attributes not used for the ES requirement					
Advanced Cooling	0.11	0.28	0.41	0.18*	0.30*
	(2769)	(1903)	(1908)		
Advanced Freezing	0.06	0.22	0.20	0.16*	0.15*
	(2769)	(1903)	(1908)		
LED Lights	0.48	0.10	0.44	-0.39*	-0.04
	(193)	(166)	(337)		
Dual Cooling	0.22	0.08	0.24	-0.13*	0.02
	(152)	(224)	(322)		
Non-energy-related attributes					
Stainless	0.09	0.16	0.25	0.07*	0.16*
	(2769)	(1903)	(1908)		
Air Filtration	0.04	0.04	0.15	0.01	0.11*
	(2769)	(1903)	(1908)		
Advanced Technology	0.09	0.24	0.36	0.15*	0.26*
	(2769)	(1903)	(1908)		
# Baskets	1.68	1.88	1.98	0.19*	0.29*
	(174)	(209)	(399)		
Warranty (# years)	1.12	1.05	1.03	-0.08*	-0.09*
	(578)	(851)	(1241)		
Beverage Rack	0.37	0.60	0.40	0.23*	0.04
	(563)	(857)	(1282)		
Metal Door Handle	0.15	0.21	0.30	0.06	0.15*
	(246)	(306)	(506)		
Best Item Positioning	0.53	0.63	0.59	0.11*	0.06*
	(1080)	(732)	(782)		

Notes: The first column corresponds to refrigerators that never met the ES requirement. The second column corresponds to refrigerators that met the ES requirement effective between 2004 and 2008, which was set at 15% below the minimum federal energy efficiency standard. The third column corresponds to refrigerators that met the ES requirement effective after 2008 (April), which was set at 20% below the federal standard. The number of refrigerators in each cell varies because attribute information is missing for some models. The table shows that ES-certified models tend to differ from non-ES-certified along energy and non-energy dimensions.

Table 2. 2008 Decertification Event

	I		II		III		IV	
	MSRP	Paid	MSRP	Paid	MSRP	Paid	MSRP	Paid
ES=1	0.0336***	0.0171***	0.0587***	0.0289***	0.0172***	0.00657	0.0249***	0.0121***
	(0.00297)	(0.00310)	(0.00518)	(0.00542)	(0.00317)	(0.00357)	(0.00331)	(0.00346)
Model FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Week-Sample FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre Time Trends	No	No	Yes	Yes	No	No	No	No
Produce Age	No	No	No	No	No	No	Yes	Yes
Sample	Full	Full	Full	Full	ES 15% & 20%	ES 15% & 20%	Non-Censored	Non-Censored
R^2	0.023	0.078	0.030	0.079	0.006	0.070	0.013	0.076
Observations	107355	107354	107355	107354	83029	83028	88464	88463

Clustered (model level) standard errors in parentheses. The non-censored sample refers to models that entered the panel after January 2007, which allows me to construct a non-censored measure of product age.

Table 3. 2010 Decertification Event

	I		II		III		IV	
	MSRP	Paid	MSRP	Paid	MSRP	Paid	MSRP	Paid
ES=1	0.0651***	0.0270***	0.0566***	0.0138	0.0636***	0.0407***	0.0642***	0.0261***
	(0.00587)	(0.00658)	(0.00654)	(0.00870)	(0.00594)	(0.00697)	(0.00580)	(0.00660)
Model FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Week-Sample FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre Time Trends	No	No	Yes	Yes	No	No	No	No
Brand × Post	No	No	No	No	Yes	Yes	No	No
Produce Age	No	No	No	No	No	No	Yes	Yes
Sample	Full	Full	Full	Full	Full	Full	Non-Censored	Non-Censored
R^2	0.075	0.093	0.075	0.093	0.075	0.095	0.085	0.101
Observations	59900	59900	59900	59900	59900	59900	58657	58657

Clustered (model level) standard errors in parentheses. The non-censored sample refers to models that entered the panel after January 2009, which allows me to construct a non-censored measure of product age.

Table 4. Difference in Markups for Matching Pairs

	I		II		III	
	MSRP	Paid	MSRP	Paid	MSRP	Paid
ES=1	0.0197*	0.0264**	0.0165*	0.0251*	0.0166*	0.0241*
	(0.00769)	(0.00906)	(0.00709)	(0.0108)	(0.00715)	(0.0108)
Model FE	Yes	Yes	Yes	Yes	Yes	Yes
Week-Sample FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-of-Entry FE	No	No	Yes	Yes	No	No
Year-of-Entry × Brand FE	No	No	No	No	Yes	Yes
Sample	Identical Pairs	Identical Pairs	Identical Pairs	Identical Pairs	Identical Pairs	Identical Pairs
Observations	6845	6845	6845	6845	6845	6845
R^2	0.550	0.456	0.555	0.460	0.556	0.461

Clustered (model level) standard errors in parentheses.

TABLE 5. Price Change after Decertification/Certification of ES Models, NPD Data

	Refrigerators		**Clothes Washers**		**Dishwashers**		**Air Conditioners**	
	(I)	**(II)**	**(I)**	**(II)**	**(I)**	**(II)**	**(I)**	**(II)**
Dependent Variable: Log(price)								
Decertified	-0.044***	-0.050***	-0.082***	-0.082**	-0.076***	-0.087***		
	(0.016)	(0.017)	(0.031)	(0.035)	(0.013)	(0.015)		
Certified							0.060	0.073*
							(0.042)	(0.041)
Linear Pre-Trend	No	Yes	No	Yes	No	Yes	No	Yes
Months On Market	Yes	No	Yes	No	Yes	No	Yes	No
Month-Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	77,922	77,922	20,507	20,507	36,381	36,381	11,248	11,248
R^2	0.954	0.954	0.897	0.897	0.934	0.935	0.835	0.835
No. of Models	4,873	4,873	955	955	2,059	2,059	642	642
No. of Certification Changes	359	359	59	59	319	319	6	6

Notes: Standard errors are clustered at the product level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6. Impact of Costly Certification

	Certification Fee		
	$10	$50	$100
Δ ES market share	-0.41%	-2.08%	-4.30%
Δ kWh/year	0.31	1.59	3.29
Δ externality/unit sold (low) ($)	0.09	0.44	0.92
Δ externality/unit sold (high) ($)	0.29	1.46	3.03
Δ externality market (low) ($M)	0.79	4.00	8.30
Δ externality market (high) ($M)	2.59	13.18	27.31
Fee collected/unit sold ($)	6.42	31.13	60.39
Fee collected market ($M)	23.29	118.63	245.83

Notes: The externality costs are computed for a lower-bound estimate of $0.024/kWh and an upper-bound of $0.079/kWh. The market size is assumed to be 9 million units.

9. Appendix

9.1. Additional Tables and Figures

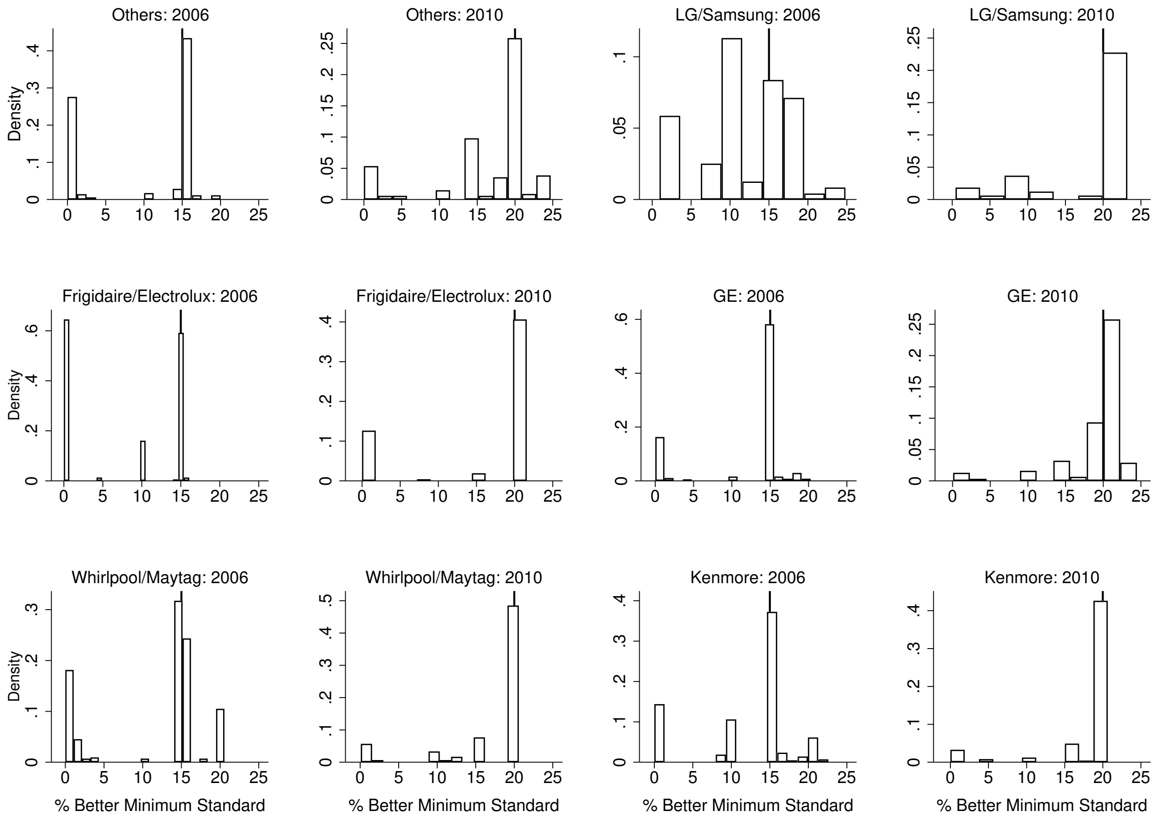


FIGURE 6. Energy Efficiency Offered by Manufacturers: 2006 and 2010.
Notes: Each panel plots the empirical density of the energy efficiency levels offered (non-sales weighted) for full-size refrigerators. The x-axis is the percentage decrease in electricity consumption (kWh/y) relative to the federal minimum energy efficiency standards. The ES certification requirement is identified by the dark line. Sources: Federal Trade Commission and EPA.

TABLE 7. Correlation between ES and Demographics

	Non ES	ES 2004 at 15%	ES 2008 at 20%	Non ES vs. ES at 15%	Non ES vs. ES at 20%
Income Level: 1-9	5.78	6.12	6.11	0.34∗	0.32∗
College Education	0.12	0.13	0.14	0.02∗	0.02∗
Age Head of Household	54.37	54.16	54.46	-0.21∗	0.10∗
# Children	0.66	0.67	0.64	0.01∗	-0.02∗
# Adults	2.53	2.60	2.59	0.07∗	0.06∗
Renter	0.02	0.01	0.01	-0.01∗	-0.01∗
Single Family House	0.81	0.79	0.83	-0.02∗	0.03∗
Democratic Voter	0.28	0.28	0.29	0.00	0.01∗
Bought More Than 2 in 5 Years	0.14	0.18	0.14	0.04∗	-0.00∗

Notes: Three categories of refrigerators are compared based on their energy efficiency level. The first column corresponds to refrigerators that never met the ES requirement. The second column corresponds to refrigerators that met the ES requirement effective between 2004 and 2008, which was set at 15% below the minimum federal energy efficiency standard. The third column corresponds to refrigerators that met the ES requirement effective after 2008 (April), which was set at 20% below the federal standard. Income is coded with nine categorical variables, where the sixth category corresponds to household income between $50k and $75k. Source: Retailer's transaction data.

TABLE 8. Number of Models Offered: Retailer's Data

% Better Than Minimum	2007	2008	2009	2010
0%	441	451	446	409
>0%, ≤15%	280	257	197	205
≥15%, <20%	1243	1193	954	645
≥20%, <25%	213	801	1065	1224
≥25%	33	50	59	150
Total	2210	2752	2721	2633

Notes. Before April 2008, models that were 15% more efficient than the minimum standard could be certified ES. These models lost the ES certification in April 2008. Models that were 20% or more efficient are ES-certified.

9.2. **Demand Model: Houde (2017)**

In Houde (2017), I estimated various demand models to elicit consumer response to energy information. The demand estimation focused on the US refrigerator market and used the

Table 9. Summary Statistics, US Appliance Market NPD Group Data

	Dishwasher	Washer	Room AC	Refrigerator
Market Share (Year 2008)				
Whirlpool/Maytag	49	64	13	33
GE	27	16	-	27
Electrolux	18	6	13	23
LG	-	6	32	3
Haier	-	-	8	6
Other:	6	8	34	8
Average Retail Price ($US)				
2005	598	644	294	1401
2006	646	657	330	1511
2007	574	663	348	1454
2008	608	704	329	1440
2009	671	734	352	1511
2010	634	714	337	1471
2011	618	667	365	1470

Sources: Market shares: *Appliance Magazine* and Department of Energy. Average prices: NPD Group.

transaction-level data from the appliance retailer during the period 2008-2011. Two sets of estimates were reported. First, I estimated a simple conditional logit for households in three different income groups to elicit the *average* response to purchase price, energy operating costs, ES label, and rebates of ES-certified products. The estimation results are reproduced in Table 11 below. The coefficient on the ES label is identified by the decertification events in 2008 and 2010. Using the ratio of this coefficient and the coefficient on price, I compute the WTP associated with the label itself. These values are reported in the bottom panel of the table.

I then estimated a structural model that accounts for heterogeneity in the way consumers collect and process energy information. The micro-foundation of this model is an information acquisition model with rational attention allocation. From a statistical standpoint, the model takes the form of a simple latent class model with three different types: consumers that process future energy costs (denoted $e = I$), consumers that rely on the ES certification (denoted $e = ES$), and consumers that dismiss energy information altogether (denoted $e = U$).

Table 10. Number of Appliance Models on the Market, NPD Data

	Decertification/Certification Events					
Refrigerators	04/2008					
	1 Year Before	1 Year After				
Total ES	601	424				
Total Non-ES	290	737				
Total Unique Models	891	1292				
No. of Decertified Models	359					
Clothes Washers	01/2007		07/2009		01/2011	
	1 Year Before	1 Year After	1 Year Before	1 Year After	1 Year Before	1 Year After
Total ES	100	143	235	311	375	359
Total Non-ES	27	116	99	76	67	77
Total Unique Models	127	259	334	387	442	436
No. of Decertified Models	25		5		29	
Dishwashers	01/2007		08/2009		07/2011	
	1 Year Before	1 Year After	1 Year Before	1 Year After	1 Year Before	1/2 Year After
Total ES	185	344	594	644	693	532
Total Non-ES	96	421	191	234	99	269
Total Unique Models	281	765	785	878	792	801
No. of Decertified Models	12		89		218	
Air Conditioners	11/2005					
	1 Year Before	1 Year After				
Total ES	72	66				
Total Non-ES	127	107				
Total Unique Models	199	173				
No. Certified Models	6					

The choice model takes the following form:

$$Q_{irt}(j) = \sum_{e=\{U,ES,I\}} H_i(e) \cdot P^e_{irt}(j), \tag{2}$$

where e represents the level of knowledge about energy costs that each consumer acquires. The term $H_i(e)$ is the probability that consumer i acquires knowledge e, and $P^e_{irt}(j)$ is the choice probability conditional on the level of knowledge. $Q_{irt}(j)$ is the overall choice probability for product j. The choice probabilities are computed for each household i and

TABLE 11. Conditional Logit by Income Group

	Income <\$50,000			Income ≥\$50,000 & <\$100,000			Income ≥\$100,000		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
Retail Price	-0.416***	-0.417***	-0.416	-0.365***	-0.365***	-0.365***	-0.32***	-0.32***	-0.319***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ENERGY STAR	0.125*		0.123*	0.163***		0.161***	0.181 ***		0.177***
	(0.05)		(0.05)	(0.05)		(0.05)	(0.04)		(0.04)
ENERGY STAR, 2008		0.070			0.138**			0.117 *	
		(0.05)			(0.05)			(0.05)	
ENERGY STAR, 2010		0.312*			0.103			0.222 *	
		(0.14)			(0.11)			(0.10)	
Rebate	0.086***	0.085***	0.084***	0.041**	0.041**	0.042 **	0.016	0.015	0.016
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Elec. Cost	-1.235***	-1.236***	-1.295***	-2.044***	-2.044***	-2.011***	-2.586***	-2.587***	-2.585***
	(0.23)	(0.23)	(0.22)	(0.25)	(0.25)	(0.25)	(0.26)	(0.26)	(0.26)
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls: Demo × Attributes	No	No	Yes	No	No	Yes	No	No	Yes
# Obs	46,097	46,097	46,097	45,487	45,487	45,487	45,249	45,249	45,249
Interpretation									
Own-Price Elasticity	-5.41	-5.42	-5.41	-4.75	-4.75	-4.75	-4.16	-4.16	-4.15
Implicit Discount Rate	0.34	0.34	0.32	0.17	0.17	0.17	0.10	0.10	0.10
WTP ES Label	29.94	-	29.68	44.59	-	43.98	56.56	-	55.55
WTP ES Label, 2008	-	16.72	-	-	37.80	-	-	36.71	-
WTP ES Label, 2010	-	74.93	-	-	28.23	-	-	69.26	-
Prob. Taking Rebate	0.21	0.20	0.20	0.11	0.11	0.12	0.05	0.05	0.05

Notes: Standard errors clustered at the zip code level in parentheses: * ($p < 0.05$), ** ($p < 0.01$), *** ($p < 0.001$). Prices, rebates, and electricity costs measured in hundreds of dollars. Average price of \$1,300 used to compute own-price elasticity. Refrigerator lifetime of 18 years used to compute implicit discount rate.

are region and time specific, denoted by the subscripts r and t, respectively. The alternative-specific utilities for each type e are

$$\begin{aligned}
&\text{e=I:} \quad U^I_{ijrt} = -\eta P_{jrt} + \delta_j + \psi R_{rt} X D_{jt} - \theta C_{jr} + \epsilon^I_{ijrt} \\
&\text{e=ES:} \quad U^{ES}_{ijrt} = -\eta P_{jrt} + \delta_j + \psi R_{rt} X D_{jt} + \tau D_{jt} - \theta ESavings_r X D_{jt} + \epsilon^{ES}_{ijrt} \\
&\text{e=U:} \quad U^U_{ijrt} = -\eta P_{jrt} + \delta_j + \epsilon^U_{ijrt},
\end{aligned}$$

where P_{jrt} is the price, δ_j is the quality of the product, R_{rt} is the rebate amount offered for ES products, and D_{jt} takes the value of one if product j is ES-certified at time t and zero otherwise. There are two differences in the specification of the alternative-specific utility for informed consumers ($e = I$) and consumers relying on ES ($e = ES$). First, informed consumers consider an accurate measure of annual energy operating costs, the variable C_{jr}, which is the product of the local electricity price, the county average in region r, and the manufacturer's reported annual electricity usage for model j. Consumers that rely on ES ($e = ES$) are not as sophisticated and rely on a heuristic to compute average energy cost. In particular, they simply compute the average energy cost savings associated with the certification, the variable $ESavings_r$, which is the difference between the average annual electricity usage of certified models and non-certified models multiplied by the local electricity price. Second, the difference is that for consumers relying on ES ($e = ES$), the ES label itself could impact the decision. The parameter τ is thus a behavioral response to the label itself. I assume that the probabilities P^e_{irt} take the form of a multinomial logit.

The latent probabilities $H_{irt}(e)$ also follow a multinomial logit, and I specified them as follows:

$$H_{irt}(e) = \frac{e^{V_{irt}(e)}}{\sum_k e^{V_{irt}(k)}} \tag{3}$$

with

$$\begin{aligned}
&V_{irt}(e = I) = -K^I - \beta^F X_i + \gamma^I_1 MeanElec_{rt} + \gamma^I_2 VarElec_{rt} + \gamma^I_3 NbModels_{rt} \\
&V_{irt}(e = ES) = -K^{ES} - \beta^{ES} X_i + \gamma^{ES}_1 MeanES_{rt} + \gamma^{ES}_2 VarES_{rt} + \gamma^{ES}_3 NbModels_{rt} \\
&V_{irt}(e = U) = 0
\end{aligned} \tag{4}$$

where K^e is a constant, X_i is a vector of consumer demographics, and the other variables aim to capture factors that could influence a consumer's decision to collect energy information, which are specific to the choice set faced by each consumer. $MeanElec_{rt}$ and $VarElec_{rt}$ are the mean and variance in electricity costs for all products offered in region r at time t. $MeanES_{rt}$ and $VarES_{rt}$ are the mean and variance of the proportion of ES models offered. Finally, $NbModels_{rt}$ is the number of models in the choice set in a given region.

The estimates of the model are reproduced in Table 12 below. They show that for all three income groups, there is a small, but constant share of consumers that rely on the ES and value the certification highly. Note that the coefficient on the ES label in this model corresponds to the WTP for certified models that goes beyond the monetary value of the average energy savings they bring.

9.3. **Setup: Policy Simulation**

To simulate the impact of a certification fee, I simulate the demand model for a large sample of households (N=3,500) representative of the population of consumers at the retailer. This sample is a subset of the observations used for the demand estimations and covers households from different income groups and living in different regions of the United States.

The demand model is simulated for two scenarios. The base case scenario represents a world where the certification is costless. In the counterfactual scenario, firms must pay a fee to ES-certified models. I assume that the certification fee increases the price of the ES-models by exactly the amount of the fee. That is, there is a 100% pass-through. I hold the choice set, prices, and all other variables (e.g., electricity prices and product attributes) fixed across scenarios.

I sample the parameters of the demand model 100 times from their estimated distributions and simulate the two scenarios for each draw. In the main text, I report the mean across these 100 iterations. The standard errors are very small and can be requested from the author.

For both scenarios, I constructed a representative choice set that represents the US refrigerator market for the year 2011. In particular, I sampled 68 refrigerator models used for the demand estimation to match the distribution along different dimensions of quality observed in the FTC data in 2011. The dimensions of quality that I considered are brand, the overall

Table 12. Information Acquisition Demand Model

	Income <\$50,000		Income ≥\$50,000 & <\$100,000		Income ≥\$100,000	
Behavioral Parameters Purchase Decision						
Retail Price (η)	-0.413***	(0.0002)	-0.362***	(0.0001)	-0.317***	(0.0002)
ENERGY STAR τ^{ES}	0.674***	(0.001)	1.528***	(0.002)	1.365***	(0.080)
Rebate (ψ)	0.145***	(0.001)	0.090***	(0.0005)	0.033***	(0.0003)
Elec. Costs (θ)	-4.003***	(0.009)	-3.408***	(0.048)	-4.429***	(0.004)
K^I	1.357***	(0.0004)	0.974***	(0.004)	2.125***	(0.001)
K^{ES}	-6.441***	(0.023)	-5.011***	(0.025)	-3.056***	(0.070)
Educ: College (β_I)	-0.122***	(0.003)	0.691***	(0.014)	0.303***	(0.012)
Educ: Graduate (β_I)	1.717***	(0.031)	2.045***	(0.026)	1.197***	(0.032)
FamSize (β_I)	-0.204***	(0.0001)	-0.318***	(0.003)	-0.049***	(0.007)
Age (β_I)	0.092***	(0.0002)	0.084***	(0.002)	0.011***	(0.001)
Political: Democrats (β_I)	-1.284***	(0.022)	-1.899***	(0.034)	-0.221***	(0.025)
Political: Others (β_I)	-1.920***	(0.008)	-1.338***	(0.013)	-0.200	(0.018)
Educ: College (β_{ES})	-0.271***	(0.002)	0.012	(0.007)	0.105***	(0.007)
Educ: Graduate(β_{ES})	-0.453***	(0.014)	0.843***	(0.018)	0.676***	(0.028)
FamSize (β_{ES})	-0.193***	(0.002)	-0.091***	(0.001)	-0.232***	(0.014)
Age (β_{ES})	0.063***	(0.0002)	0.045***	(0.001)	0.024***	(0.001)
Political: Democrats (β_{ES})	-0.255***	(0.006)	-0.421***	(0.015)	-0.045	(0.024)
Political: Others (β_{ES})	-0.578***	(0.0003)	-0.469***	(0.009)	0.018	(0.025)
mean-ElecCost	0.107***	(0.003)	0.075**	(0.001)	0.105***	(0.008)
var-ElecCost	0.006***	(0.00002)	-0.101***	(0.001)	0.026***	(0.001)
# Models (γ^I)	0.007***	(0.0001)	0.012***	(0.0001)	0.004 ***	(0.0004)
Variance Price (γ^I)	-1.003***	(0.004)	-0.729***	(0.012)	-0.390***	(0.004)
Proportion-Estar	2.837***	(0.002)	0.975***	(0.001)	2.324***	(0.114)
# Models (γ^{ES})	-0.006***	(0.0002)	-0.001***	(0.0000)	-0.003***	(0.001)
Variance Price (γ^{ES})	0.316***	(0.004)	0.211***	(0.004)	0.109***	(0.006)
Interpretation						
Own-Price Elasticity	-5.36		-4.70		-4.12	
Implicit Discount Rate	0.08		0.08		0.03	
WTP ES Label (\$)	163.43		422.22		430.33	
Prob. Taking Rebate	0.35		0.25		0.10	
$H(e = I)$	0.34		0.50		0.56	
$H(e = ES)$	0.21		0.10		0.17	
$H(e = U)$	0.45		0.41		0.27	
# Obs.	46,097		45,487		45,249	
LLE	188,088		194,394		195,969	

Notes: Asymptotic robust standard errors in parentheses: * ($p < 0.05$), ** ($p < 0.01$), *** ($p < 0.001$). Prices, rebates, and electricity costs measured in hundreds of dollars. Average price of \$1300 used to compute own-price elasticity. Refrigerator lifetime of 18 years used to compute implicit discount rate.

volume, and freezer location. Table 13 presents summary statistics of the representative choice set and shows how it compares with the FTC data.

After simulating the demand model for each scenario, I compute the change in average electricity cost, which is simply a weighted sum of the manufacturers' reported annual electricity consumption and market shares. I then translate these average in externality costs using estimates of emission factors and externality costs associated with electricity generation (Table 14).

Table 13. Summary Statistics of Representative Choice Sets: FTC versus Supply Estimation/Policy Simulation

	Observed FTC 2011		Constructed Retailer's Sample	
	Mean	S.D.	Mean	S.D.
Model Share (%) by Brand				
A	16.7		10.3	
B	19.2		22.1	
C	15.5		19.1	
D	8.5		10.3	
E	20.6		11.8	
F	19.5		26.5	
Model Share (%) by Door Design				
Top Freezer	32.5		22.1	
Side-by-Side	37.9		41.2	
Bottom-Freezer	29.7		36.8	
Overall Volume (Cu. Ft.)	22.0	3.4	23.6	2.8
Manufacturers' Reported kWh/y	507.5	91.5	514.0	74.2
% Certified ES	58.4		67.7	
% More Efficient Minimum Standard	17.2	7.0	18.3	7.4
# Models	1828		68	

Notes: The FTC provides data for all refrigerator models offered on the market for the year 2011. The first two columns report the mean standard deviation for various attributes "observed" in the FTC data. The ES certification status of each model offered was added using data from the EPA. The "constructed" choice set consists of a random sample of refrigerator models drawn from the set of models offered by the retailer and used in the demand estimation. All values reported are not sales-weighted. The constructed choice set is used for both the estimation of the unit retail costs and the policy simulations.

Table 14. Emission Factors and Externality Costs

Non-baseload Output Emission Rates (U.S. Average)			
Pollutant	Estimate		Source
CO_2	1583 lb/MWh		
CH_4^a	35.8 lb/GWh		
N_2O^a	19.9 lb/GWh		EPA, eGRID2007
SO_2	6.13 lb/MWh		
NOx	2.21 lb/MWh		
Damage Cost (2008 $)			
Pollutant	Low Estimate	High Estimate	Source
CO_2	$21.8/t	$67.1/t	Greenstone, Kopits, and Wolverton (2011)
SO_2	$2060/t	$6700/t	low: Muller and Mendelsohn (2012), high: EPA[b]
NOx	$380/t	$4591/t	low: Muller and Mendelsohn (2012), high: DOE[c]

Notes: (a) Externality costs associated with CH_4 and N_2O are assumed to be the same as for CO_2. CH_4 and N_2O are converted in CO_2 equivalent using estimates of global warming potential (GWP). The GWP used for $CH4$ is 25, and the GWP used for N_2O is 298. Source: IPCC Fourth Assessment Report: Climate Change 2007. (b) Estimate used in the illustrative analysis of the 2012 regulatory impact analysis for the proposed standards for electric utility generating units. (c) Higher value of the estimate used in the federal rule for new minimum energy efficiency standards for refrigerators (1904-AB79).

Working Papers of the Center of Economic Research at ETH Zurich

(PDF-files of the Working Papers can be downloaded at www.cer.ethz.ch/research/working-papers.html).

18/292 S. Houde
Bunching with the Stars: How Firms Respond to Environmental Certification

18/291 L. Bretschger and A. Vinogradova
Escaping Damocles' Sword: Endogenous Climate Shocks in a Growing Economy

18/290 S. Houde
The Incidence of Coarse Certification: Evidence from the ENERGY STAR Program

18/289 J. Blasch, N. Boogen, C. Daminato and M. Filippini
Empower the consumer! Energy-related financial literacy and its socioeconomic determinants

18/288 L. Bretschger and S. Soretz
Stranded Assets: How Policy Uncertainty affects Capital, Growth, and the Environment

18/287 S. Rausch and H. Yonezawa
The Intergenerational Incidence of Green Tax Reform

18/286 J. Abrell, S. Rausch, and C. Streitberger
The Economics of Renewable Energy Support

18/285 K. Borissov, L. Bretschger and A. Vinogradova
Carbon Pricing, Technology Transition, and Skill-Based Development

17/284 H. Gersbach, A. Mamageishvili and O. Tejada
Assessment Voting in Large Electorates

17/283 H. Gersbach, A. Mamageishvili and O. Tejada
Sophisticated Attacks on Decoy Ballots: A Devil's Menu and the Market for Lemons

17/282 S. Houde, J. E. Aldy
The Efficiency Consequences of Heterogeneous Behavioral Responses to Energy Fiscal Policies

17/281 Chiara Colesanti Senni
Energy Transition, Technological Spillovers and Elasticity of Substitution

17/280 Anna Alberini, Olha Khymych and Milan Scasny
Response to Extreme Energy Price Changes: Evidence from Ukraine

17/279 M. Filippini, G. Masiero and S. Steinbach
The Impact of Ambient Air Pollution on Hospital Admissions

17/278 M. Filippini and T. Wekhof
The Effect of Culture on Energy Efficient Vehicle Ownership

17/277 L. Bretschger, A. Pattakou
As Bad as it Gets: How Climate Damage Functions Affect Growth and the Social Cost of Carbon

17/276 J. Blasch, M. Filippini, N. Kumar, A. Martinez.Cruz
Narrowing the energy efficiency gap: The impact of educational programs, online support tools and energy-related investment literacy

17/275 M. Filippini, W. Greene, N. Kumar, A. Martinez.Cruz
A note on the different interpretation of the correlation parameters in the Bivariate Probit and the Recursive Bivariate Probit

17/274 D. Basin, H. Gersbach, A. Mamageishvili, L. Schmid and O. Tejada
Election Security and Economics: It's all about Eve

17/273 J. Abrell, M. Kosch and S. Rausch
The Economic Cost of Carbon Abatement with Renewable Energy Policies

17/272 H. Gersbach and O. Tejada
Semi-Flexible Majority Rules for Public Good Provision

17/271 D. Cerruti, A. Alberini, J. Linn
Charging Drivers by the Pound: The Effects of the UK Vehicle Tax System

17/270 H. Gersbach, P. Muller, O. Tejada
A Dynamic Model of Electoral Competition with Costly Policy Changes

17/269 J. Blasch, N. Boogen, M. Filippini, N. Kumar
The role of energy and investment literacy for residential electricity demand and end-use efficiency

17/268 H. Gersbach, M.-C. Riekhof
Technology Treaties and Climate Change

17/267 Christos Karydas
The inter-temporal dimension to knowledge spillovers: any non-environmental reason to support clean innovation?

17/266 Christos Karydas, Lin Zhang
Green tax reform, endogenous innovation and the growth dividend

17/265 Daniel Harenberg, Stefano Marelli, Bruno Sudret, Viktor Winschel
Uncertainty Quantification and Global Sensitivity Analysis for Economic Models

16/264 Marie-Catherine Riekhof
The Insurance Premium in the Interest Rates of Interlinked Loans in a Small-scale Fishery

16/263 Julie Ing
Adverse selection, commitment and exhaustible resource taxation

16/262 Jan Abrell, Sebastian Rausch, and Giacomo A. Schwarz
Social Equity Concerns and Differentiated Environmental Taxes

16/261 D. Ilic, J.C. Mollet
Voluntary Corporate Climate Initiatives and Regulatory Loom: Batten Down the Hatches

16/260 L. Bretschger
Is the Environment Compatible with Growth? Adopting an Integrated Framework

16/259 V. Grossmann, A. Schaefer, T. Steger, and B. Fuchs
Reversal of Migration Flows: A Fresh Look at the German Reunification

16/258 V. Britz, H. Gersbach, and H. Haller
Deposit Insurance in General Equilibrium

16/257 A. Alberini, M. Bareit, M. Filippini, and A. Martinez-Cruz
The Impact of Emissions-Based Taxes on the Retirement of Used and Inefficient Vehicles: The Case of Switzerland

16/256 H. Gersbach
Co-voting Democracy

16/255 H. Gersbach and O. Tejada
A Reform Dilemma in Polarized Democracies

16/254 M.-C. Riekhof and J. Broecker
Does the Adverse Announcement Effect of Climate Policy Matter? - A Dynamic General Equilibrium Analysis

16/253 A. Martinez-Cruz
Handling excess zeros in count models for recreation demand analysis without apology

16/252 M.-C. Riekhof and F. Noack
Informal Credit Markets, Common-pool Resources and Education