Means-Tested Subsidies and Market Power: Evidence from a French Heat Pump Program

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Abstract

We use a theoretical framework, a regression discontinuity design and a discrete choice model to evaluate the distributional consequences of an environmental subsidy under imperfect competition. Our empirical setting is the largest heat pump subsidy program in France (Ma Prime Rénov'), amounting to €3bn of annual public spending. The scheme splits eligible households into income groups, with subsidy level declining with income. Leveraging discontinuities in the subsidy schedule at income thresholds, we find that heat pump prices differ across income groups by 1.3 times the subsidy differential. Our theoretical framework identifies two mechanisms for this result, with opposing effects on relative prices: first, means-testing enables price discrimination across income categories. This adds to the progressivity of the scheme, provided demand elasticity is higher among low-income households. Secondly, the effect on prices of the subsidy differential itself can be attenuated by incomplete pass-through within each sub-market. Estimating a structural model of demand for heat pumps, we find that a limited effect of price discrimination and high pass-through of the subsidy combine into higher progressivity, when discrimination is allowed. Accounting for this mechanism in policy design is however non trivial, as the sign and magnitude of the effects depend on several demand and supply primitives: market power, elasticity and curvature of the demand curves in each income group.

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1 Introduction

We evaluate a means-tested environmental subsidy and its interaction with imperfectly competitive supply. We identify two ways in which market power can distort the effects of such policies. First, we find that by providing information on income of households, means-testing enables firms to price discriminate, which alters relative prices and the composition of demand. Secondly, market power affects pass-through of the subsidy in each income group. Both mechanisms distort the distributional effects of the policy, that can differ from the ones embedded in the subsidy schedule. Not accounting for imperfect competition biases the evaluation of the policy, both in terms of overall take-up, externality abatement and redistribution.

We study these mechanisms in the context of the largest subsidy program to residential energy efficiency in France, called *Ma Prime Rénov'*. Implemented in 2020, the program shifted the main French policy instrument for residential housing renovation away from a uniform, single-rate income tax credit scheme, towards a means-tested subsidy. By increasing overall spending and targeting subsidies towards low-income households, this reform had both efficiency and equity motives: it was planned to reduce windfall effects among high-income households, alleviate credit constraints among low-income households and increase overall investment. In our analysis, we focus on subsidies to heat pumps, one of the most popular residential energy efficiency investments, as well as one of the most efficient ones for energy savings (Bernard et al., 2025). We find that through its interaction with imperfectly competitive supply, the program had progressive impact on heat pump prices beyond the one embedded in the subsidy schedule.

Our analysis is motivated by two observations. First, means-tested investment subsidies are an attractive policy option for tackling environmental externalities, be it in the transportation or housing energy sectors (*eg* EV tax credits with income thresholds, WAP or HEAR programs in the US). Indeed, it circumvents the inability of Pigouvian taxation to reach total progressivity (Sallee, 2019; Bonnet et al., 2025), which plays a major role in its unpopularity compared to subsidies (Dechezleprêtre et al., 2022). It also prevents two pitfalls of large investment subsidies: they may struggle to trigger additional take-up (Allcott and Greenstone, 2024), especially at the bottom of the distribution, where credit constraints are difficult to override. Take-up is

concentrated at the top, where a large share represents windfall effects (Borenstein and Davis, 2024).

Secondly, the ability of means-tested subsidies to reach their efficiency and equity objectives depends on how prices react on the supply side. This reaction is uncertain *ex ante*: subsidy incidence can indeed be altered by market power. Given growing demand linked to the green transition and constrained supply in skilled labor force (Jagger et al., 2013), that limits firm entry, it can also be expected in the residential energy efficiency market and other sectors linked to the low-carbon transition in households. Furthermore, means-testing can indirectly provide information to firms on consumer's income. The way firms leverage this information to discriminate across households matters for policy evaluation.

Means-tested subsidy incidence under market power How does imperfect competition distort the targeting of means-tested subsidies? To answer this question, we develop a discrete choice model of demand for heat pumps, where individuals' preferences differ with respect to income. Imperfect competition is modeled by Bertrand-Nash symmetric pricing between firms. We then introduce a means-tested subsidy targeted only at low-income households. We study distributional effects of the subsidy in two cases: in the first one, firms resort to uniform pricing. The differential in consumer prices across low-income and high-income households is therefore exactly equal to the subsidy level. In the second case, we consider that means-testing provided information to firms on income category of consumers through their subsidy level. In that case, the resulting price differential is the sum of two effects: price differential resulting from price discrimination itself, and pass-through of the subsidy among low-income households. We find that the first one increases with elasticity differential between income groups and level of market power. The second one increases with the convexity of the low-income demand function and decreases with market power. Depending on those parameters, distributional consequences of the subsidy under price discrimination can overshoot the ones embedded in the subsidy formula, or undershoot them: low-income households respectively win or lose from the existence of price discrimination.

Detecting price discrimination How can one empirically identify that such mechanisms are at play? One of the predictions of the model is that, provided price discrimination occurs, producer prices should differ across income categories for the same product. In a longitudinal analysis around the 2020 reform, we show that such price discrepancies did not exist when the subsidy took the form of a single-rate income tax credit. After the introduction of means-testing, we observe that high-income households are consistently exposed to higher producer prices. We then leverage cross-sectional variations in subsidy level at income category thresholds to prove the existence of price discrimination, in a regression discontinuity design. We show that out of two households with otherwise similar observable characteristics, the one in a higher income category faces a premium of 400€ in pre-subsidy price. Leveraging data on performance of installed equipment, we show that this cannot be explained by differential quality in heat pumps across income categories.

Quantifying welfare effects of supply-side distortions What are the effects of such price discrimination and incomplete pass-through on aggregate and relative take-up of the subsidy? The theoretical model predicts that the direction and magnitude of these effects are ambiguous and depend on the level of market power, elasticity levels and demand curvatures across income categories. Leveraging exhaustive micro data on take-up and prices, we develop and estimate a discrete-choice model of heat pump demand on French local markets to recover these parameters. On the demand side, we allow for observed heterogeneity in demand determinants, especially along the income dimension. On the supply side, we allow for firms to charge different prices across income groups. In counterfactual exercises, we disentangle the price discrimination and pass-through effects of market power for the scheme's welfare effects.

Related literature – Evaluation of energy efficiency subsidies Energy efficiency programs represent a large share of governments' spending into clean energy (IEA Government Energy Spending Tracker, 2022). Massive public intervention is motivated by the health and environmental externalities poor housing efficiency represents (International Energy Agency, 2019; Kahouli, 2020). It has in turn fostered a now large literature studying the design and effects of such policies. We

complement this literature in two ways: first, to the best of our knowledge, we are the first to analyze the interaction of energy efficiency subsidies with their supply side. Using administrative and survey data on firms of the energy retrofit market, we document the fact that retrofit markets are constrained and concentrated. Secondly, we identify how interactions with an imperfectly competitive supply affects optimal targeting of these policies.

Most of the existing literature related to energy efficiency subsidies focuses on the demand-side mechanisms that explain how much these policies are able to reduce energy consumption. Allcott and Greenstone (2024) states that second-best policies should be "Pigouvian", *ie* subsidy levels should equal the social benefit of achieved lifetime externality reduction. Many theoretical and empirical papers evaluate the divergence to this benchmark (Allcott and Greenstone, 2024; Fowlie et al., 2015; Gillingham et al., 2013; Chan and Gillingham, 2015; Gillingham et al., 2016; Fowlie et al., 2018, 2015; Allcott and Greenstone, 2024), and the reasons for these shortfalls: rebound effect, distortions to the investment decision, overestimated theoretical gains [1]. Interestingly, all these studies assume, explicitly or implicitly, perfectly elastic supply and complete consumer pass-through of subsidies. We show that not accounting for supply-side reactions to demand-side policies biases their evaluation. In doing so, we relate to a theoretical literature on optimal targeting of energy efficiency policies (Allcott et al., 2015; Colas and Reynier, 2024). We are the first study to evaluate empirically the effects of such targeted policies. We argue that the recent backlash against carbon taxes, following the Yellow Vest movement in France, pushes equity considerations at the forefront of current and future environmental policies (Dechezleprêtre et al., 2022). In this study, we are able to document under which conditions means-tested subsidies are able to reach these equity goals.

Related literature – Incidence under imperfect competition We also relate to a broader literature at the crossroads of public finance and industrial organization, that deals with incidence of tax and subsidy schemes under imperfect competition. We contribute to it by studying the interaction of third-degree price discrimination and means-testing, isolating the drivers of its effects and estimating them empirically.

[1] See Giandomenico et al. (2022) for a survey on the effect on energy savings.

By doing so, we refer to a theoretical literature on the demand and supply determinants of tax incidence, following Weyl and Fabinger (2013). We build on two predictions of this seminal paper, namely that under imperfect competition, mark-ups decrease with the elasticity of demand, and tax pass-through increases with the convexity of the demand curve. We also relate to a theoretical literature studying the welfare effects of price discrimination (Adachi, 2023). Compared to these studies our contribution is twofolds: we extend these theoretical frameworks by studying the interaction of price discrimination with targeted subsidies, and we estimate empirically the drivers of endogenous pass-through under imperfectly competitive supply. Such empirical studies are few. Polyakova and Ryan (n.d.) show, in the case of the Affordable Care Act, how means-testing distorts the pricing decision, but assume away price discrimination. In a context closer to ours, Fack (2006) shows that French homeowners capture most of in-kind housing transfers to low-income renters. Regarding environmental policies, one can cite Pless and van Benthem (2019), that studies the pass-through of solar subsidies and identifies overshifting as a sufficient condition for market power. We show theoretically that, provided the scheme is means-tested, overall incidence can be above 100% without overshifting, and estimate structurally the demand primitives that drive this result. The closest study to ours is probably Fillmore (2023), that studies the impact of letting colleges manage federal student aid applications. These applications provide colleges with information on students' willingness to pay, income and number of college applications. The author finds that colleges adjust their bidding behavior – tuition prices proposed to students – accordingly. We complement this analysis in the following ways: we disentangle the effect of price discrimination from the effect of pass-through of the subsidy and estimate them separately. To do so, we leverage exhaustive micro data on prices and take-up, in a discrete choice BLP model with micro moments, following Berry et al. (2004); Conlon and Gortmaker (2024). We also consider a more usual market structure for such policies: business to consumers, Bertrand-Nash competition instead of first-price auction, where firms are not themselves in charge of the policy.

Outline The rest of the paper proceeds as follows. In section 2, we present the institutional setup of the French residential energy efficiency market, on both demand and supply sides. Section 3 documents the data sources used in our empirical analysis. Section 4 develops a model of demand for heat pumps under third-degree price discrimination and means-testing, to isolate how such a policy can be affected by discrimination, and the drivers of these distortions. Sections 5 analyses empirically the effect of the subsidy on relative prices across income categories. Section 6 estimates baseline and counterfactual scenarios of demand and supply, to isolate the effects of market power on efficiency and distributional outcome of the means-tested subsidy.

2 Institutional framework

In this section we describe the residential energy efficiency market in France. Section 2.1 details the characteristics of the main national policies that aim at supporting demand for energy efficiency investments. The main policy change occurred in 2020, when means-testing of energy efficiency subsidies was implemented. The main consequences on subsidy schedule – targeting and overall generosity – are described. An emphasis is made on subsidy schedule change for heat pumps, the focus of our study. We focus on this type of energy efficiency investment for two main reasons: first, it is the second most popular option in the scheme, representing around 100k installations every year. Secondly, it is one of the most efficient in terms of energy consumption and externality reduction. Policy impact on prices and take-up for this investment type are therefore of particular importance. Section 2.2 describes the supply side of the subsidized heat pump market.

2.1 Demand-side policies – Energy efficiency programs

Income tax credit (up to 2020) From 1999 to 2020, an income tax credit was available to all French tax households. Households could claim a percentage of the total amount spent on eligible renovation works carried out on their main residence, up to a certain cap[2]. Since its creation, the scheme underwent several reforms regarding many of its different characteristics

[2]Only housing units that had been constructed at least prior 2 years prior to the application were eligible.

(rates, types of renovation works covered, caps on total credit value, eligible households, etc); however it was stable in the few years immediately preceding the reform. Subsidized retrofits covered a wide array of types of renovation work (called "actions" or "steps"). At the time the tax credit disappeared, the subsidy rate stood at 30%[3].

Means-tested subsidy (starting 2020) In 2020, the French government started the *Ma Prime Rénov'* (MPR) subsidy scheme to increase the number of energy-efficient residential housing renovations. During 2020, both programs were coexisting. In stark contrast to the CITE, this subsidy is targeted to low-income households, which makes it more similar to the US Weatherization Program. The administration of the renewed subsidy scheme was delegated to the French National Housing Agency (*Agence Nationale pour l'Amélioration de l'Habitat*, ANAH), which was already in charge of similar, smaller schemes supporting renovations of very poor and "insalubrious" homes.

Homeowners of non-new housing units are eligible to the subsidy[4] for 26 types of investments as of 2021, such as external insulation or heat pumps. MPR subsidy level is a flat amount that depends on investment chosen and on income category. Four income categories are defined based on fiscal revenue (hereafter called TMO, MO, INT and SUP).

The application process works as follows: Households first visit ANAH services to be informed on eligible actions and subsidy levels (for MPR and other programs). Other types of housing retrofit subsidies indeed coexist with MPR, and can be cumulated with the MPR subsidy, just like they could with the income tax credit. They then select a firm and apply to MPR. Interestingly, households can now delegate the application process to the selected firm. This option, called "mandating", gives the firm access to some private information on households, including their income category. Upon completion of the work and final invoicing, the agency transfers the subsidy directly to the firm and the household pays the remainder[5].

The 2020 reform had two main effects. First, it increased the average generosity of the scheme.

[3]Except for double-glazed windows, which were subsidized at a rate of 15 %. There was also a subsidy ceiling at 8k € for a single member household, 16k € for a two person household and an additional 400 € per children.

[4]From 2020 to 2021, the housing unit had to have been constructed at least 2 years prior to the application. This threshold has been increased to 15 years on January 1st, 2022.

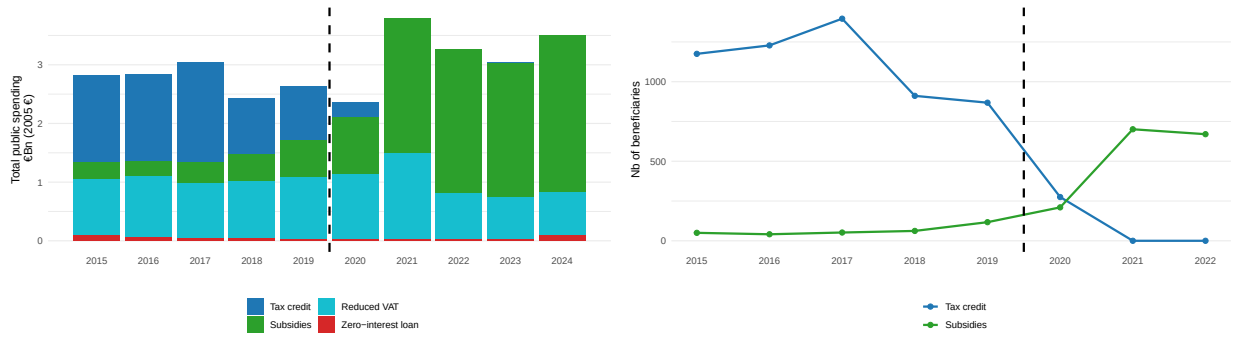
[5]Renovation work must be completed within two years of the subsidy's award's decision date.

In a typical year, the budget allocated to renovation subsidies is higher by around 50% (from 2 billion to 3 billion) as Figure 1a shows. MPR subsidizes less recipients than the CITE did, for a larger total public spending (Figure 1b).

Figure 1: Aggregate public spending and number of beneficiaries of public support schemes to housing retrofit

(a) Total public spending, CITE and MPR

(b) Number of beneficiaries, CITE and MPR



NOTE : This figure shows the total sum of retrofits public subsidies for each year in billions of 2005 euros (Panel a), and the number of beneficiaries of the income tax credit and direct subsidies (Panel b). In dark blue, the amounts corresponds to the CITE tax credits. In green, all subsidies by the ANAH which includes but is not limited to the MPR subsidy.
SOURCE :Aggregate figures from yearly reports of the tax administration (DGFiP), and housing agency (ANAH)

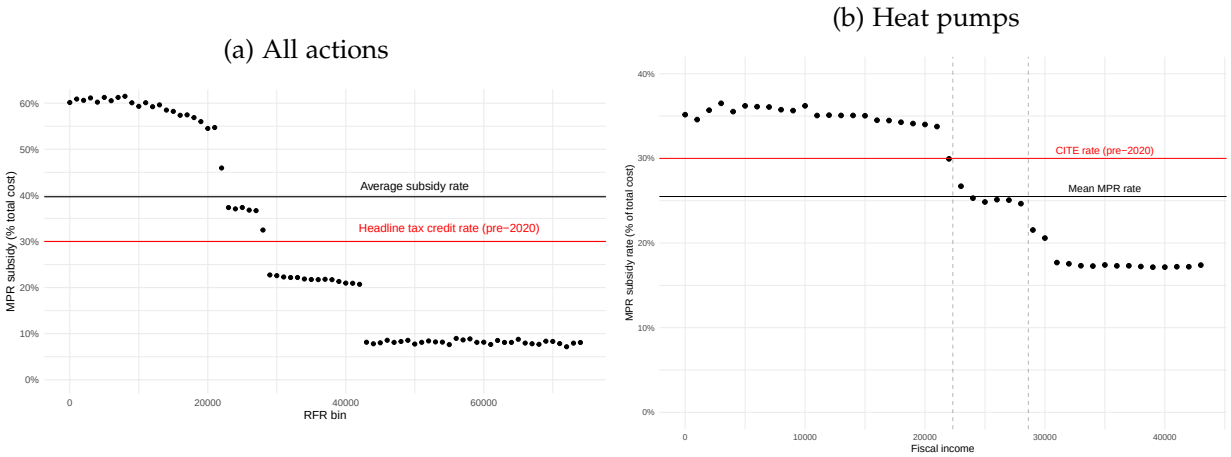
Secondly, the scheme operated a massive shift in the targeting of the scheme towards low-income households. The level of public support indeed shifted away from a uniform 30% of the total value of renovation works under the CITE, to a heterogeneous subsidy rate, across types of households and types of renovation works. Figure 2 represents the average subsidy rate by bins of taxable income, for all two-member households in 2022 outside the Île-de-France region, for heat pumps alone and for all eligible actions [6]. Poorer households saw an increase in their subsidy rate following the reform, while richer households saw a decrease. The sharp decreases correspond to eligibility thresholds. Note that among heat pumps, the fourth (richest) income category lost eligibility. On average, even among the three eligible income category, the average subsidy rate decreased for heat pumps relative to the flat income tax credit rate.

As a result, low-income households represented a higher share of total spending post-reform. Figure 3 displays the share of the total amount of subsidy by year (whether the tax credit or the

[6]For simplicity, and because the income cutoff depends on number on inhabitants and location, we only show data for the largest subpopulation for which the scheme's thresholds are defined in a homogeneous way.

direct subsidy) across income groups. The CITE tax credit benefited mostly high income groups whereas, the largest share of public funds were allocated to low-to-medium income groups after the reform.

Figure 2: Average MPR subsidy rate, as a function of taxable income



Note : This figure presents the average subsidy rate per bin of 1.000€ of taxable income, in 2022, for all eligible actions and for heat pumps alone. Subsidy rate is defined as the amount of Ma Prime Rénov' subsidy received as a fraction of total cost of renovation work. Sample is made of one observation per observed retrofit action, for households composed of two individuals living in province.

Source :

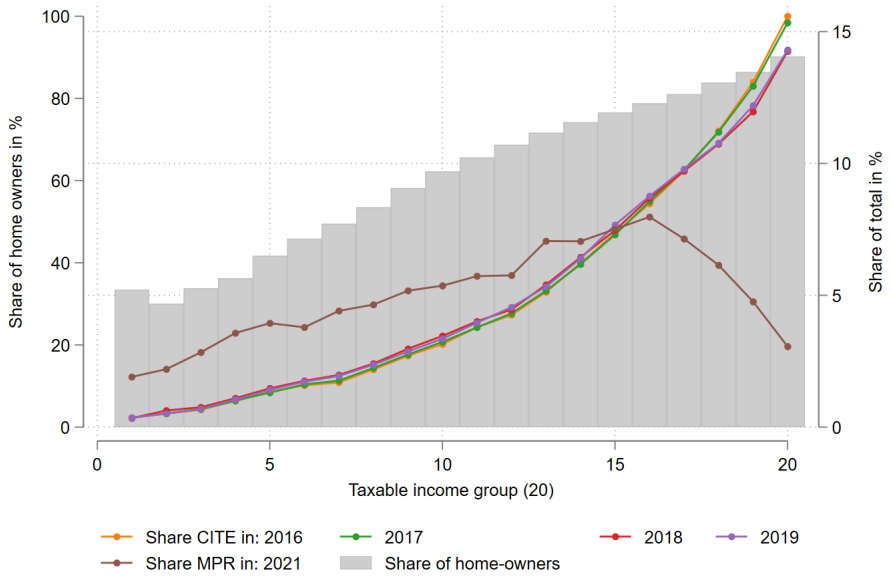
2.2 Supply – Certified energy efficiency market

In 2015, the RGE certification was created to guarantee the quality of subsidized retrofit works[7]. Since then, households that wish to benefit from public subsidy programs – including CITE before 2020, and MPR after – are required to opt for an RGE-certified company. In what follows, we therefore consider RGE firms as the relevant market for our analysis.

This market is locally concentrated and shows signs of market power. Density of eligible RGE companies is relatively low (and heterogeneous across geographies), as Figure 7 shows. In Appendix Figure 18, we show that operating margin of RGE firms is on the whole increasing with local market concentration. It suggests that companies in concentrated markets are indeed able to price above marginal cost.

[7]RGE stands for "Certified as Guarantor of the Environment" (*Reconnu Garant de l'Environnement*)

Figure 3: Share of the total subsidy amount across income groups



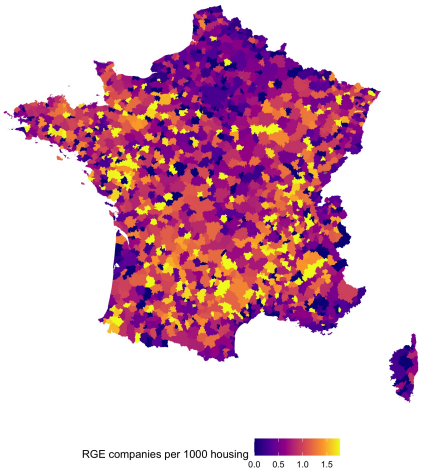
Note : This figure presents the share of the total amount of public spending every year by income groups of either the tax credit (CITE 2016 to 2019 here) or MPR (2021 only here). Every point represents 5% of the taxable income distribution, a purely equal distribution would be a stable line at 5%. A similar graph but with fixed income bins in amounts instead of quantiles is shown in appendix Figure 19.
Source : Fideli, POTE, MPR, INSEE

There are several reasons for this relatively low level of competition on the certified energy efficiency market. The first one is an institutional barrier to entry: certification is costly and needs to be renewed every four years. It is made of an administrative fee and costs associated to training of firm's craftsmen and monitoring audits made by the certifying body during the four-year span of the certification. The precise annual amount therefore depends on the number of trained professionals and on the certifying body. It is estimated to be around 2000€ [8] for a company where only one professional is trained, or 6% of the median MPR turnover of RGE companies in 2022. This certification and its cost are retrofit action-specific. For example, a company that wishes to enter the subsidized market both for heat pumps and water heaters needs to pay for two certifications. In Appendix Figure 21, we show that in practice, firms mostly focus on a small range of actions.

Another competitive constraint on this market is that it is local. In Appendix Figure 20, we

[8] Estimated using the 2024 tariff grid of Qualibat, one of the main RGE certification bodies.

Figure 4: Number of heat pump RGE companies per 1000 MPR-eligible households, 2021

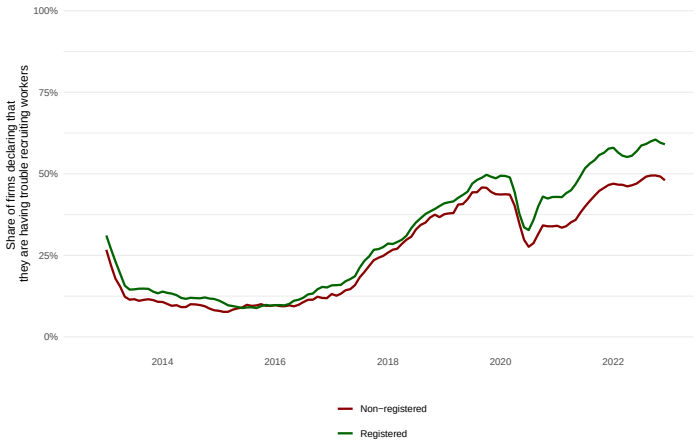


NOTE : This figure presents the average number of active heat pump RGE companies per 1000 housing, aggregate at the "Bassin de vie" (*living zones*) level in 2021. A living zone is the smallest territory on which residents have access to everyday facilities and services, as defined by INSEE (*National Institute of Statistics and Economic Studies*). An active RGE company is a company that has been certified for at least one kind of retrofit actions during the year and was selected by at least one household to perform an MPR work.

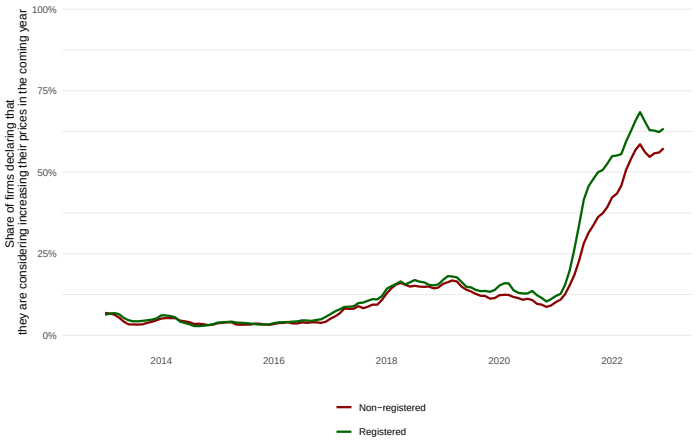
point to the presence of sizable search costs for households that would wish to opt for firms outside of their local market. Finally, entry and capacity might be limited on the retrofit market by constraints on the labor market. On the labor demand side, retrofit companies are indeed in competition with the market for new construction, that recruits similar profiles. On the supply side, it might not be profitable for employees of the construction sector to seek training to acquire retrofit skills. Figure 5 shows in a survey of the construction sector that around 50% of installers of energy efficiency investments declare difficulties in hiring craftsmen. Furthermore, this trend increased since 2020 and the demand shock of MPR on the sector and increased more among RGE companies, directly affected by this demand shock. This divergence in trend can also be observed in prices: beginning in 2021, the first post-Covid year of full implementation of MPR, RGE firms declare more frequently that they predict price increases than their non-RGE counterparts. This is suggestive evidence that labor supply frictions limited entry as a result of the reform, consolidated market power. Another suggestive evidence is that the number of certified firms actually decreased between 2019 and 2020, as displayed in Appendix Figure 22. It still hasn't reached in 2023 its 2019 level.

Figure 5: DID results - Survey

(a) Hiring difficulties



(b) A future increase in prices



NOTE : This figure presents the result of the an INSEE survey on the construction sector, collected every three months with a panel of firms. Figure 5a displays declared hiring difficulties, while Figure 5b displays forecast price increase for the next three months, for RGE and non-RGE firms. An active RGE company is a company of the panel that has been certified at least once during the period, for at least one type of retrofit action.

3 Data

Geolocalized household tax data The first of our two main source of data is the Fidéli database. This is the exhaustive dataset of French households and their residence. The Fidéli database, created by INSEE and based on tax filings, offers a comprehensive representation of the French population. It consolidates data from income tax returns, property tax records, land files, and the Filosofi database, providing detailed insights into both housing and individual demographics. Fidéli's key strength is its extensive coverage and its precise geolocalisation.

Geolocalized MPR subsidy individual level data The second main dataset we use is the MPR data. This data provides information on household income and composition, geolocalisation, type date and amount of work for each application, as well as price and subsidies received for each retrofit action. We also have the Siren identifier of the firm that was chosen to perform the retrofit work. This dataset contains 2.0 million applications between 2020 and early 2024, among which around 100k yearly heat pump applications.

We match these two main datasets using geographical coordinates of MPR files and Fidéli housing units, as well as other common variables: type of housing (appartment or house), ownership status (owner- or tenant-occupied housing), number of occupants, household income. This matching procedure has two main objectives: first, retrieve all information on housing characteristics and household composition from Fidéli for each MPR application. Secondly, identify, among all eligible Fidéli households, those that take up the subsidy. We are able to match an MPR application with a Fidéli housing in around 95% of cases. We detail the matching procedure and characterize its performance in Appendix A.

Income tax data In order to study the shift of retrofit policy, we also gather information on the former tax credit directly from the exhaustive income tax database. The POTE data contains a panelized version of income tax declarations for all French tax households. It contains all items that are filled in a typical tax filing. It notably contains information on the value of each renovation step subsidized via the tax credit. For years 2017 to 2020, we are able to match

these detailed information on the tax credit with the exhaustive geolocalized household tax data described above.

Corporate income tax records In order to understand the effect on firms, we use the FARE database. This dataset was created by INSEE and gathers information on firm's activity and balance sheets from various different sources. This dataset allows us to have information on almost all retrofit firms that we observe on the MPR data. The latest vintage available so far is 2022.

Survey on the construction sector We use the INSEE survey on the construction sector (*Enquête mensuelle de conjoncture dans l'industrie du bâtiment*). This survey is done every three months on firms from the construction sector. It contains question on the activity of firms but also on prices, hiring, production capabilities. It aks questions on the current situation and on beliefs for the near future.

Energy Efficiency Certificates The Energy Efficiency Certificate scheme, known as CEE, was introduced by the French government in 2006 to help fund the energy transition. Under this scheme, energy suppliers are required to encourage consumers to reduce their energy consumption, with specific targets to meet over defined periods. Among other variables, CEE data contains information on CEE date, amount, retrofit action type, technical properties of the installed equipment, and information on housing, including location.

4 A model of incidence for means-tested subsidies

In this section, we consider a discrete choice model of heat pump acquisition with imperfect competition. We first recall some usual results on uniform pricing under symmetric Bertrand-Nash competition: equilibrium mark-up is driven by industry demand's elasticity and firms' marginal cost. We then introduce a means-tested policy, whereby low-income households only benefit from a subsidy. We consider two cases: either firms are able to perform third-degree price discrimination, or they do not. Comparison of these two cases enables to derive a necessary and sufficient condition for price discrimination to be progressive. We isolate three drivers of the distributional impact of price discrimination: higher demand curvature and differential in elasticity of demand across income categories improve the progressivity of price discrimination, while market power has an ambiguous effect.

The model We consider a discrete choice model with unit demand, in a market characterized by imperfect competition. Consumers are made of a continuum of individuals defined by income $i \in [0,1] = \mathcal{I}$, with density $g(i)$[9]. In what follows, we also distinguish between the low- and high income groups, respectively $\mathcal{I}_w = [0, \bar{i}]$ and $\mathcal{I}_s = [\bar{i}, 1]$.

On this market, consumers choose between two products $j \in \{1,2\}$, proposed by two separate firms, and an outside option[10]. Individual's choice probability for a certain product j, given prices p_1 and p_2, is denoted $s_{ij}(p_1, p_2)$. Income group-specific and aggregate demands are given by:

$$\forall m \in \{w,s\}, \forall j \in \{1,2\}, s_{jm}(p_1,p_2) = \int_{i \in \mathcal{I}_m} s_{ij}(p_1,p_2) g(i) di$$

$$s_j(p_1,p_2) = s_{jw}(p_1,p_2) + s_{js}(p_1,p_2)$$

In what follows, we make three assumptions: one simplifying assumption on the cost struc-

[9]Other dimensions of heterogeneity, including unobserved ones, could be added. Miravete et al. (2025) however shows that income is a sufficient source of heterogeneity to accommodate any possible elasticity-curvature combination, the two main drivers of this analysis.

[10]The number of products could easily be extended, at the expense of clarity of exposition, but without any impact on the drivers of the results.

ture of firms, a typical assumption on substitutability across products, an assumption on the curvature of the demand curve:

Assumption 1. Firms face constant marginal cost, equal across products and income group:

$$\forall m \in \{w, s\}, \forall j \in \{1, 2\} c_{jm} = c$$

Assumption 2. For any level of price, products 1 and 2 are partial substitutes, that is:

$$\forall m \in \{w, s\}, \forall j \in \{1, 2\}, 0 < \frac{\partial s_{jm}}{\partial p_{-jm}}(p_1, p_2)$$
$$\frac{\partial s_{-jm}}{\partial p_{jm}}(p) \leq \left| \frac{\partial s_{jm}}{\partial p_{jm}}(p) \right|$$

Assumption 3. We define $\rho_m(p)$ the curvature of aggregate demand in submarket m. The following condition on $\rho_m(p)$ ensures that demand is not too convex:

$$\rho_m(p) \equiv \frac{s_m(p) \left[\frac{\partial^2 s_{1m}}{\partial p_1^2} + \frac{\partial^2 s_{1m}}{\partial p_1 \partial p_2} \right]}{\frac{\partial s_{1m}}{\partial p_1}(p) \left[\frac{\partial s_{1m}}{\partial p_1} + \frac{\partial s_{1m}}{\partial p_2} \right]} < 2$$

The first assumption could easily be relaxed and is only used for clarity of exposition of the results. The third one is a mild assumption on preferences. Note that it still accommodates cases of log-convexity, that requires $\rho_m(p) \geq 1$, and is a necessary and sufficient condition for cost pass-through above 1, *ie* overshifting, following Weyl and Fabinger (2013). Also note that this definition of curvature considers both intrinsic effects of the firm's pricing and strategic effects from demand substitution across products.

Lemma 1. Under assumptions 1, 2 and 3, firms' marginal profit is decreasing with symmetric market price, that is:

$$\frac{d}{dp} \left[\frac{\partial \pi_{jm}}{\partial p_j}(p) \right] < 0$$

This property on the concavity of the profit function ensures that the firm's profit maximisation problem is well behaved.

Uniform and discriminatory pricing In a baseline exercise, we consider the effect of third-degree price discrimination across the two income groups on relative prices[11]. We identify the condition under which the low-income group benefits from price discrimination. To do so, we first define two concepts of elasticity: elasticity of own- and industry's demand, that takes into account both the effects of own and competitors' price change on demand. Both are related by the conduct parameter $\theta_m(p)$, that measures the level of market power.

$$\begin{aligned}
\epsilon_m^I(p) &\equiv -\frac{ds_{1m}}{dp}(p)\frac{p}{s_{1m}} = -\left[\frac{\partial s_{1m}}{\partial p_1}(p) + \frac{\partial s_{1m}}{\partial p_2}(p)\right]\frac{p}{s_{1m}} \\
\epsilon_m^{own}(p) &\equiv -\frac{\partial s_{1m}}{\partial p_1}(p)\frac{p}{s_{1m}} = \frac{\epsilon_m^I(p)}{\theta_m(p)} \\
\theta_m(p) &\equiv 1 + \frac{\frac{\partial s_{1m}}{\partial p_2}(p)}{\frac{\partial s_{1m}}{\partial p_1}(p)}
\end{aligned}$$

In the case when firms are able to price discriminate across income groups m, symmetric prices are denoted p_m^* and given by the usual Lerner index:

$$\begin{aligned}
\frac{p_w^* - c}{p_w^*} &= \frac{1}{\epsilon_w^{own}(p_w^*)} = \frac{\theta_w(p_w^*)}{\epsilon_w^I(p_w^*)} \\
\frac{p_s^* - c}{p_s^*} &= \frac{1}{\epsilon_s^{own}(p_s^*)}
\end{aligned}$$

Price is increasing in marginal costs, market power level and decreasing with the elasticity of demand. We also consider the case where firms are not able to discriminate based on income category m. In this case, firms consider the market-share weighted average of income group-specific elasticities for uniform price $\overline{p}$:

[11] Note that we consider the case where discrimination is not costly and therefore systematically carried out, as long as it is enabled

$$\frac{\overline{p}-c}{\overline{p}} = \frac{1}{\sum\limits_{m\in\{w,s\}} \frac{s_m(\overline{p})}{s_w(\overline{p})+s_s(\overline{p})}\epsilon_m^{own}(\overline{p})}$$

Proposition 1. Under assumptions 1, 2 and 3, w is the weak market if and only if price elasticity is higher in w at uniform price:

$$p_w^* < \overline{p} < p_s^* \iff \epsilon_w^{own}(\overline{p}) > \epsilon_s^{own}(\overline{p}) \tag{1}$$

The comparison of the discriminatory and uniform prices might be viewed as the effect of a policy solely providing information to firms on income group, on which they can then discriminate. The previous result states that such a policy has progressive impacts, as long as low-income households are more price-sensitive. In what follows, we assume that 1 holds.

Introduction of a means-tested subsidy We now consider that a means-tested subsidy $b > 0$ is implemented on the weak market only. When price discrimination is allowed, the effect on consumer prices in w is given by the integral of cost pass-through between 0 and $-b$:

Lemma 2. Pass-through of the subsidy onto consumer prices in market w is given by:

$$p_w^*(b) - p_w^* = \int_0^{-b} \frac{1}{1+\theta_m(t)(1-\rho_w(t))}dt < 0$$

Note that given Assumption 3, and noticing that conduct parameter is always between 0 and 1, pass-through at any given t is always positive, *ie* w consumers always benefit from part of the subsidy. It can also be above 1, as soon as demand curvature is above 1, a phenomenon called "overshifting". An interpretation for the effect of demand curvature is the following: for a given level of elasticity, a more convex demand means that as a result of a shift in marginal cost (or tax), the firm focuses on a different customer type, which allows it to pass-through a higher share

of this change.

In the two following propositions, we answer the two following questions: is the subsidy more redistributive when allowing price discrimination? Which income group benefits from price discrimination?

Proposition 2. The redistributive effect of the means-tested subsidy is higher under price discrimination if and only if:

$$c\left[\frac{\epsilon_s^I(p_s^*)}{\epsilon_s^I(p_s^*)+\theta_s(p_s^*)}-\frac{\epsilon_w^I(p_w^*)}{\epsilon_w^I(p_w^*)+\theta_w(p_w^*)}\right]+\int_0^{-b}\frac{1}{1+\theta_m(t)(1-\rho_w(t))}dt>b \tag{2}$$

The right-hand side of the condition corresponds to the equilibrium differential in prices under uniform producer price and means-tested subsidy: b. The left-hand side corresponds to $p_s^* - p_w^*(b)$, the differential in prices post-subsidy under price discrimination. It is driven by the effect of price discrimination itself, through differential in elasticities – first term – and the pass-through effect of the subsidy on market w – second term. Overall, redistributivity of the scheme increases with curvature of the demand function through subsidy pass-through. It increases with the elasticity differential across income groups through the price discrimination effect. Market power has an ambiguous effect: it allows for stronger price discrimination, but reduces subsidy pass-through.

Finally, let us characterize winners and losers from price discrimination under a means-tested subsidy. To do so, we define the profit maximization problem of firms under the constraint $\tilde{p}_w = \tilde{p}_s - t, t \geq 0$, where these are consumer prices. Increasing t might be thought of as allowing for more redistribution to take place. Optimal value of t corresponds to the one under perfect price discrimination defined in Proposition 2. The first order condition of this problem defines $\tilde{p}_s(t)$ as an implicitly function of this leniency level t.

Lemma 3. Consumer price in the strong market increases with t, and it decreases in the weak

market:

$$p_s'(t) > 0$$
$$p_w'(t) < 0$$

The monotonicity of prices in each income category with respect to the discrimination leniency level allows to characterize winners and losers from discrimination, depending on overall redistributivity of the policy:

Proposition 3. Customers in w (s) benefit (loses) from discrimination if and only if 2 holds.

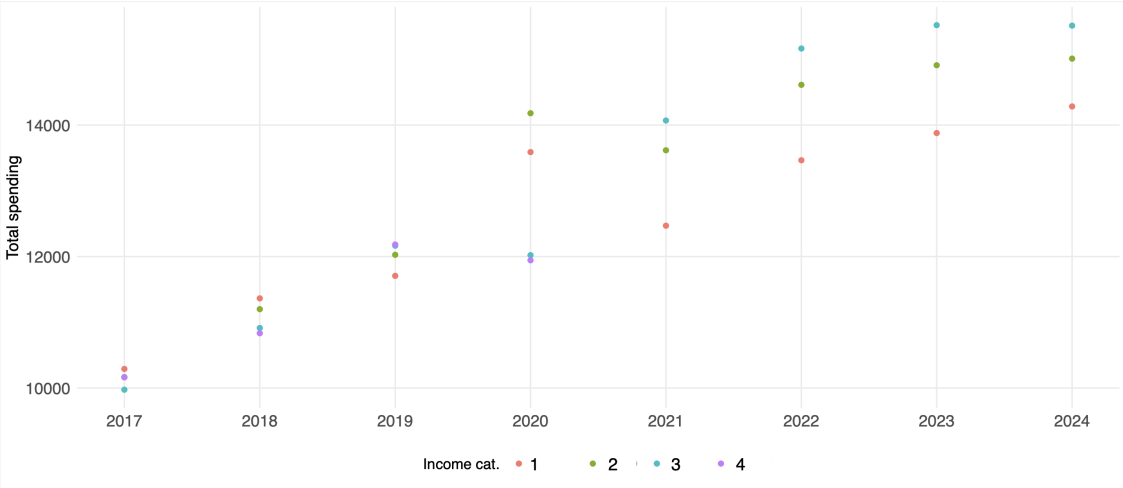
In particular, if 2 does not hold, uniform pricing is more redistributive, as discriminatory prices are lower among high-income households and higher among low-income households. Distributional consequences of a means-tested subsidy allowing for price discrimination are therefore a priori ambiguous, as they depend on demand primitives that are not easily observable.

5 Identifying price discrimination: discontinuity in prices and take-up at income thresholds

One of the most general predictions of the model described above is that, in the presence of price discrimination, consumer price differential across income groups should not be equal to the subsidy differential. Said otherwise, firm's prices should differ across discriminated groups. In Figure 6, we plot observed average price for heat pumps by year and income category around the 2020 reform. Before the introduction of MPR, subsidy level is homogeneous and prices of heat pumps are very comparable across income categories. A gap appears starting in 2021 with richer paying higher prices than the poorer households, before accounting for differential subsidies. The 2020 transition and Covid year is harder to interpret as the richer and poorer households did not benefit from the same public policy, the richer remaining eligible to the CITE and the poorer gaining access to MPR.

Another mechanism could however explain the apparition of this price differential: subsidy

Figure 6: Average heat pump producer price by year and income category



NOTE : We plot the average total cost spent by beneficiary households on subsidized heat pump installations. Prior to 2020, these correspond to installations subsidized by the CITE; post 2020, by MPR. 4 income categories are the ones defining eligibility to MPR. These categories did not apply for the CITE (except in 2020): we extrapolate income thresholds for the pre-2020 period, in order to classify households in a similar fashion. SOURCE : Fideli, POTE, MPR

differential alters the composition of demand in each income category. If low-income households now opt for lower quality – despite higher subsidy level – one could observe a similar pattern without discrimination. In this section, we leverage discontinuities at income category thresholds to control for this potential mechanism. In 5.1, we detail the methodology we use to correct for differential take-up and demand composition at income thresholds, in a regression discontinuity design. Section 5.2 displays the result. We show that otherwise identical households, in the same market conditions, are exposed to different producer prices depending on their income category: high-income households pay an extra €400 for the same heat pump. We interpret this as the proof that third-degree price discrimination, with respect to income category, is at play.

5.1 Methodology

Our main strategy is to mobilize two sharp MPR income thresholds that split the income distribution into three income categories[12], as an exogenous variation in subsidy level.

[12]The fourth category – higher income levels – is not eligible to MPR heat pump subsidies and is excluded from this analysis.

Price discrimination In the main analysis, outcome variable of interest is price before subsidy, denoted Y_i. Forcing variable Z_i is fiscal income normalized to 0 at income threshold z_0. The treatment $D_i \in \{0, 1\}$ corresponds to being in the upper income category. Since Anah systematically cross-checks declared fiscal revenue with fiscal administrative data, the design is sharp, *ie* all individuals are compliers and $D_i = \mathbb{1}_{Z_i \geq 0}$. We are interested on the average causal effect of treatment at the cutoff:

$$\theta_{LATE} = \mathbb{E}[Y_i^1 - Y_i^0 | Z_i = 0]$$

where Y_i^1 and Y_i^0 are potential outcomes in case of treatment and non-treatment. Without price discrimination, it should be null: same individuals, with same characteristics, should be offered the same pre-subsidy price on both sides of the thresholds. With price discrimination, it should be interpreted as cumulative price discrimination effect of being in another income category, plus the pass-through effect of the subsidy differential across income categories.

Typical RDD identifying assumption is the continuity of potential outcomes around the cutoff. In particular, it supposes that nothing affects potential outcomes at the cutoff. In our case, we are not concerned about manipulation of the treatment, or by an other simultaneous treatment at the same cutoff, but rather by selection into take-up as a side effect of the treatment. We indeed only observe outcome among individuals who take up the MPR subsidy, and the decrease in subsidy on the right of the cutoff might reduce take-up.

Figure 7 does show that density of MPR files is discontinuous at income thresholds: it is 30% lower on average on the right of the threshold, where subsidy level is lower. Identification assumption does not hold, as composition of the sample varies at the cutoff. In Appendix Figure 23, we show by performing pseudo-RDD on exogenous housing characteristics that many of them are unbalanced at the threshold.

To deal with these cases, Frölich and Huber (2019) consider an alternative identifying assumption, whereby potential outcomes are orthogonal to treatment at the threshold, conditioning on observables:

$$\{Y_i^1 - Y_i^0, D_i(z)\} \perp Z_i | X_i$$

Provided this assumption holds, conditional and unconditional treatment effects are respectively given by γ_X and γ:

$$\begin{aligned}
\gamma_X &= \lim_{\epsilon \to 0} \mathbb{E}[Y^1 - Y^0 | X, D(z_0 + \epsilon) > D(z_0 - \epsilon), Z = z_0] \\
&= m^+(X, z_0) - m^-(X, z_0) \\
m^+(X, z) &= \lim_{\epsilon \to 0} \mathbb{E}[Y | X, Z = z + \epsilon] \\
\gamma &= \frac{\int \gamma_x \frac{f^+(x|z_0) + f^-(x|z_0)}{2} dx}{\int \frac{f^+(x|z_0) + f^-(x|z_0)}{2} dx}
\end{aligned}$$

Estimators of $m^+(X_i, z_0)$ is provided by estimation of a local linear non parametric regression of Y on (X, Z), predicted for each i at $z = z_0$:

$$\arg\min_{abc} \sum_{j=1}^{n} \big(Y_j - a - b(Z_j - z_0) - c'(X_j - x)\big)^2 K_j I_j^+ \tag{3}$$

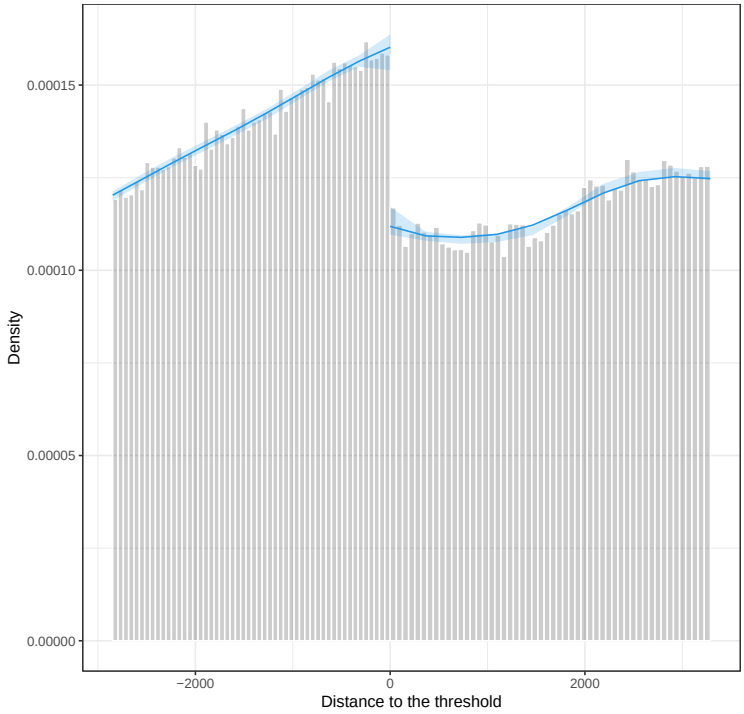
$$K_j = K_j(x, z_0) = \kappa(\frac{Z_j - z_0}{h_z}) \cdot \prod_{l=1}^{L} \overline{\kappa}(\frac{X_{jl} - x_l}{h_x}) \tag{4}$$

Estimator $\hat{\gamma}$ is then given by the Kernel-weighted sum of these individual effects:

$$\hat{\gamma} = \frac{\sum_{i=1}^{n} (\hat{m}^+(X_i, z_0) - \hat{m}^-(X_i, z_0)) K_h(\frac{z_i - z_0}{h})}{\sum_{i=1}^{n} K_h(\frac{z_i - z_0}{h})} \tag{5}$$

We follow recommendation of the paper for kernel orders and bandwidths that ensure that bias and standard deviation of this estimator converge at rate $n^{-2/5}$ to zero. We estimate this parameter using $L = 10$ covariates that correspond to variations in subsidy schedule faced by the

Figure 7: Density of MPR files, by distance to the income discontinuity threshold



Note : This figure presents the observed density of MPR files by distance to the income threshold. An observation corresponds to an MPR heat pump file between 2020 and 2024. Income threshold is normalized to zero. This average differential in take-up, estimated using the local polynomial density estimator proposed in Cattaneo et al. (2021), equals 30.1%.

housing or housing characteristics that might be correlated to potential outcomes[13].

We consider that the conditional continuity in outcomes assumption is not unrealistic in our setup. It would not hold if individuals with same observables are charged heterogeneous prices for the same good, depending on some unobservables that are also correlated with the take-up decision. That is equivalent to saying that firms price discriminate according to some characteristics unobservable to us. We consider this to be unlikely, given the richness of characteristics we observe, that give a precise description of the conditions in which households take up the subsidy: geography, market and subsidy conditions, housing characteristics.

[13]These correspond to: dummies for period of the subsidy schedule (two in the observed period) interacted with the two types of income threshold considered (between income category 1-2 or 2-3), date of construction, surface, date of take-up, number of certified firms in a 50-km radius, number of MPR actions including the heat pump, dummy for being outside of Ile-de-France, dummy for gas as heating fuel.

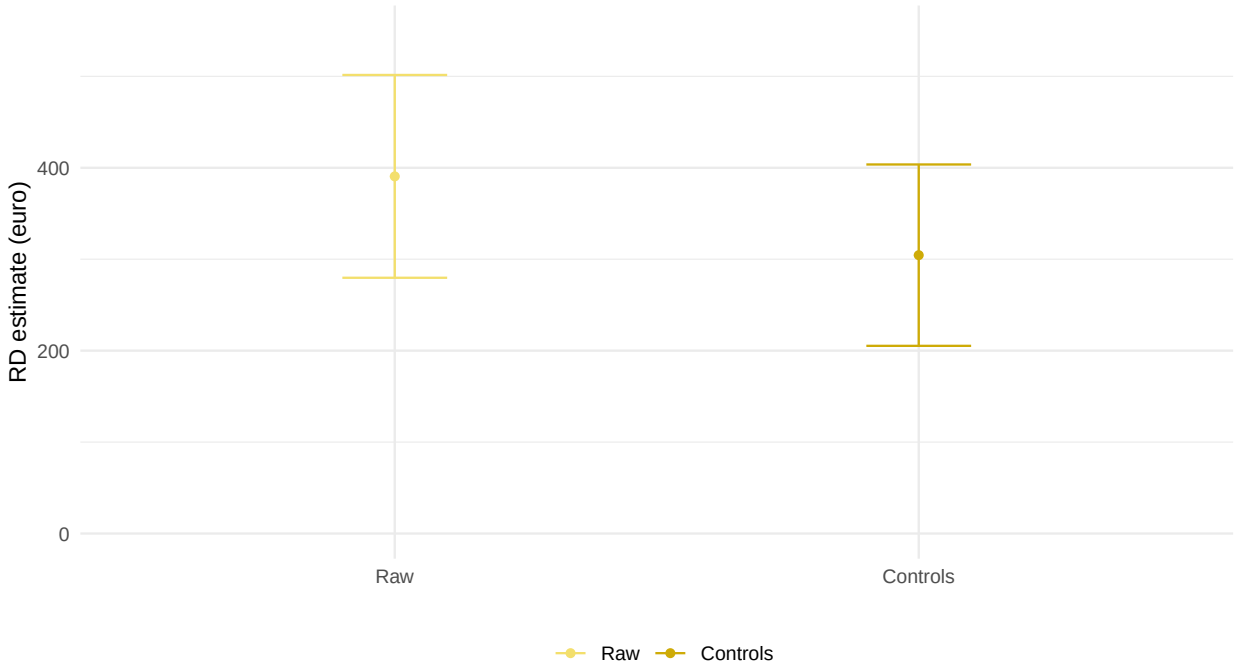
5.2 Results

Figure 8 presents our main result: the average differential in heat pump producer price estimated at MPR income thresholds. We present both the naive estimate ("raw") and the one obtained by weighted average of conditional treatment effects ("controls"). The average price differential is positive and significant in both cases, between €300 and €400 per heat pump, on top of the €1000 MPR subsidy differential. We interpret the slightly lower effect with controls as an indicator that firms maybe discriminate with respect to other characteristics than income, that vary discontinuously at the threshold, that are also observed to us, and that we control for.

Based on the results of the theoretical framework, we interpret this positive effect as the proof that price discrimination is taking place, and that discrimination and pass-through add up to a more than 100% incidence of the subsidy differential – around 130%. Recall that the effect of price discrimination needs not go in that direction. In, Appendix Figure 25, we extend the analysis to other energy efficiency investment types. We find that discrepancies in producer prices at MPR thresholds are not an exception applying only to heat pumps. However, we find that in some cases (*eg* wood boilers, insulation), it has regressive effects higher producer price among low-income households. It suggests that demand primitives or market conditions vary significantly across energy efficiency investment types. This robustness result reinforces the idea that the mechanisms at play are difficult to anticipate in policy design: enabling discrimination is a risky policy choice.

Heterogeneity: mandating Enabling discrimination is precisely what mandating does. Indeed, when households mandate firms, these are in charge of the subsidy application process. It means that they systematically have access to the income category of their customer – asking for the precise income level is however forbidden – at the beginning of the quotation process. The role of this policy feature is to lower the hassle cost of take-up. It could however facilitate third-degree discrimination, which was not foreseen. To verify this hypothesis, we estimate the same regression for mandated files and non-mandated files separately. The results are found in Figure 9. It appears that the price differential is positive and significant for both mandated and

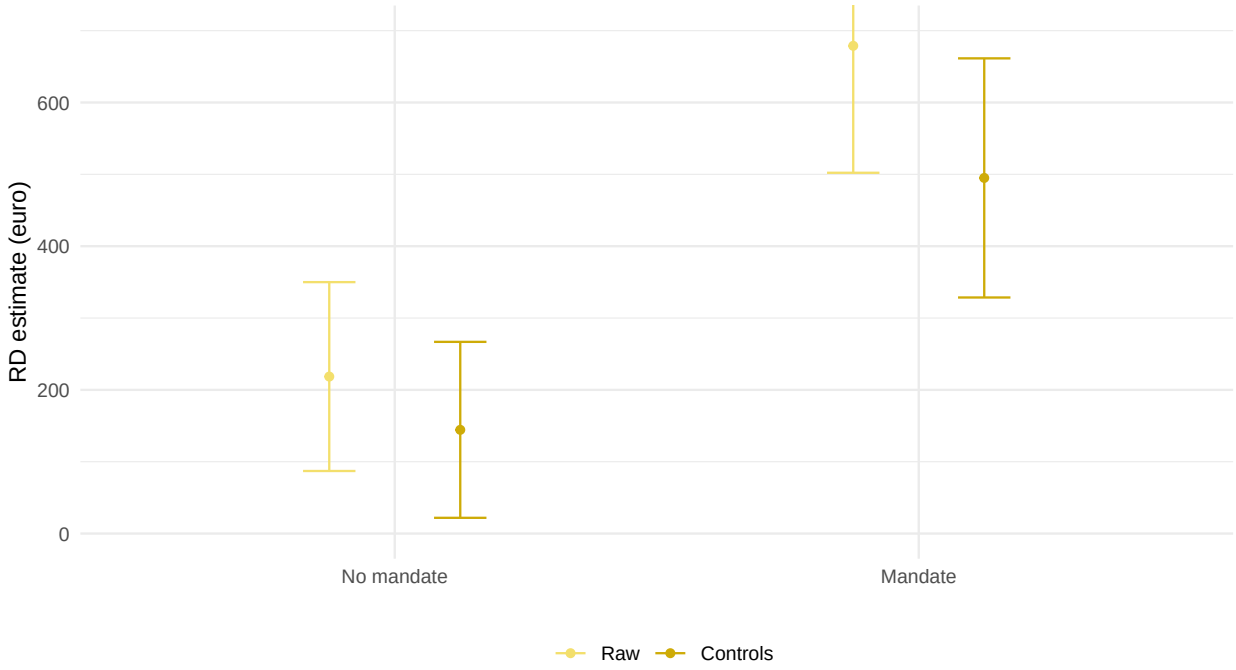
Figure 8: RDD result – producer price differential at MPR thresholds



Note : This figure presents the observed producer price differential at MPR income thresholds, estimated on the whole sample (Raw) or as a weighted average of conditional treatment effects (Controls). Sample is made of one observation by MPR file-action involving a heat pump.

non-mandated files. It is however three times higher among mandated files.

Figure 9: RDD result – producer price differential at MPR thresholds, by mandate



Note : This figure presents the observed producer price differential at MPR income thresholds, estimated on the whole sample (Raw) or as a weighted average of conditional treatment effects (Controls), for mandated and non-mandated files separately. Sample is made of one observation by MPR file-action involving a heat pump.

Note that the observed difference in treatment effects between mandated and non mandated files is not necessarily causal, as selection into mandating is endogenous: households and firms might differ between mandated and non mandated files. Given the sign and magnitude of this difference, it could mean for example that low-income households that select into mandating are particularly elastic. It could also be rationalized by high market power of firms that select into mandating, or a high willingness to discriminate. We therefore interpret our result as additional suggestive evidence that the policy facilitated third-degree price discrimination.

Heterogeneity: local market conditions In section 4, we showed that the effect of market power is *a priori* ambiguous on the distributional outcomes of the policy: on one hand, it increases the effect of discrimination itself, on the other hand, it decreases subsidy pass-through, provided

there is no overshifting, *ie* demand is not log-convex. The effect can therefore be positive or negative and needs not be monotonous with intensity of competition. It is therefore an empirical question.

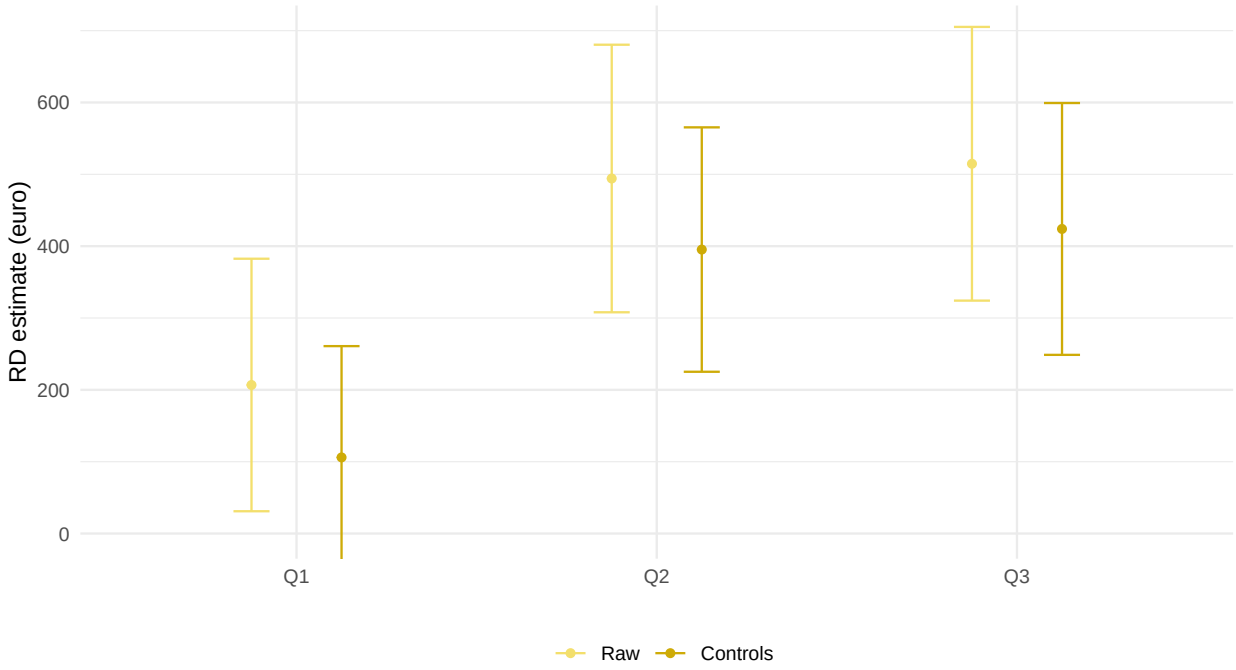
We proxy market competition by HHI of RGE firms performing heat pump installation and located in a radius of 50km around the housing. Households with no firm at less than 50km are given an HHI of 1. We split all observations into terciles of HHI and aim at identifying heterogeneity in price differential at the threshold across these terciles. We show in Table 1 that even for a relatively conservative definition of the limits of local markets, a sizable share of households that take up an MPR-subsidized retrofit action do so in a relatively (HHI > 0.15) or highly (HHI > 0.25) concentrated market.

Table 1: Mean HHI by concentration tercile and selected radius

Radius	Q1	Q2	Q3
10	0.21	0.50	0.96
25	0.07	0.16	0.53
50	0.03	0.06	0.20
100	0.01	0.02	0.12

Figure 10 presents the RD estimates by HHI tercile. It appears that price differential is slightly higher in less competitive – more concentrated – markets: it is around three times higher in the third tercile, compared to the first one. We do not interpret these differences as the causal effect of market power: as for our previous heterogeneity analysis, local market conditions are likely to be highly endogenous. Indeed, firms probably self-select into local markets depending on the structure of local demand. We interpret it as suggestive evidence that the price discrimination effect of market power dominates the pass-through effect, or that demand is log-convex. We use estimation of our structural model in the next section to identify the correct option.

Figure 10: RDD result – producer price differential at MPR thresholds, by concentration tercile



Note : This figure presents the observed producer price differential at MPR income thresholds, estimated on the whole sample (Raw) or as a weighted average of conditional treatment effects (Controls), by HHI tercile. Sample is made of one observation by MPR file-action involving a heat pump.

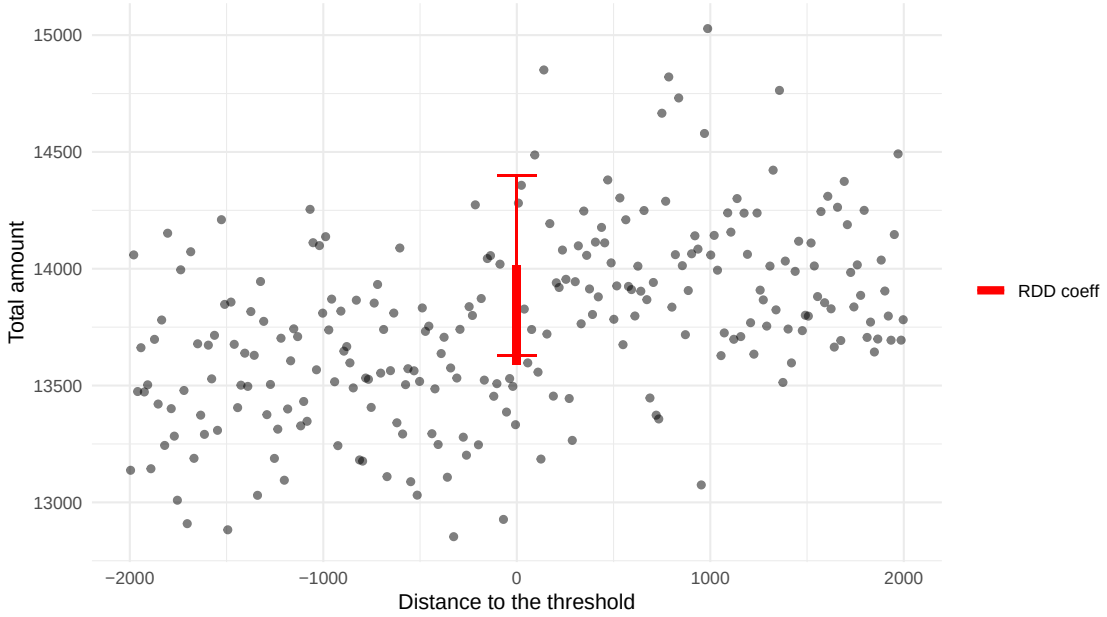
Quality differential We mentioned the possibility that the producer price differential that we find could be explained by differential quality in installed equipment, on both sides of the threshold, either because of quality discrimination by firms in the products they offer, or because of differences in preferences. Note that there is little chance that this mechanism could explain the direction of the differential we find: it would mean that households with the same income, identical on observables, but with lower subsidy level, would choose a higher quality (with higher price). If anything, the reverse could be true. It would mean that our estimate is a lower bound of the price discrimination effect.

Also note that quality of heat pumps is not a covariate that we used to define conditional treatment effects. We therefore separately perform RDD on this outcome, leveraging administrative data from Energy Efficiency Certificates (CEE). In this related subsidy program, coefficient of performance (COP) of the heat pump enters the computation of subsidy level and is therefore. We consider this measure as a proxy of quality for the equipment[14]. Most MPR files also take up CEE, and the corresponding subsidy amount is filled out in MPR administrative data: we therefore match these datasets based on location, take-up date, firm doing the installation and price of the investment. On matched files, we perform two RD exercises, using the same matching procedure as before: the first on total cost before subsidy, the second on coefficient of performance. Results, displayed in Figure 11, are twofolds: first, differential in producer price on the matched subsample is consistent with previous results and equal to around €500. Secondly, there is no significant change in quality of equipment at the threshold. It suggests that firms do not exploit information provided by MPR for quality discrimination. In Appendix Figure 27, we show that most firms specialize in one quality level, which rules out quality discrimination. We however show in Appendix Figure 28 that the null result holds when focusing on firms that do several quality levels.

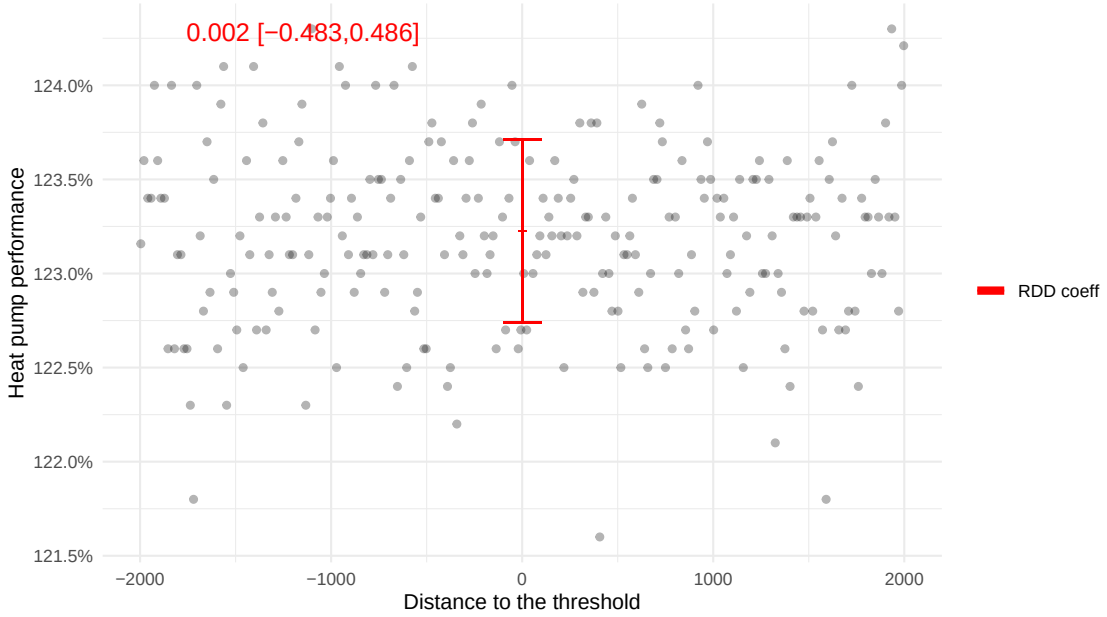
[14] A complementary measure of its quality is its size. We therefore make the implicit assumption that heat pump size – that is largely driven by the size of housing – does not vary discontinuously at the threshold.

Figure 11: RDD result – heat pumps

(a) Producer price



(b) Coefficient of performance



Note : This figure presents RD estimated parameters for air-water heat pumps, for total cost (panel a) and coefficient of performance of installed heat pumps (panel b), as well as a scatter plot of these variables as a function of distance to the income threshold, on a matched sample. Each dot corresponds to the average price of 1.000 observations. RD coefficient is displayed as a red bar, with associated 95% confidence intervals.

6 Structural model: price discrimination and pass-through under means-testing

Previous sections shed light on a key mechanism that mediates the effects of MPR on prices: local markets are rationed, probably through a shortage of skilled labor supply, potentially through other barriers to entry related to the RGE monetary and non-monetary costs. The relatively low number of firms in local markets leads to the exercise of market power. The means-tested quality of the MPR scheme makes the exercise of market power twofold. First, the organization of the scheme gives firms the possibility of discriminating across income categories through prices. Second, within each sub-market made up of a given income category, market power affects pass-through. The goal of this section is to disentangle these mechanisms and quantify their effect on prices and take-up under a means-tested scheme. This exercise matters for two reasons: first, a high level of redistribution observed in reduced-form can be rationalized by either high levels of price discrimination, or high levels of pass-through. These scenarios can have very different implications for future policy changes. Secondly, estimating demand and supply primitives allows to build counterfactual scenarios and approach the welfare effect of the policy implementation, with and without price discrimination.

In 6.1 we first define and estimate a discrete choice model of demand for heat pumps, to identify the three drivers of price discrimination and pass-through effects: substitution patterns identify the level of product differentiation and market power, price sensitivity parameters the whole distribution of price elasticity of demand and demand convexity. Estimated demand parameters are then plugged in a model of supply in 6.2. It allows to recover marginal costs of firms, a final determinant of firms' pricing decision. We use these demand and supply parameters in 6.3 to build counterfactual policies that go in two directions: first, we remove differentials in subsidy levels across income categories, to identify pass-through of this differential. Secondly, we shut down the ability for firms to charge different prices for the same product, thus identifying the effects of such discrimination on prices and demand. Results of these three exercises are found in 6.4.

6.1 Theoretical model of demand for heat pumps

We first present our theoretical discrete choice model of demand for heat pumps. In each market $m \in \{1, ..., M\}$, each potential consumer $i \in \{1, ..., n_m\}$ chooses among a set of $J_m + 1$ goods $\{0, ..., J_m\} \equiv \mathcal{J}_m$, where each $j > 0$ corresponds to the combination of a heat pump model and a firm providing it and $j = 0$ corresponds to the outside good – not investing in a heat pump. We denote by $J = \sum_m J_m$ the total number of inside products across markets.

We assume that firms only observe the income category of each consumer i, denoted $c = c(i) \in \{1, 2, 3\}$[15] and thus offer category-specific prices p_{cjm} for good j and income category c. In what follows, p_{cjm} should be understood as consumer price after income category-specific subsidies b_c or flat income tax credit τ[16]. Firm price before subsidy is denoted q_{cjm}, so that $p_{cjm} = q_{cjm} \cdot (1 - \tau) - b_c$.

We allow consumers to be heterogeneous in their demand for heat pumps, within income category. This heterogeneity is assumed unobserved by the firm but observed by the econometrician. Deterministic utility of consumer i for $j > 0$ is given by:

$$U_{ijm} = \gamma + \zeta_{e(j)} + \psi_m + \sum_{k=1}^{K} \beta_x^k x_{jm}^k + \beta_p^i \log(p_{c(i)jm}) + \sum_{r=1}^{R} \beta_y^r y_i^r + \beta_d d_{ijm} + \chi_{c(i)jm} \tag{6}$$

$$\tag{7}$$

while $U_{i0m} = 0, \forall (i, m)$. $e(j)$ denotes coefficient of performance of the product. x^k and y^r are respectively product- and consumer-specific characteristics. Note that there is no variation in individual characteristics across products. They only drive the preference to invest in any heat-pump, relative to not investing at all ($j = 0$). d_{ijm} corresponds to the distance between the product's firm and consumer's housing. Note that this specification considers an intercept γ that corresponds to the mean-utility of installing a heat-pump, a quality fixed effect $\zeta_{e(j)}$, a market fixed effect ψ_m, as well as a mean-zero product-income category residual χ_{cjm}.

[15] There are four income categories in the MPR scheme. The fourth one is not eligible for an MPR subsidy for a heat pump investment. We therefore exclude it from the analysis.

[16] In the baseline scenario, $\tau = 0$ and b_c corresponds to MPR subsidy

Preferences for price vary across consumers according to income, that is β_p^i is of the form:

$$\beta_p^i = \beta_p^0 + \beta_p^1 I_i \tag{8}$$

As typical in the BLP literature, we add to deterministic preferences an idiosyncratic error term ϵ_{ijm} that is *iid* extreme-value distributed, so that indirect utility is given by:

$$V_{ijm} = U_{ijm} + \epsilon_{ijm}, \forall (i, j, m) \tag{9}$$

Each consumer chooses the product that maximizes her indirect utility. This choice is captured by $\mathbb{1}_{ijm}$, a dummy equal to 1 if individual i chooses product j. Observed market shares are then given by [17]:

$$s_{cjm}^d = \frac{1}{n_m} \sum_{i, c(i)=c} \mathbb{1}_{ijm} \tag{10}$$

Extreme-value errors yield the multinomial logit form for the probability s_{ijm} to choose product j:

$$s_{ijm} = \frac{\exp(U_{ijm})}{1 + \sum_{j'=1}^{J_m} \exp(U_{ij'm})} \tag{11}$$

In what follows, we are particularly interested in the interaction between firms' pricing decision and consumers' demand. A key driver of this interaction is the level of price elasticity and its heterogeneity across income categories. In that regard, note that at a given vector of prices p, own-price elasticity if given by:

[17] Note that market shares are defined at the market level so that $\sum_c \sum_j s_{cjm}^d = 1, \forall m$.

$$\eta_{ijm}(p) \equiv \frac{\log(s_{ijm}(p))}{\log(p_{cjm})} = (1 - s_{ijm})\beta_p^i \tag{12}$$

Considering that overall take-up for heat pumps in a given year is relatively low, of the order of a few percent, and spread over tens of firms in a given market, market share of a given product s_{ijm} is typically low. Our specification therefore implies close to constant price elasticity that can be approximated by parameter β_p^i. Incidentally, constant elasticity implies log-convexity of demand and pass-through overshifting. In robustness checks, we test more flexible price sensitivity, that allow for pass-through lower than 100%. We find very similar levels of elasticity and that overshifting still prevails.

Data and parameters We estimate the above model on metropolitan France in 2022, the year with highest take-up of MPR for heat pumps. A market m corresponds to a department. We focus on $M = 70$ departments with more than a thousand heat pump MPR files in 2022. Within each market, a consumer i is a housing eligible to an MPR subsidy. We further restrict our analysis to owner-occupiers and houses. Take-up is indeed typically very low in rented housing and appartments due to landlord-tenant split incentives and coordination failures in multi-housing buildings. A product j is made of any firm-heat pump model combination that has been chosen at least once by consumers during the year. Note that we therefore allow firms located outside of the department m bounds to be in the choice set $\mathcal{J}_m$, as long as they were chosen by at least one housing in m[18]. A heat pump model is characterized by its coefficient of performance. For simplicity we consider two models: below and above 125%.

In our main specification, we consider two product characteristics: the age of the company and its size, proxied by the number of FTE employees. Individual characteristics are dummies for construction period (before 1949, between 1949 and 1975, between 1975 and 2000, after 2000), the share of winter days spent in extremely cold temperatures, housing quality index and housing surface. Income is defined by fiscal income divided by the number of household inhabitants.

[18]In practice, more than half of MPR files correspond to a firm-housing combination located in the same department

Except for construction dummies, all product and individual characteristics are normalized to avoid scale effects in estimation.

Identification challenges Main identification challenges regard potential correlation between firms' characteristics and residual demand shocks.

We first assume exogeneity of firms' characteristics, especially firm size, in the short run. One might be concerned about the fact that firms adjust capacity and size to demand. We assume that in the short run, capacity is relatively constrained and does not adjust to demand shocks.

Secondly, we need to take into account the fact that firms self-select into markets, in terms of location. One might be concerned about omitted variables that would be both correlated to firms' characteristics and demand. Given the rich set of observed consumer characteristics that determine demand, we consider this risk as limited. We assume that determinants of demand that are unobserved to us are also unobserved to firms when they first choose their location.

Finally, a typical challenge for identification of β_p^i is the endogeneity of price with demand. We deal with it using instrumental variables for prices, in a two-step estimation procedures developed in Berry et al. (2004) and detailed below.

Estimation procedure We are interested in estimating the set of parameters $\theta^d = \{\theta_1^d, \theta_2^d\}$, where $\theta_1^d = \{\gamma, \zeta, \psi^T, \beta_x^T, \beta_p^0\}^T$ is the vector of mean taste parameters and $\theta_2^d = \{\beta_p^1, \beta_y^T, \beta_d\}^T$ is the vector that captures heterogeneity of tastes across consumers. Following Berry et al. (2004), we estimate the model by a two-step GMM procedure. The main aspects are explained below, while the precise estimation procedure is detailed in Appendix C.

In the first step, we note that utilities U_{ijt} can be rewritten:

$$U_{ijm} = \delta_{c(i)jm} + \beta_p^1 \log(p_{c(i)jm}) \cdot I_i + \sum_{r=1}^{R} \beta_y^r y_i^r + \beta_d d_{ijm} \tag{13}$$

$$\delta_{cjm} = \gamma + \zeta_{e(j)} + \psi_m + \sum_{k=1}^{K} \beta^k x_{jm}^k + \beta_p^0 \log(p_{cjm}) + \chi_{cjm} \tag{14}$$

For any given value of θ_2, we note that there is a bijection between the vector of mean utilities

δ and predicted market shares s_{cjm}:

$$s_{cjm}(\delta, \theta_2) = \frac{1}{n_m} \sum_{i, c(i)=c} s_{ijm}(\delta, \theta_2) \tag{15}$$

We find the unique vector $\hat{\delta}(\theta_2)$, so that predicted market shares match observed market shares, that is $s_{cjm}(\hat{\delta}(\theta_2), \theta_2) = s^d_{cjm}, \forall c, j, m$. Because of observed heterogeneity in our specification, this system of equations has no closed-form solution for $\hat{\delta}(\theta_2)$. Instead, we rely on a nested fixed point algorithm.

This first step presents two advantages. First, it reduces the number of parameters to be estimated by GMM, as the high number of θ^d_1 parameters are concentrated out of the problem. Secondly, it concentrates out the price endogeneity problem. Indeed, δ_{cjm} encompasses both the mean price components and demand residual. We are therefore able to estimate the set of δ_{cjm} and θ^d_2 parameters with no endogeneity issue.

The main challenge for this estimation procedure is the high number of products J_m in each market and high market share of the outside option. Estimation of the δ vector requires a large number of observed choice for each option j for the subsequent estimation of θ^d_1 to be precise. That is not the case when market shares s^d_{cjm} are small and noisy. We deal with this challenge by aggregating market shares of firms at the quality-location level. For each m, we split products into two quality levels and into firm groups based on firm's location. More specifically, firms at aggregated in hexagons of 25 km radius. Two products are of the same group $g = g(j) = g(j')$ if they have the same quality and are located in the same hexagon. For a given g, we consider mean product characteristics, including for price and distance to housing, so that all products share the same characteristics and $s_{cgm} = n^p_{gm} \cdot s_{cjm}, g(j) = g$, where n^p_{gm} denotes the number of "identical" products in group g. The δ vector to be estimated therefore has $\sum_m \sum_c G_m = 3 \cdot G$ components, where we respectively denote by G_m the number of groups of products per market and overall number of products in the sample.

Given the set of $\hat{\delta}(\theta_2)$, we compute $R + 2$ micro-moments of the type:

$$\begin{cases} h_1^M & = \sum_{m=1}^{M} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\wp_{igm} - \mathbb{1}_{igm}) \log(p_{c(i)jm}) \cdot I_i \\ h_{r+1}^M & = \sum_{m=1}^{m} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\wp_{igm} - \mathbb{1}_{igm}) y_i^r, \forall r \in [1, ..., R] \\ h_{R+2}^M & = \sum_{m=1}^{m} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\wp_{igm} - \mathbb{1}_{igm}) d_{igm} \end{cases}$$

These micro-moments target the correlation between group of product choice and each individual-product characteristics. This sub-problem is just-identified, as there are as many moments as parameters in θ_2^d. These moments also correspond to the first-order conditions of the maximum likelihood of the logit model, on the sub-problem of finding θ_2^d after having concentrated out the δ. We define $h^M(\delta(\theta_2), \theta_2)) = Z^T\xi$ the vector made of these micro-moments, where $Z \in \mathbb{R}^{N^{full} \times (R+2)}$ matrix of individual-product covariates and $\xi \in \mathbb{R}^{N^{full} \times 1}$ is the matrix of choice residuals, where $N^{full} = \sum_m n_m G_m$. Our GMM estimator is therefore:

$$\hat{\theta}_2^d = \arg\min_{\theta_2} \xi^T Z Z^T \xi \tag{16}$$

In a second step, we estimate $\hat{\theta}_1^d$ parameters from estimated $\hat{\delta}(\hat{\theta}_2^d)$ using instrumental variables for prices and two-stage least square estimation. We use four instruments for log-price $\log(p_{cgm})$: subsidy level, mean salary per FTE employee for group g firms, mean price for the same good in adjacent markets m (excluding firms active in market m), mean HHI in heat pump adjacent markets.

6.2 Supply model

In each market m, F_m firms f propose each a set of goods $j \in \mathcal{J}_{fm}$ (such that $\bigcup_f \mathcal{J}_{fm} = \mathcal{J}_m \backslash \{0\}$) to three categories of consumers c at price $p_{cjm} = q_{cjm} - b_c$, where $b_c > 0$ is the subsidy level for income category c and q_{cjm} is the pre-subsidy price. Note that in our setup, a given firm offers at most two products: a heat pump with coefficient of performance below 125% and one above. Each firm therefore optimizes the following function with respect to own prices:

$$\pi_{fm} = \sum_{j \in \mathcal{J}_{fm}} \sum_{c=1}^{3} (p_{cjm} + b_c - mc_{cjm}) s_{cjm}(p_m) \tag{17}$$

Note that we allow for marginal cost to vary for a same product across income categories. Variations in marginal costs for a same product can correspond to differentials in installation costs (variations in housing characteristics) or administrative costs (opportunity cost of being mandated to take care of the administrative process)[19]. Since we allow for price discrimination, setting pre-subsidy prices q_{cjm} is equivalent to setting consumer prices p_{cjm}. For firm f, first-order condition with respect to consumer price $p_{cjm}, j \in \mathcal{J}_{fm}$ is given by:

$$FOC_{cjm} : \frac{\partial \pi_{fm}}{\partial p_{cjm}} = s_{cjm} + \sum_{j' \in \mathcal{J}_{fm}} \frac{\partial s_{cj'm}}{\partial p_{cjm}} (p_{cj'm} + b_c - mc_{cj'm}) = 0 \tag{18}$$

In matrix form, we obtain the following system of $3J$ first-order conditions (number of products across markets times the number of income categories) that allows to recover marginal costs:

$$S + \Delta(P + B - C) = 0 \tag{19}$$

$$C = P + B + \Delta^{-1} S \tag{20}$$

where $S \in \mathbb{R}^{3J \times 1}$, $\Delta \in \mathbb{R}^{3J \times 3J}$, $P \in \mathbb{R}^{3J \times 1}$, $B \in \mathbb{R}^{3J \times 1}$, $C \in \mathbb{R}^{3J \times 1}$ are respectively the matrices of observed market shares, derivative of market shares with respect to prices, consumer prices, subsidies, marginal costs. Coefficients of Δ are given by:

[19] Misspecification of the demand model or noise can also be drivers of differences in marginal costs. In appendix **??**, we test an alternative methodology with homogeneous costs and explore implications for counterfactual exercises.

$$\frac{\partial s_{cjm}}{\partial p_{c'j'm'}} = \begin{cases} 0 & \text{if } m \neq m' \text{ or } c \neq c' \text{ or } j \in \mathcal{J}_{fm}, j' \in \mathcal{J}_{f'm}, f \neq f' \\ \frac{1}{n_m} \sum_{i,c(i)=c} s_{ijm}(1 - s_{ijm}) \frac{\beta_p^i}{p_{cjm}} & \text{else if } j = j' \\ \frac{-1}{n_m} \sum_{i,c(i)=c} s_{ijm} s_{ij'm} \frac{\beta_p^i}{p_{cj'm}} & \text{otherwise.} \end{cases} \tag{21}$$

Note that for a single-quality firm – the majority of them are, see Figure 27 – equation 19 implies that the pricing decision is driven by the following Lerner index:

$$\frac{p_{cjm} + b_c - c_{cjm}}{p_{cjm}} = \frac{1}{\epsilon^D_{cjm}(p)} \tag{22}$$

$$= \frac{\partial p_{cjm}}{\partial s_{cjm}} \cdot \frac{s_{cjm}}{p_{cjm}} \tag{23}$$

The main assumption we make for identification of marginal costs is that local markets are independent. We mentioned the fact that local markets are indeed local. However, their limits are blurry. In particular, a firm might be active at the limit of two markets t, t' with a similar pricing strategy that depends on demand parameters of the two markets. We choose relatively large local markets (departments) to limit these frontier effects. In Appendix **??**, we estimate the model using different limits for local markets and show that results are qualitatively similar.

Also note that we estimate marginal costs at the product level j, not group level g. To do so, we combine parameter estimates $\hat{\theta}$ with product and product-individual characteristics (price, age, size, distance) rather than their group-level means, to compute market shares and derivative of market shares. The rationale is to allow for richer product differentiation in the Bertrand competition problem, especially along the location dimension, to yield more realistic price mark-ups.

6.3 Counterfactuals

In section 5, we showed that heat pump prices increased around the reform and that this increase was stronger among high income categories. There are however multiple mechanisms that can explain these results: change in input costs, change in overall public spending, price discrimination across income category, incidence of subsidy differential within each income category. We are particularly interested in isolating the effect of these two last mechanisms, as they represent the total effect of means-testing on prices. We propose and simulate a series of counterfactual policies to decompose these effects.

These exercises make two assumptions. First, we assume constant marginal costs within each income category. In particular, it implies constant returns to scales and perfect elasticity of supply[20]. Secondly, we assume that the outside option $j = 0$ does not react to policy changes, in terms of relative prices. In practice, the outside good includes non-subsidized renovation works. Non-RGE firms in this sector might adjust strategically their prices. In Appendix **??**, we show that non-certified firms represent a small share of total activity in the heat pump market. We therefore assume that price adjustments in the non-subsidized sector have negligible impact on overall prices and take-up.

1 – Baseline We first simulate equilibrium prices in the baseline policy scenario, with means-tested subsidies. This simulation aims at confirming that our estimates of marginal costs and demand parameters are consistent with observed prices and market shares.

2 – Same subsidy across income categories We then consider a policy in which all income categories receive the same heat pump subsidy amount $b_c = b$. It is taken as the observed average of subsidies among observed MPR files. This ensures that the mechanical effect of this simulated reform is budget-neutral. This counterfactual shuts down the distributional effect of differential subsidy and allows to estimate subsidy pass-through within each income category.

[20]Constant marginal cost of heat pump installation might seem reasonable for small-scale changes in quantities. An interpretation of our assumption is that the changes in demand implied by the counterfactual policies are small enough for firms not to change their size and cost structure.

3 – MPR replaced by CITE In a final scenario, we remove MPR subsidies – keeping other subsidy schemes intact – and add a 30% income tax credit on total cost. This last counterfactual shuts down the change in overall generosity of the scheme.

For each of these scenarios, we also simulate a case without price discrimination: firms are not able or allowed to propose different prices to different income categories for the same good. This might be thought of as a world where the MPR administrative process does not allow firms to learn customers' income category. This modified price-setting problem with J price unknowns instead of $3J$, as well as simulation procedure of prices in all other counterfactuals, can be found in Appendix D.

We present in the next subsection the results of these counterfactuals in terms of change in prices, quantities, mark-up, profits, by income category. As a benchmark, we report observed observed outcomes under MPR. We interpret residual differences between counterfactual 3 without price discrimination and observed CITE as the sum of estimation error and the effect of 2020-2021 inflation that is not due to the 2020 reform itself.

6.4 Results

Table 2 displays the main estimated demand parameters. All of them display a sign consistent with intuition. Interestingly, the effect of a heat pump with high coefficient of performance is very small and insignificant, suggesting that households do not value higher quality in this product. The main parameters of interest for our analysis relate to price sensitivity. First, we find high levels of mean absolute price sensitivity (and incidentally own elasticity at individual level) of around 2.9. Secondly, we find a very small impact of household income on price sensitivity. Income is normalized, with standard deviation of around €13k, approximately the distance between the first and second income category thresholds. Individuals at the first threshold only have elasticity levels 0.05 higher. It suggests that price discrimination alone has small progressive effects.

We find that redistribution is rather driven by overshifting in pass-through of the subsidy differential across income categories: constant own-elasticity of demand of around 3 indeed

Table 2: Selection of demand parameter estimates

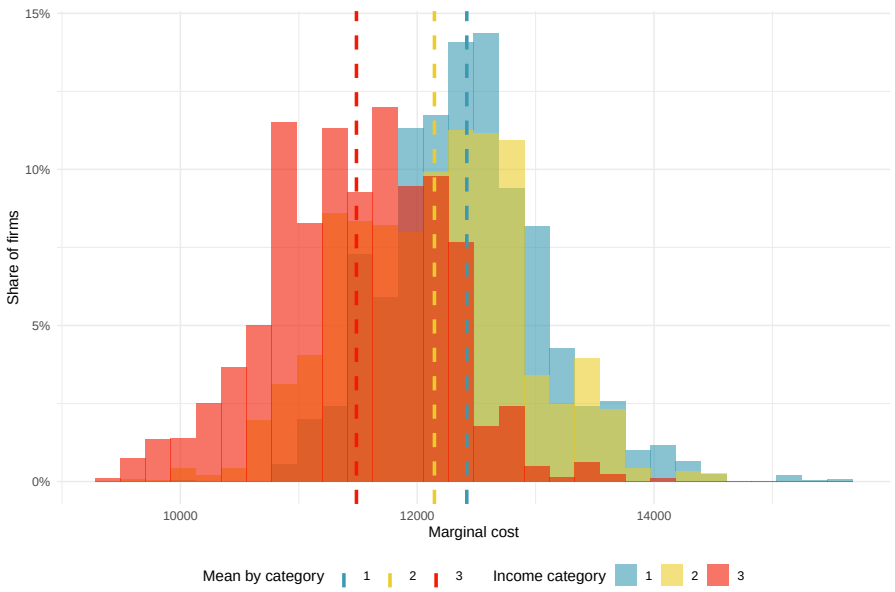
	Parameter	Std-err
Price sensitivity		
Mean	-2.867^{**}	0.356
Income	0.048^{**}	0.000
Mean utility parameters		
Mean	14.047^{**}	3.131
Firm age	-1.021^{**}	0.085
Firm size	0.581^{**}	0.075
Perf. $>$ 125%	0.011	0.148
Individual characteristics		
Built 49–74	0.293^{**}	0.001
Built 75–2000	-0.069^{**}	0.001
Built $>$2000	-0.472^{**}	0.001
Share extr. cold days	0.031^{**}	0.001
Standing	-0.077^{**}	0.000
Surface	0.218^{**}	0.000
Firm-housing characteristics		
Distance	-3.103^{**}	0.010
Objective function	4.736e-12	

Notes: Significance levels — $^{*}p < 0.05$, $^{**}p < 0.01$.

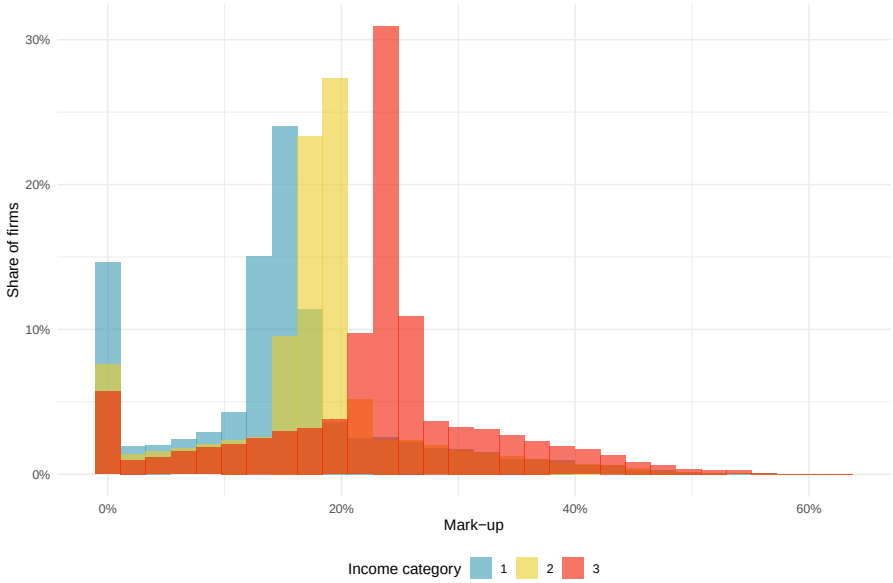
implies a pass-through of around 150%. This would be inconsistent with observed consumer price differential of 140% of subsidy differential, if marginal costs are constant across income categories: resulting redistribution should be greater than 150%, from Lemma 2 of our theoretical framework. Solving the supply first-order conditions using estimated demand parameters indeed yields 8% lower marginal costs for the highest income category, compared to the lowest, as displayed in Figure 12. One way of rationalizing this result would be that low-income households quotation process and administrative process takes longer: marginal cost would price in this opportunity cost of time.

Figure 12: Distribution of marginal costs and mark-ups, by income category

(a) Mark-up



(b) Marginal costs



Note : This figure presents the distribution of marginal costs and mark-ups by income category. An observation corresponds to a firm-quality-income category combination.

Given demand and supply parameters, we turn to counterfactual policy scenarios, summed up in Table 3. Results are consistent with our theoretical framework and estimated parameters.

Overall, by comparing baseline policy (MPR) with and without price discrimination, we do find that without price discrimination, consumer prices for low-income households would be higher – by 3%, and lower for high-income households – by 2%.

We then disentangle this overall effect between the price discrimination and pass-through effects. Comparing consumer prices under an homogeneous subsidy level with and without price discrimination, we find a negative effect of price discrimination itself on the progressivity of the scheme: under uniform pricing, consumer prices of low-income households would be 15% lower. It is because the small elasticity differential across income categories is largely offset by the differential in marginal costs, that disadvantage low-income households.

Finally, the pass-through effect of price discrimination can be obtained by comparing consumer price differentials between homogeneous and baseline subsidy, with and without discrimination. Without price discrimination, 75% of the increase in subsidy resulting from MPR is passed-through to low-income consumers, against 152% under price discrimination.

Combining these effects has significant consequences on relative- but not on overall take-up. We interpret the comparison between the flat income tax credit (without discrimination) and the predicted baseline as the effect of the MPR reform. We find price discrimination accentuated the positive effect of the reform on take-up of low-income households by 12%. Reversely, the negative effect on take-up of the highest income category was 14% stronger. However, across all income categories, the existence of price discrimination only has a marginal effect on overall take-up: 600 additional heat pumps yearly.

Table 3: Results of counterfactual scenarios

Income cat	Type	Scenario	Nb	PP	CP	Sub	Mark-up (%)	Profit (m)
1	Price discrimination	Observed baseline	19483	13392	5431	7961	11	36
		Predicted baseline	16230	13507	5436	8071	14	30
		Homog. subsidy	5293	14443	8180	6264	19	15
		Homog. tax credit	4305	15962	8801	2372	27	19
	No price discrimination	Predicted baseline	15099	13639	5600	8039	15	30
		Homog. subsidy	8347	13189	6925	6264	12	13
		Homog. tax credit	5655	14792	7982	2372	21	18
2	Price discrimination	Observed baseline	15612	13263	6469	6794	14	35
		Predicted baseline	16981	13476	6651	6824	17	39
		Homog. subsidy	12403	13720	7456	6264	19	32
		Homog. tax credit	9182	15297	8336	2372	27	38
	No price discrimination	Predicted baseline	16002	13635	6812	6823	18	39
		Homog. subsidy	15181	13182	6919	6264	16	31
		Homog. tax credit	10366	14784	7977	2372	25	38
3	Price discrimination	Observed baseline	26095	13549	8869	4679	21	82
		Predicted baseline	27979	13778	9108	4670	23	90
		Homog. subsidy	66501	12807	6543	6264	18	154
		Homog. tax credit	43360	14447	7741	2372	27	169
	No price discrimination	Predicted baseline	29468	13628	8946	4682	22	90
		Homog. subsidy	58240	13168	6904	6264	20	154
		Homog. tax credit	40247	14769	7966	2372	29	170

NOTE : This table presents the results of counterfactual policy scenarios simulated from demand and supply parameters, with or without price discrimination (Type column). Policy simulated is given by "Scenario" column: the first two scenarios correspond to the MPR schedule, observed and simulated. We then simulate an homogeneous average MPR subsidy level for all income categories, and a flat 30% income tax credit amounting to the previous CITE. Outcomes are, in sequence, the number of heat pumps installed, producer price, consumer price, subsidy level, mark-up and total firms' profit.

7 Conclusion

Subsidies targeted at low-income households are an attractive policy to tackle environmental externalities, compared to first-best Pigouvian taxation, especially for political acceptability reasons and distributional ones. The equity-efficiency trade-off that they represent, compared to Pigouvian taxation, is often evaluated assuming perfect competition on the supply side.

In this paper, we argue that not accounting for potential imperfect competition leads to biased evaluation of such programs. We find in the case of a French program of support to residential energy efficiency investments, that means-tested schemes interact with market power in two main ways: First, by providing information on subsidy levels to firms, means-tested schemes can allow firms to price discriminate between low- and high-income households. Whether or not it affects relative prices and redistribution depends on relative demand elasticities and marginal costs of different income groups and on how effective firms are at exploiting this information. Secondly, market power affects pass-through of subsidies to consumers. In our case, we find that higher market power decreases the share of subsidy that translates in lower prices for low-income households.

Because of imperfect competition, that is prevalent in many markets, effects of means-tested schemes depend on several parameters that may be unknown to the social planner. However, not accounting for them can largely bias the equity assessment of such policies. For a policy planner concerned with redistribution considerations, these results argue in favor of preventing access of firms to the subsidy eligibility criteria and customers' subsidy level.

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A MPR-Fidéli match

The match between MPR applications of a given year and Fidéli housing data of the same vintage is made of the following steps: first, we restrict Fidéli data to housing occupied as primary residence or secondary residence. This is the set of housing that is eligible to an MPR subsidy.

Secondly, we restrict the Etalab cadastral parcel dataset to parcels where one of these Fidéli housing is located. We then match each MPR application to the parcels at less than 100m from its indicated longitude and latitude. The parcel variable in Fidéli therefore allows us to match each given application to all housing at less than 100m.

Third, we compute the following matching variables for each match: distance, difference in type of housing, ownership type, number of inhabitants, household income. For each of these variables, we compute standard deviation (on a restricted sample made of one observation per application, the one with the lowest value of the criteria). We normalize each criterion by this standard deviation and add up all variables to create a single ranking grade. The lower the grade, the closest the MPR application to its matched housing.

Finally, we perform one-to-one matching using the following algorithm: we rank matches by application and housing (up to now, we have a many-to-many match, a single housing might be matched to several applications within a radius of 100m). Observations where housing is the closest to the application, and reversely, are selected and removed from the sample. This algorithm is repeated until depletion of housing to match to remaining applications. Finally note that in this process, we prioritise matches where matching variables are equal to 0 (exact distance for example), with the following order of priority: type of housing and ownership, distance, number of inhabitants, income.

The percentage of matched MPR applications, as well as the share lost at each step of the matching procedure, are found in Table 4. One can notice that the percentage of applications that get matched with a Fidéli housing is relatively consistent across the years, although it seems to be improving for latest vintages. One can also notice that the main source of absence of match is when longitudes and latitudes of the MPR application are missing (7% of applications in 2021). Figures 13 and 14 respectively present the share of applicants matched by geographical county

Table 4: Descriptive statistics - share of applicants matched by year

Step	**2020**	**2021**	**2022**	**2023**	**2024**
Initial applications (k)	172	669	655	483	36
Geolocalisation (% prec.)	97.2	93.0	95.3	99.5	99.5
Parcel (% prec.)	98.9	99.2	99.1	99.1	99.2
Housing (% prec.)	99.5	99.6	99.8	99.8	99.8
Matched housing (% prec.)	98.9	99.9	99.9	99.9	100
Final applications (k)	163	614	617	475	35
% initial	94.6	91.8	94.2	98.3	98.6

and by household income, as stated in the MPR dataset. It appears that this share is relatively homogeneous across counties, except in ultramarine ones (counties on the right of the graph). We exclude these counties from our incidence analysis. There is also a slight gradient in matched share along the income distribution. However, since this gradient is quite smooth and linear, we make the assumptions that it does not affect our analysis at income thresholds in our incidence analysis.

Figure 13: Descriptive statistics - share of applicants matched by county id

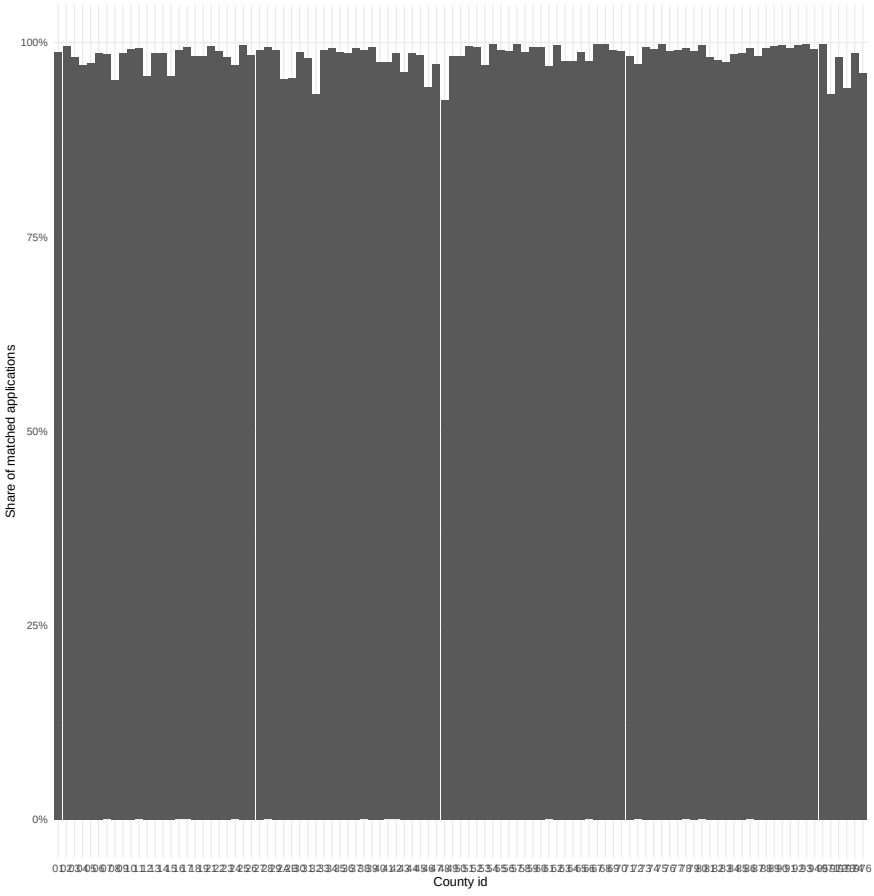
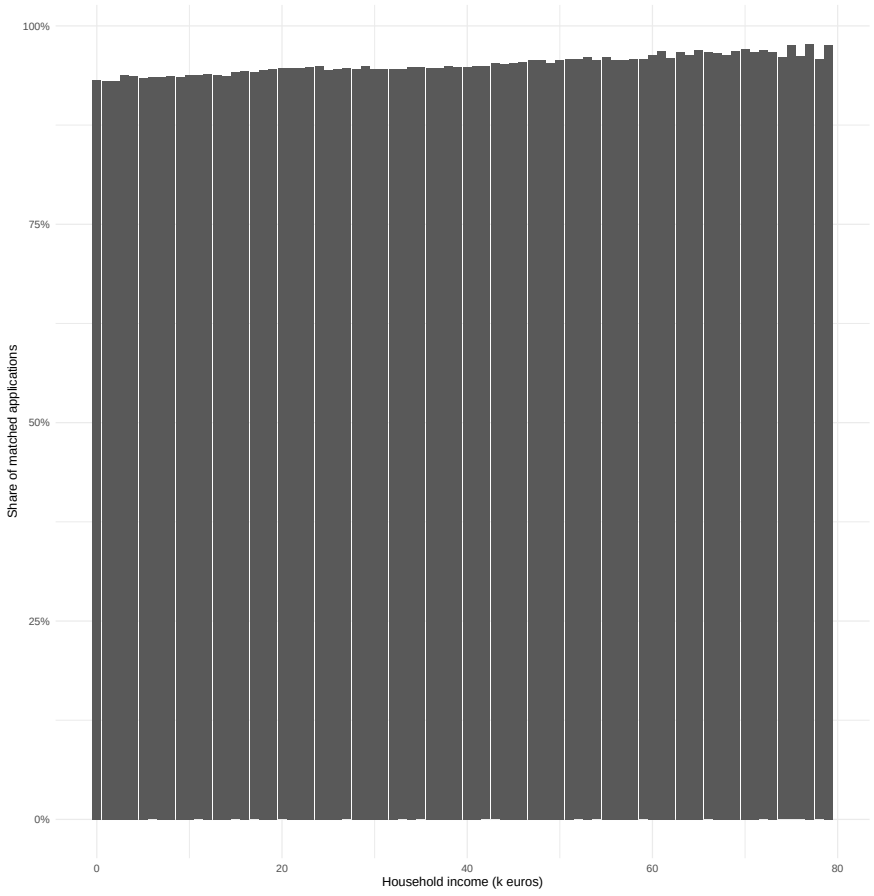


Figure 14: Descriptive statistics - share of applicants matched by household income



In terms of quality of the matching procedure, we present hereafter a few descriptive statistics: 92% of MPR applications are matched with their closest housing, in terms of matching grade ranking. Table 5 shows that selected matches are relatively close in terms of number of inhabitants and distance, while household income is a somewhat less reliable matching criterion. Finally, figures 15 and 16 present a more detailed distribution of matching quality, respectively for geographical distance and difference in number of inhabitants.

Table 5: Descriptive statistics - quality of matches

Statistics	Distance (m)	Inhabitants diff. (#)	Income diff. (%)
mean	7.49	0.49	27
median	1.28	0.00	10
standard deviation	14.36	0.85	40

Figure 15: Distribution of distance to matched housing (2021)

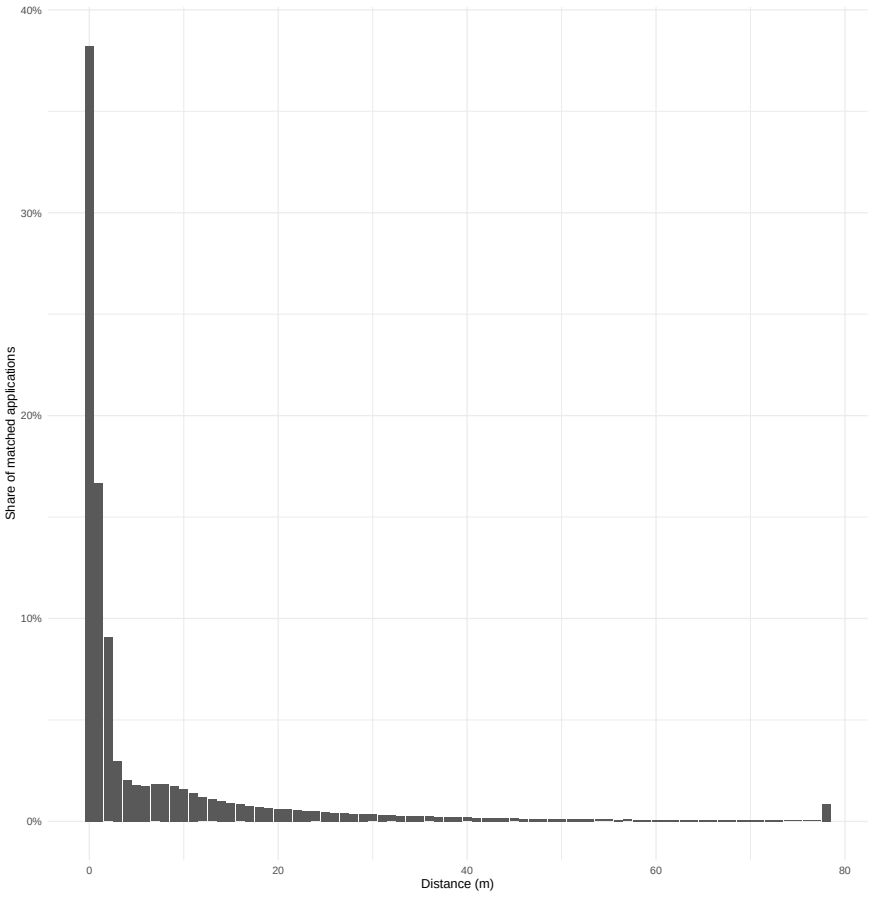
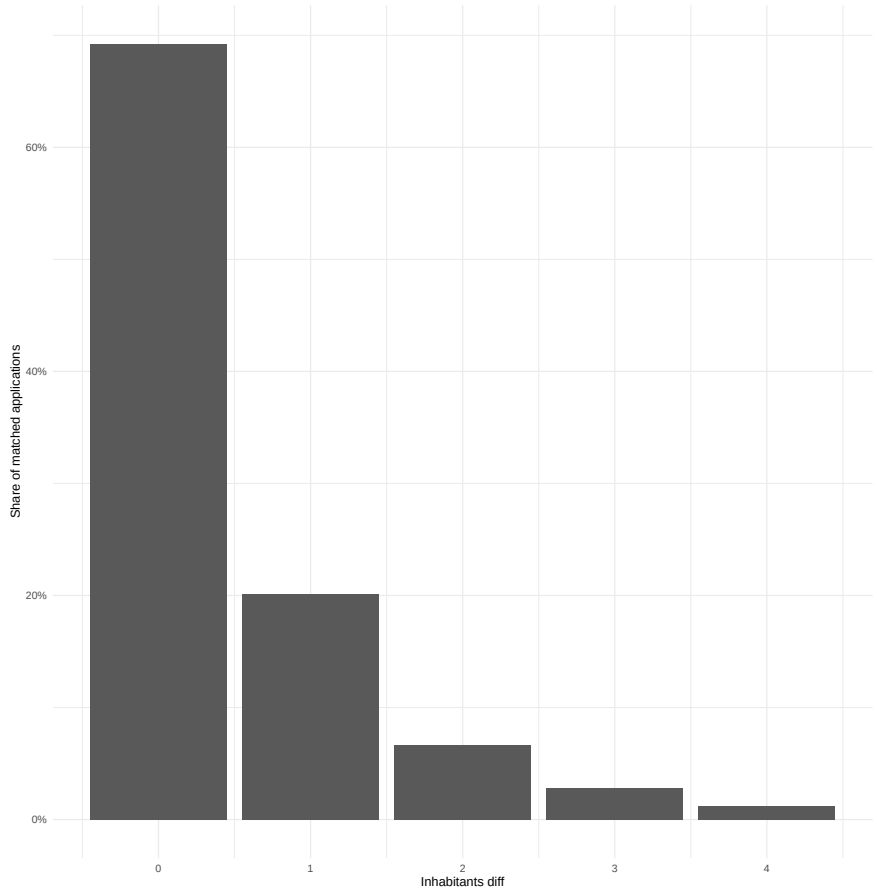


Figure 16: Distribution of difference in inhabitants between MPR applicant and matched housing (2021)



B Model of incidence for means-tested subsidies: proofs

Lemma 1. First-order condition of the profit maximization problem is the partial derivative of profit with respect to own price, evaluated at symmetric Bertrand-Nash price. We then differentiate it with respect to market price.

$$\begin{aligned}
\frac{\partial \pi_{jm}}{\partial p_j}(p) &= s_{jm}(p) + (p-c)\frac{\partial s_{jm}}{\partial p_j}(p) \\
\frac{d}{dp}\left[\frac{\partial \pi_{jm}}{\partial p_j}(p)\right] &= 2\frac{\partial s_{jm}}{\partial p_j}(p) + \frac{\partial s_{jm}}{\partial p_{-j}}(p) + (p-c)\left[\frac{\partial^2 s_{jm}}{\partial p_j^2}(p) + \frac{\partial^2 s_{jm}}{\partial p_j \partial p_{-j}}(p)\right] \\
&= 2\frac{\partial s_{jm}}{\partial p_j}(p) + \frac{\partial s_{jm}}{\partial p_{-j}}(p) + \frac{s_{jm}}{\frac{\partial s_{jm}}{\partial p_j}}\left[\frac{\partial^2 s_{jm}}{\partial p_j^2}(p) + \frac{\partial^2 s_{jm}}{\partial p_j \partial p_{-j}}(p)\right] \\
\frac{d}{dp}\left[\frac{\partial \pi_{jm}}{\partial p_j}(p)\right] < 0 &\iff \rho_m(p) < 2 + \left(\frac{1}{\theta_m(p)} - 1\right)
\end{aligned}$$

Noticing that conduct parameter $\theta_m(p) \in [0,1]$ yields the result. □

Proposition 1. Lerner index derived from first-order condition under uniform pricing considers a weighted average of weak- and strong market elasticities. It yields the following equivalence:

$$\begin{aligned}
\epsilon_w^{own}(\overline{p}) > \epsilon_s^{own} &\iff \frac{1}{\epsilon_w^{own}(\overline{p})} < \frac{\overline{p}-c}{\overline{p}} < \frac{1}{\epsilon_s^{own}(\overline{p})} \\
&\iff \frac{\partial \pi_{jw}}{\partial p_j}(p) < 0 < \frac{\partial \pi_{js}}{\partial p_j}(p)
\end{aligned}$$

Monotonicity of $\frac{\partial \pi_{jm}}{\partial p_j}(p), \forall m \in \{s,w\}$ from Lemma 1 yields the result. □

Lemma 2. Total differentiation of firms' first-order conditions with respect to t yields cost pass-through at any given level of t

$$\frac{\partial p}{\partial c}(t) = \frac{1}{1 + \theta_w(t)(1 - \rho_w(t))} > 0$$

Assumption 2 and 3 ensure that pass-through is positive. Integrating it between 0 and full subsidy (negative tax $-b$) yields the result. □

Proposition 2. The first term is the price discrimination effect: $p_s^* - p_w^*$. It is obtained using the Lerner index under discriminated pricing. The second term is total pass-through of the subsidy in the weak market derived in Lemma 2. □

Lemma 3. Profit maximization under constrained redistribution level t writes:

$$\pi_{1w}(p-t) + \pi_{1s}(p) = (p - t - c + b)s_{1w}(p-t) + (p-c)s_{1s}(p)$$

First-order condition can be written $F(\tilde{p}_s(t), t) = 0$. Applying the implicit function theorem to it and noticing that $\frac{\partial \tilde{p}_w}{\partial t} = \frac{\partial \tilde{p}_s}{\partial t} - 1$ yields:

$$\frac{\partial \tilde{p}_s}{\partial t} = \frac{-\frac{\partial F}{\partial t}}{\frac{\partial F}{\partial p}} = \frac{\pi_w''}{\pi_w'' + \pi_s''} > 0$$
$$\frac{\partial \tilde{p}_w}{\partial t} = -\frac{\pi_s''}{\pi_w'' + \pi_s''} < 0$$

Where we denote $\pi_m'' = \frac{d}{dp}\left[\frac{\partial \pi_{jm}}{\partial p_j}(p)\right] < 0$ from Lemma 1. □

Proposition 3. Let us denote t^* the optimal level of price differential between the weak and strong market. It is the one defined in Proposition 2. If $t^* < b$, uniform pricing can be seen as forcing t to go beyond t^*, thus increasing $\tilde{p}_s$ and decreasing $\tilde{p}_w$, from Lemma 3. The reverse is true for $t^* \geq b$. □

C Estimation: Demand model

Following Berry et al. (2004), the estimation of θ_2^d proceeds in two steps. First, for a given value of θ_2, a fixed point algorithm is used to concentrate out mean utilities $\delta(\theta_2)$. In a GMM estimation, $\delta(\theta_2)$ and θ_2 are used to compute predicted choice probabilities and targeted moments, that allow to recover $\hat{\theta}_2^d$ and $\hat{\delta}(\hat{\theta}_2^d)$. In a second step, $\hat{\theta}_1^d$ is estimated by two-stage least squares on estimated $\hat{\delta}(\hat{\theta}_2^d)$.

C.1 First step – Estimation of θ_2^d

Concentrating out mean utilities For a given value of θ_2, we search for the δ_{cm} vector in each income category-market that ensures that observed market shares equal predicted market shares for all groups of products:

$$\begin{aligned} & s_{cm}^d = s_{cm}(\delta_{cm}, \theta_2) \\ \iff & \delta_{cm} = s_{cm}^{-1}(s_{cm}^d, \theta_2) \end{aligned}$$

Berry et al. (1995) shows that this vector is unique and that the following fixed point algorithm converges towards this unique $\hat{\delta}(\theta_2)$:

1. Initialize $\delta^0 = \log(s^d) - \log(s_0)$.
2. Compute predicted shares $\hat{s}(\delta^{(t)})$.
3. Update $\delta^{(t+1)} = \delta^{(t)} + \log(s^d) - \log(\hat{s}(\delta^{(t)}))$.
4. Repeat until convergence.

In practice, to avoid logs for computational reasons and following Nevo (n.d.), we iterate over $\tilde{\delta}^{(t)} = \exp(\delta^{(t)})$, so that $\tilde{\delta}^{(t+1)} = \tilde{\delta}^{(t)} \circ s^d \oslash \hat{s}(\delta^{(t)})$. Convergence is obtained when $\frac{\|\tilde{\delta}^{(t+1)} - \tilde{\delta}^{(t)}\|}{\|\tilde{\delta}^{(t)}\|} \leq 10^{-10}$.

Method of moments estimator To estimate $\hat{\theta_2}^d$, we consider $R+2$ moments corresponding to the differences between the observed and predicted correlations between individual characteristics and product characteristics. Theoretical moments are of the type:

$$h(w_i, \theta_2^d) = \sum_j \jmath^d(\theta_2^d) z_{ij} - z_{ij(i)}$$

where z_{ij} corresponds to a $(R+2, 1)$ vector of individual-product characteristics. Orthogonality condition is given by $\mathbb{E}[h(w_i, \theta_2^d)] = 0$ and sample analogs are given by:

$$\begin{cases} h_1^M & = \frac{1}{N} \sum_{m=1}^{M} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\jmath_{igm} - \mathbb{1}_{igm}) \log(p_{c(i)jm}) \cdot I_i \\ h_{r+1}^M & = \frac{1}{N} \sum_{m=1}^{m} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\jmath_{igm} - \mathbb{1}_{igm}) y_i^r, \forall r \in [1, ..., R] \\ h_{R+2}^M & = \frac{1}{N} \sum_{m=1}^{m} \sum_{i=1}^{n_m} \sum_{g=1}^{G_m} (\jmath_{igm} - \mathbb{1}_{igm}) d_{igm} \end{cases}$$

where $N = \sum_m n_m = \sum_c \sum_m n_{cm}$ is the total number of individuals. We define $h(\delta(\theta_2), \theta_2)) = \frac{1}{N} Z^T \xi$ the vector made of these sample micro-moments, where $Z \in \mathbb{R}^{N^{full} \times (R+2)}$ matrix of individual-product covariates and $\xi \in \mathbb{R}^{N^{full} \times 1}$ is the matrix of choice residuals $\jmath_{igm}, \forall m, g \in [1...G_m], i \in [1, ..., n_m]$. Our method of moments estimator therefore minimizes:

$$\hat{\theta}_2^d = \arg\min_{\theta_2} F = \frac{1}{N^2} \xi^T Z Z^T \xi \tag{24}$$

In practice, we solve for this minimization problem using the non-linear programming solver "fminunc" on Matlab, using a trust-region algorithm with objective gradient. Number of iterations is limited to 30, step tolerance is set to 10^{-6} and termination tolerance on the function value to 10^{-14}.

Analytical gradient Gradient of F is given by $\frac{\partial F}{\partial \theta_2} = \frac{2}{N^2} \frac{\partial \xi}{\partial \theta_2}^T Z Z^T \xi$, where $\frac{\partial \xi}{\partial \theta_2}$ is the $\mathbb{R}^{N^{full} \times (R+2)}$ matrix of derivative of predicted probabilities with respect to demand parameters:

$$\frac{d\mathcal{s}_{igm}}{d\theta_{2,k}} = \frac{\partial \mathcal{s}_{igm}}{\partial \theta_{2,k}} + \sum_{g'=1}^{G_m} \frac{\partial \mathcal{s}_{igm}}{\partial \delta_{g'm}} \frac{\partial \delta_{g'm}}{\partial \theta_{2,k}}$$

We denote by $D^s_{\theta_2}$ the $\mathbb{R}^{N^{full} \times (R+2)}$ matrix of partial derivatives of predicted choice probabilities with respect to demand parameters:

$$\frac{\partial \mathcal{s}_{igm}}{\partial \theta_{2,k}} = \mathcal{s}_{igm}(z^k_{igm} - \sum_{g'=1}^{G_m} z^k_{ig'm} \mathcal{s}_{ig'm})$$

D^s_{δ}, the $\mathbb{R}^{N^{full} \times (3G)}$ matrix of derivatives of choice probabilities with respect to δ is a block-diagonal matrix given by:

$$\frac{\partial \mathcal{s}_{igm}}{\partial \delta_{cg'm'}} = \begin{cases} 0 & \text{if } m \neq m' \text{ or } c(i) \neq c \\ \mathcal{s}_{igm}(1 - \mathcal{s}_{igm}) & \text{else if } g = g' \\ -\mathcal{s}_{igm}(\mathcal{s}_{ig'm}) & \text{otherwise.} \end{cases}$$

Nevo (n.d.) notes, from implicit function theorem, that the $\mathbb{R}^{(3G) \times (R+2)}$ matrix of derivative of δ with respect to θ_2 has an analytical form given by:

$$D^{\delta}_{\theta_2} = -(D^{\bar{\mathcal{s}}}_{\delta})^{-1} D^{\bar{\mathcal{s}}}_{\theta_2}$$

where $D^{\bar{\mathcal{s}}}_{\delta} \in \mathbb{R}^{(3G) \times (3G)}$ is the matrix of mean derivative of choice probabilities with respect to δ:

$$\frac{\partial s_{cgm}}{\partial \delta_{c'g'm'}} = \begin{cases} 0 & \text{if } m \neq m' \text{ or } c \neq c' \\ \frac{1}{n_{cm}} \sum_{i,c(i)=c} s_{igm}(1 - s_{igm}) & \text{else if } g = g' \\ \frac{1}{n_{cm}} \sum_{i,c(i)=c} -s_{igm} s_{ig'm} & \text{otherwise.} \end{cases}$$

and $D^{\bar{s}}_{\theta_2} \in \mathbb{R}^{(3G)\times(R+2)}$, the matrix of mean derivative of choice probabilities with respect to θ_2:

$$\frac{\partial s_{cgm}}{\partial \delta_{c'g'm'}} = \begin{cases} 0 & \text{if } m \neq m' \text{ or } c \neq c' \\ \frac{1}{n_{cm}} \sum_{i,c(i)=c} s_{igm}(1 - s_{igm}) & \text{else if } g = g' \\ \frac{1}{n_{cm}} \sum_{i,c(i)=c} -s_{igm} s_{ig'm} & \text{otherwise.} \end{cases}$$

The gradient of the objective function is therefore given by:

$$\frac{\partial F}{\partial \theta_2} = \frac{2}{N^2}(D^s_{\theta_2} - D^s_{\delta}(D^{\bar{s}}_{\delta})^{-1} D^{\bar{s}}_{\theta_2})^T Z Z^T \xi$$

Note that the only change in the way the gradient is computed, compared to Nevo (n.d.) relates to the presence of price discrimination: choice probabilities s_{igm} are independent of $\delta_{cg'm}$ as soon as $c(i) \neq c$. We therefore aggregate derivative of choice probabilities at the market-income category level, which amounts to considering separate income categories as separate sub-markets in the estimation of the model. This will however not be the case anymore in simulations of counterfactuals without price discrimination.

C.2 Second step – Estimation of θ_1^d

The first step defines $\hat{\theta}_2^d$ and related $\hat{\delta}(\hat{\theta}_2^d)$. Mean utilities δ satisfy a linear regression equation of the form:

$$\delta_{cjm} = \gamma + \zeta_{e(j)} + \psi_m + \sum_{k=1}^{K} \beta^k x_{jm}^k + \beta_p^0 \log(p_{cjm}) + \chi_{cjm}$$

which we write as $\delta = X\theta_1^d + \chi$, where X is made of product characteristics, including intercept-, efficiency- and market dummies, θ_1^d. Identification problem is that price is clearly endogenous and may be correlated with residual χ. We deal with this challenge by two-stage least square estimation. Denoting by Z_{IV} the set of instruments, including exogenous covariates – all demand characteristics except for price – the two-stage least square estimator for θ_1^d is given:

$$\hat{\theta}_1^d = [X' P_Z X]^{-1} [X' P_Z \delta]$$
$$P_Z = Z_{IV} (Z_{IV} Z_{IV}')^{-1} Z_{IV}'$$

C.3 Consistency and inference

The two-step procedure can be considered as a larger GMM estimation, stacking three types of targeted moments: $M + K + 2$ aggregate moments from the two-stage least square estimation of θ_1^d, of the type $\mathbb{E}[Z_{IV}\chi] = 0$ for each instrument, where $\xi = \delta - X\theta_1^d$, $R + 2$ micro moments from the first step of the estimation, and moments targeting aggregate market shares. This last set of moments is by definition equal to 0, whatever the value of $\theta = [\theta_1, \theta_2]$. It will therefore not intervene in the gradient of the objective function or in standard errors of estimated parameters.

Following Berry et al. (2004), consistency is obtained as long as $N \to \infty$. For inference, we stack the sample analogs of the first two set of samples into $h(\theta_1, \theta_2) = \begin{bmatrix} h^A(\theta_1, \delta(\theta_2)) \\ h^M(\theta_2, \delta(\theta_2)) \end{bmatrix}$. The two-step procedure therefore minimizes $h'Wh$, with weighting matrix $W = I$ in our case.

Newey and McFADDEN (n.d.) states that under *iid* observations across households, and provided (i) θ^d is in the interior of Θ which is compact, (ii) $\hat{h}$ is continuously differentiable in a neighborhood $\mathcal{N}$ of θ^d, (iii) $\mathbb{E}[h(\theta^d)] = 0$ and $\mathbb{E}[\|h(\theta^d)\|^2]$ is finite, (iv) $\mathbb{E}[\sup_{\theta \in \mathcal{N}} \|\nabla h(\theta)\|] < \infty$, (v) $H^T W H$ is non-singular where $H = \mathbb{E}[\nabla h(\theta^d)]$, then:

$$\sqrt{3G}(\hat{\theta} - \theta^d) \xrightarrow{d} N(0, (H^T W H)^{-1} H^T W \Omega W H (H^T W H)^{-1})$$

where $3G$ the number of aggregate observations (groups of products) across submarkets (markets-income categories), and $\Omega = \mathbb{E}[h'(\theta^d)h(\theta^d)]$ is the variance matrix of the vector of moments. Conlon and Gortmaker (2024) provides several thought experiments to derive Ω in the case of combined micro and macro moments. We consider the case where the number of submarkets $3M \to \infty$ and is equal to the number of markets for which we have micro data. In that case, Ω can be written as a block-diagonal matrix:

$$\Omega = \begin{bmatrix} \Omega^A & 0 \\ 0 & \Omega^M \end{bmatrix}$$

Non-diagonal blocks are zero: since micro data is generated conditional on aggregate data, Conlon and Gortmaker (2024) consider zero covariance between aggregate and micro moments. Ω^A is the $\mathbb{R}^{(M+K+2)\times(M+K+2)}$covariance matrix of aggregate moments:

$$\Omega^A_{pq} = \mathbb{E}[G_m] \cdot \mathbb{E}[1/G_m] \cdot \frac{1}{3G} \sum_{cgm} \chi^2_{cgm} z^p_{iv,cgm} z^q_{iv,cgm}$$

Ω^M is the $\mathbb{R}^{(R+2)\times(R+2)}$covariance matrix of micro moments:

$$\hat{\Omega}^M_{pq} = \mathbb{E}[G_m] \cdot \mathbb{E}[1/n_{cm}] \cdot \frac{1}{N} \sum_{igm} s_{igm}(s_{igm} - \mathbb{1}_{igm})^2 z^p_{igm} z^q_{igm}$$

Finally, the gradient of stacked moments with respect to θ_1 and θ_2, H, is given by:

$$H = \begin{bmatrix} H^A_{\theta_1} & H^A_{\theta_2} \\ 0 & H^M_{\theta_2} \end{bmatrix}$$

Note that the micro moments are not a function of θ_1. Bottom-left block of H is therefore null. The derivative of micro moments with respect to θ_2 was obtained above as $H^M_{\theta_2} = \frac{1}{N} Z^T \frac{d\xi}{d\theta_2}$. Derivative of aggregate moments with respect to θ_1 is $H^A_{\theta_1} = \frac{1}{3G} Z^T_{IV} \frac{d\chi}{d\theta_1} = -\frac{1}{3G} Z^T_{IV} X_{IV}$. Finally, note that aggregate moments are a function of θ_2 through δ. $H^A_{\theta_2}$ is therefore given by:

$$\begin{aligned} H^A_{\theta_2} &= \frac{1}{3G} Z^T_{IV} \frac{d\chi}{d\theta_2} \\ &= \frac{1}{3G} Z^T_{IV} \frac{\partial \delta}{\partial \theta_2} \\ &= -\frac{1}{3G} Z^T_{IV} (D^{\bar{\jmath}}_{\delta})^{-1} D^{\bar{\jmath}}_{\theta_2} \end{aligned}$$

D Estimation: Counterfactuals

With price discrimination In scenarios where price discrimination is allowed, firms implicitly fix consumer prices for each income category and product $p_{cjm} = q_{cjm}(1-\tau) - b_c$, where $b_c > 0$ is the subsidy level for income category c, q_{cjm} is the pre-subsidy price and $\tau > 0$ is the tax credit rate. Each firm optimizes profit with respect to prices of its single or two products:

$$\pi_{fm} = \sum_{j \in \mathcal{G}_{fm}} \sum_{c=1}^{3} (\frac{p_{cjm} + b_c}{1-\tau} - mc_{jm}) \mathcal{s}_{cjm}(p_m) \tag{25}$$

First-order conditions are of the form:

$$FOC_{cjm} : \frac{\partial \pi_{fm}}{\partial p_{cjm}} = \frac{\mathcal{s}_{cjm}}{1-\tau} + \sum_{j' \in \mathcal{G}_{fm}} \frac{\partial \mathcal{s}_{cj'm}}{\partial p_{cjm}} (\frac{p_{cj'm} + b_c}{1-\tau} - mc_{j'm}) = 0 \tag{26}$$

This yields the following system of $3J$ first-order conditions:

$$S + \Delta(P + B - (1-\tau) \cdot T \cdot C) = 0$$

Note that S and Δ are also a non-linear function of P so that there is no closed-form solution to this system of $3J$ equations. To solve for equilibrium prices, we instead adopt the following fixed point algorithm:

1. Initialize $P^{(0)} = P^{baseline}$.
2. For each iteration t, compute individual choice probabilities, resulting aggregate market shares $S(P^{(t)})$ and matrix of derivatives with respect to prices $\Delta(P^{(t)})$ using this price vector.
3. Update $P^{(t+1)} = -B + (1-\tau) \cdot T \cdot C - \Delta(P^{(t)})^{-1} \cdot S(P^{(t)})$.
4. Repeat until convergence.

Without price discrimination When firms are not allowed to price discriminate, firms fix a set of J pre-subsidy prices $q_{jm} = \frac{p_{cjm}+b_c}{1-\tau}$. Note that consumer prices are still income category-specific, since subsidies also are in the general case. Each firm optimizes the sum of profit across income categories with respect to these pre-subsidy prices:

$$\pi_{fm} = \sum_{j \in \mathcal{J}_{fm}} (q_{jm} - mc_{jm}) \sum_{c=1}^{3} s_{cjm}(q_m, b_c, \tau) \tag{27}$$

First-order conditions are of the form:

$$FOC_{jm} : \sum_{c=1}^{3} s_{cjm}(q_m, b_c, \tau) + \sum_{j' \in \mathcal{J}_{fm}} (q_{j'm} - mc_{j'm}) \sum_{c=1}^{3} \frac{\partial s_{cj'm}}{\partial q_{jm}} = 0 \tag{28}$$

This yields the following system of J first-order conditions:

$$\tilde{S} + \tilde{\Delta}(Q - C) = 0$$

where $\tilde{S} \in \mathbb{R}^{J \times 1}$ and $\tilde{\Delta} \in \mathbb{R}^{J \times J}$ are respectively the matrix of aggregate market shares across income categories $s_{jm} = \sum_c s_{cjm}$ and derivative of these aggregate market shares with respect to prices:

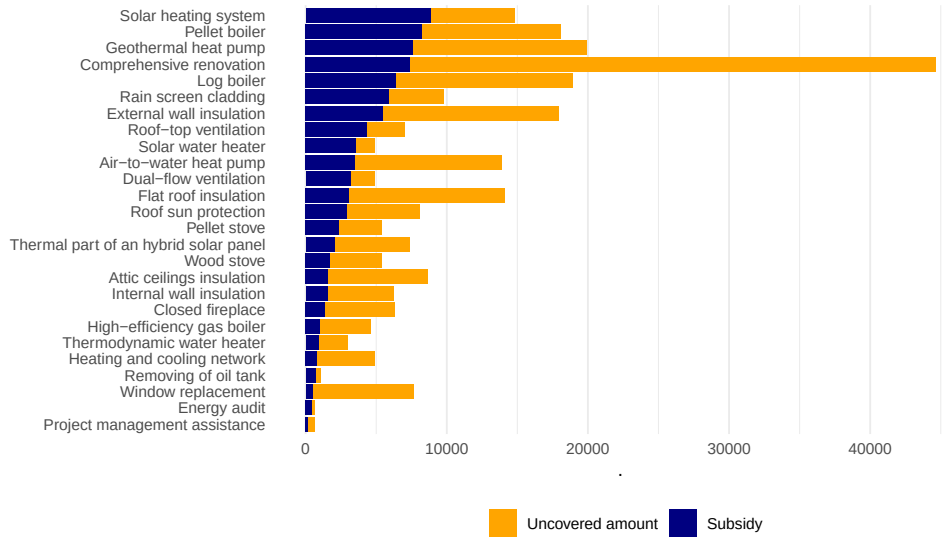
$$\begin{aligned} \frac{\partial s_{jm}}{\partial q_{j'm'}} &= \sum_c \frac{\partial s_{cjm}}{\partial q_{j'm'}} \\ &= \sum_c \frac{\partial s_{cjm}}{\partial p_{cj'm'}} \frac{\partial p_{cj'm'}}{\partial q_{j'm'}} \\ &= (1-\tau) \sum_c \frac{\partial s_{cjm}}{\partial p_{cj'm'}} \end{aligned}$$

Again, $\tilde{S}$ and $\tilde{\Delta}$ are non-linear functions of Q so that there is no closed-form solution to this system of J equations. We therefore estimate Q and resulting P from the following fixed point

algorithm:

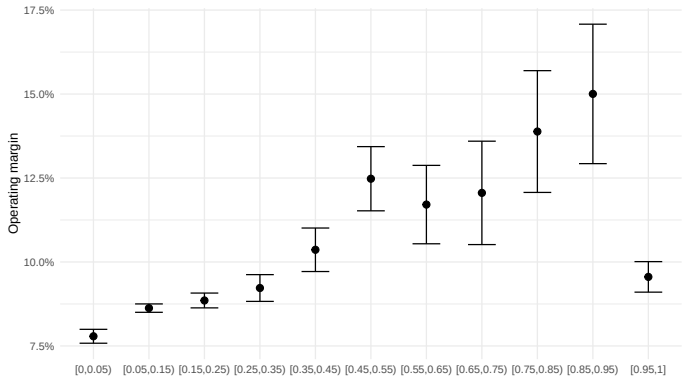
1. Initialize $Q^{(0)} = Q^{baseline}$, where $Q_{jm}^{baseline} = \frac{\sum_c \vartheta_{cjm} q_{cjm}^{baseline}}{\sum_c \vartheta_{cjm}}$.
2. For each iteration t, compute consumer prices, individual choice probabilities, resulting aggregate market shares, $\tilde{S}(Q^{(t)})$ and $\tilde{\Delta}(Q^{(t)})$ from price vector $Q^{(t)}$.
3. Update $Q^{(t+1)} = -\tilde{\Delta}(Q^{(t)})^{-1}\tilde{S}(Q^{(t)}) + C$.
4. Repeat until convergence.

Figure 17: Average subsidy and total renovation works costs, per renovation step



Note : This figure presents the average MPR subsidy amount (blue), and uncovered amount (blue), for each of the 26 retrofit actions covered by the scheme. These two amounts sum up to average total cost of a given renovation step. Sample is made of one observation per retrofit action, for all MPR files from 2020 to first quarter of 2024.
Source :

Figure 18: Operating margin of RGE firms, as a function of local market's concentration, 2021



Note : This figure presents the result of the regression of operating margin of active RGE firms on the concentration of their local market. An active RGE company is a company that has been certified for at least one kind of retrofit actions during the year and was selected by at least one household to perform an MPR work. Concentration is defined at the household level using the Herfindahl-Hirschmann Index of active companies present in a 50km radius around the housing. Households with no firms at less than 50km are attributed a HHI of 1. HHI at the firm level is defined as the average HHI of households that opted for the company.

E Additional Figures

E.1 Heat pump market description

Figure 19: Take-up CITE and MPR by income bracket

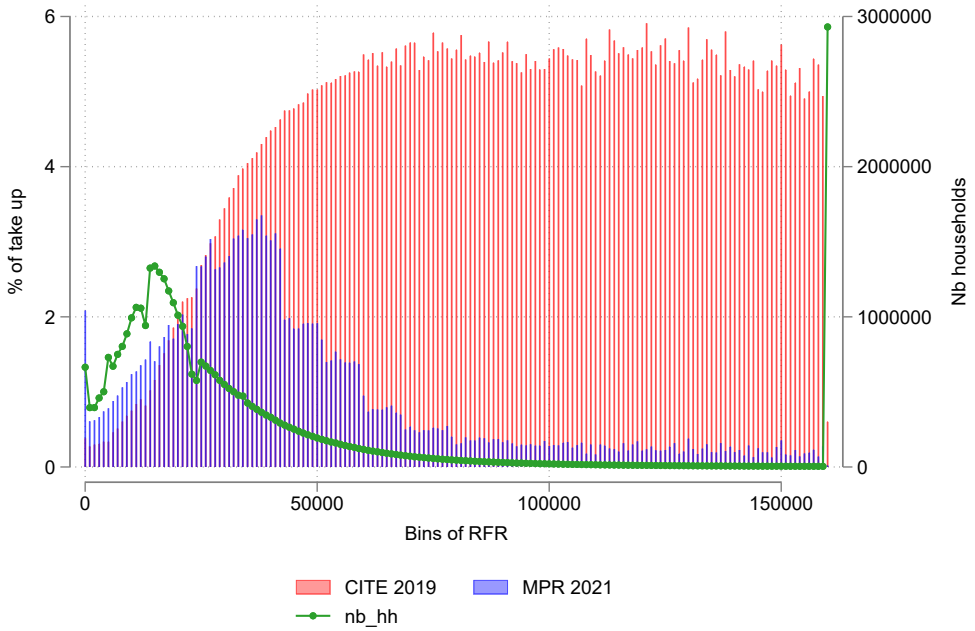
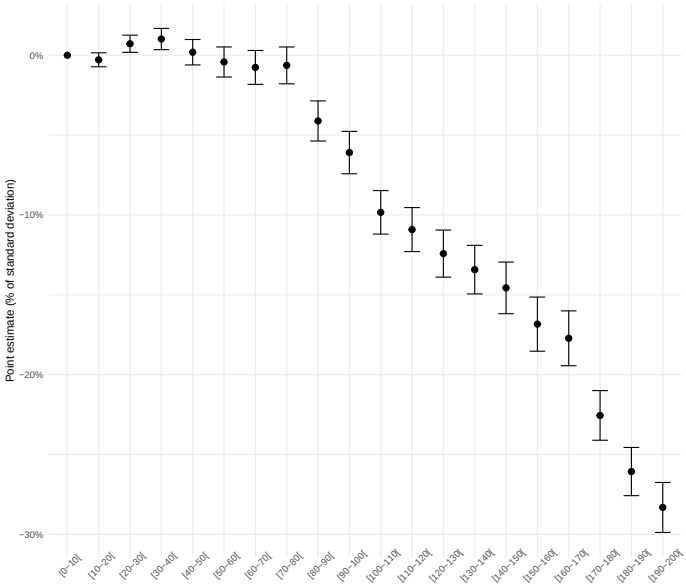
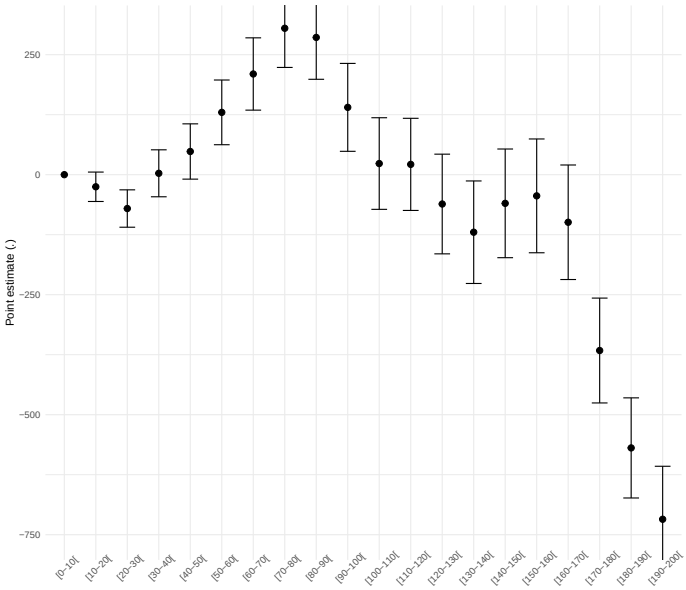


Figure 20: Investment producer price, by distance to the chosen company

(a) All MPR actions



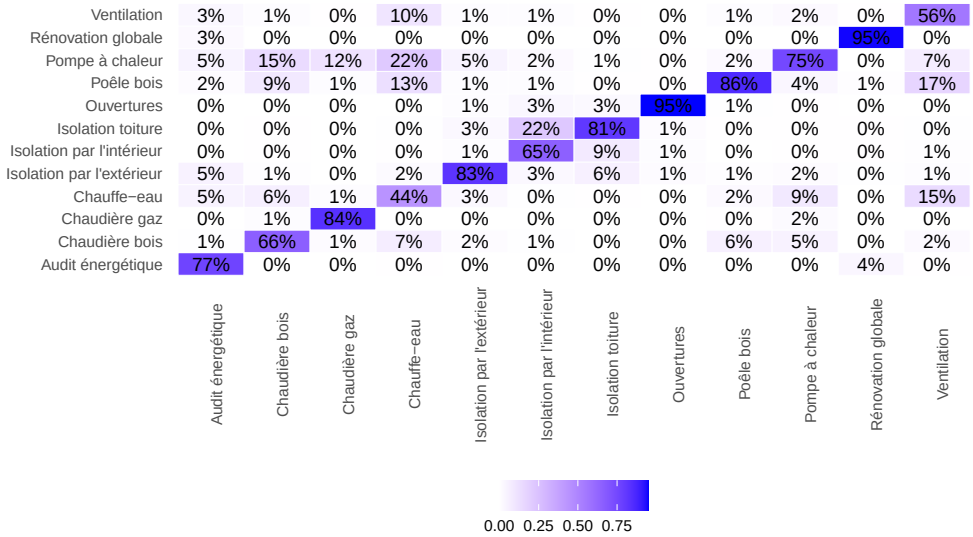
(b) Heat pumps



Note : This figure presents correlation between total price of observed MPR actions and bins of distance to the chosen company. In Figure 20, the sample is made of all MPR actions, and prices are normalized within actions. Estimated differentials are in percents of a standard deviation within a given retrofit action type. In Figure 20, the sample is made of heat pump MPR actions and point estimates are in euros. In both figures, regression controls for HHI of the local market, date of the contract, housing characteristics (surface, number of rooms, individual housing, owner-occupier fixed effects), department fixed effect.

Lecture : Equilibrium prices are 0.3 standard deviation lower when chosen company is 200km away from the household versus at less than 10km. Lower price suggests the presence of non-monetary search costs that need to be compensated for. For heat pumps in Figure 20b, price differential reaches 750€, *i.e.* 6% of average heat pump MPR total price.

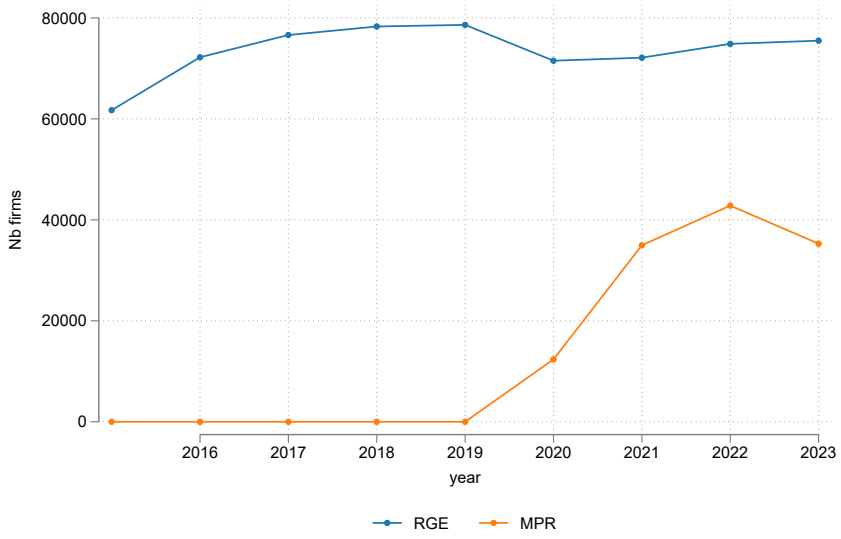
Figure 21: Distribution of MPR activity across cluster for RGE companies, by main cluster



Note : This figure presents the distribution of MPR turnover across the 11 clusters of MPR-eligible actions. X-axis corresponds to the main cluster of a given RGE firm (the one in which MPR turnover is highest. On the y-axis, each square corresponds to the average share of total MPR activity in a given cluster. Shares therefore sum up to 1 in each column. Sample is made of all RGE companies active in the MPR market in 2022. The color of the square is proportional to the share.

Source :

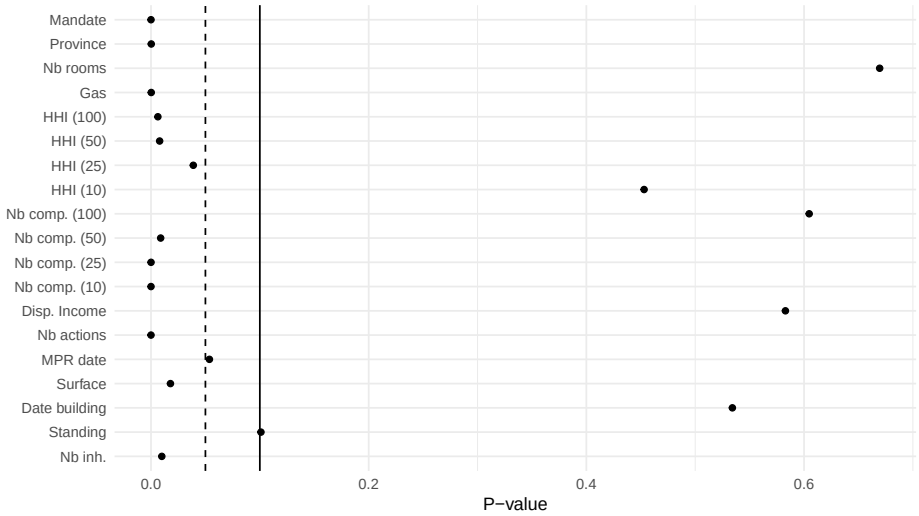
Figure 22: Number of RGE firms overtime (overall and active in the MPR market)



Note : This figure presents the number of firms with at least one RGE certification, by year between 2015 (RGE certificate creation) and 2023 (blue line). The number of said firms that performed at least one retrofit action subsidized by the MPR subsidy is indicated by the orange line.

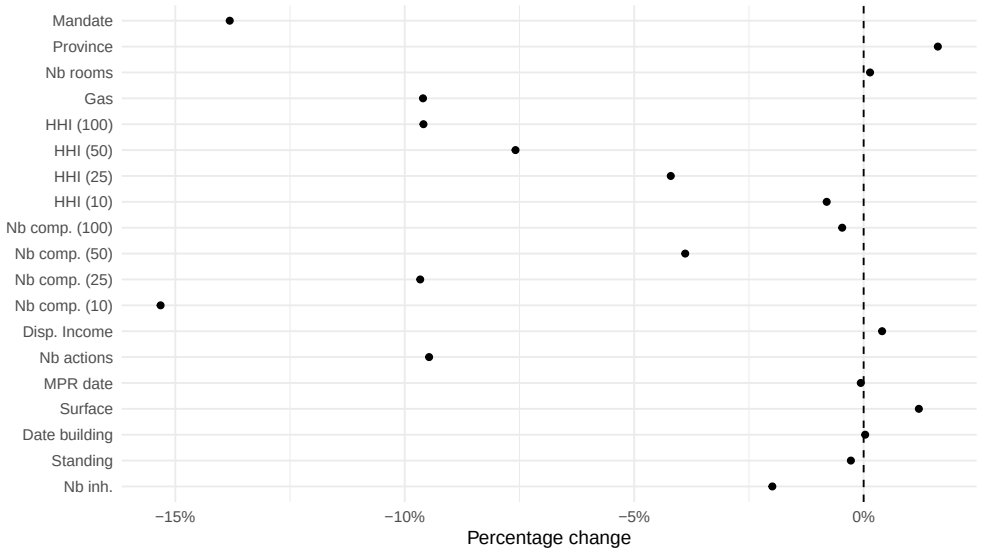
E.2 Identifying price discrimination: robustness

Figure 23: Pseudo RDD - p values of point estimates



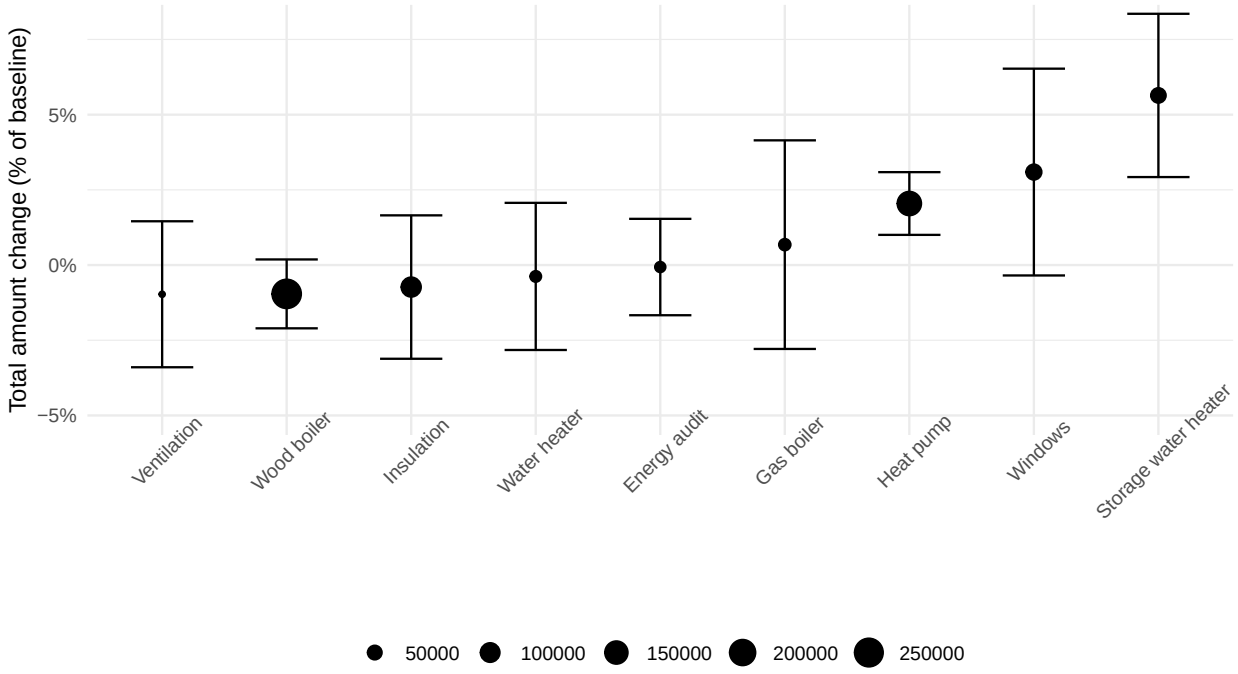
Note : This figure presents the p-value of RDD point estimates, on a set of pseudo-outcome variables, at the MPR income thresholds. Estimation sample is made of observations at less than €2.000 of the discontinuity. Income threshold is normalized to zero. Estimates are estimated non-parametrically, following Calonico et al. (2014).

Figure 24: Pseudo RDD - point estimate as % of baseline



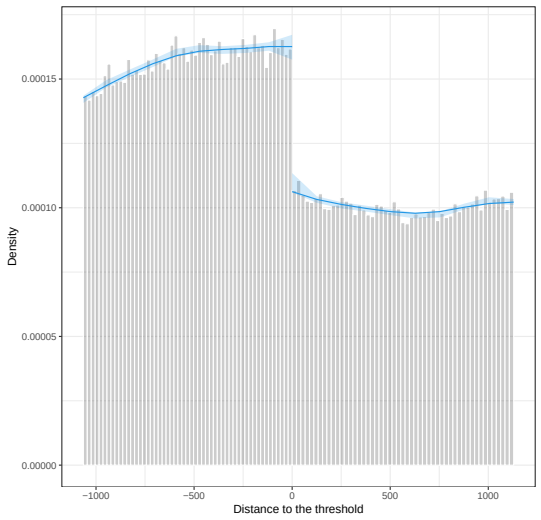
Note : This figure presents the RDD point estimates, on a set of pseudo-outcome variables, at the MPR income thresholds, as a percentage of baseline value (on the left of the threshold. Estimation sample is made of observations at less than €2.000 of the discontinuity. Income threshold is normalized to zero. Estimates are estimated non-parametrically, following Calonico et al. (2014).

Figure 25: RDD result – total price differential at MPR thresholds, all investment types

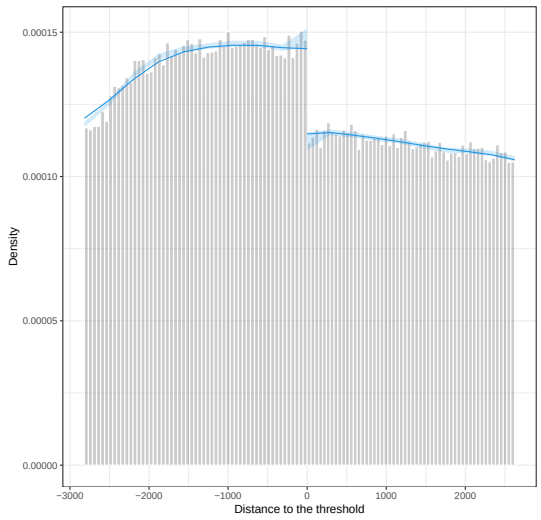


Note : This figure presents the estimated normalized producer price differential at income thresholds, estimated by naive RDD, by investment type. For better comparison, RD estimates are displayed as percentage of baseline (average total cost on the left of the threshold). Sample is made of all observations at less than €2.000 of a given threshold – one observation by MPR file-investment. Clusters are ranked in increasing order of estimated coefficients.

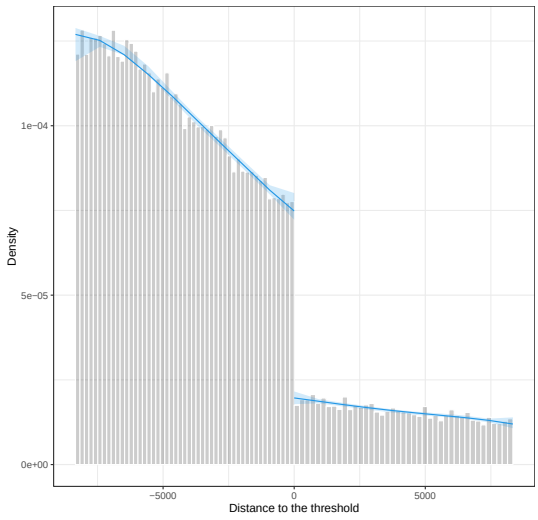
Figure 26: Density of MPR files, by distance to the income discontinuity threshold, by income threshold



(a) TMO-MO



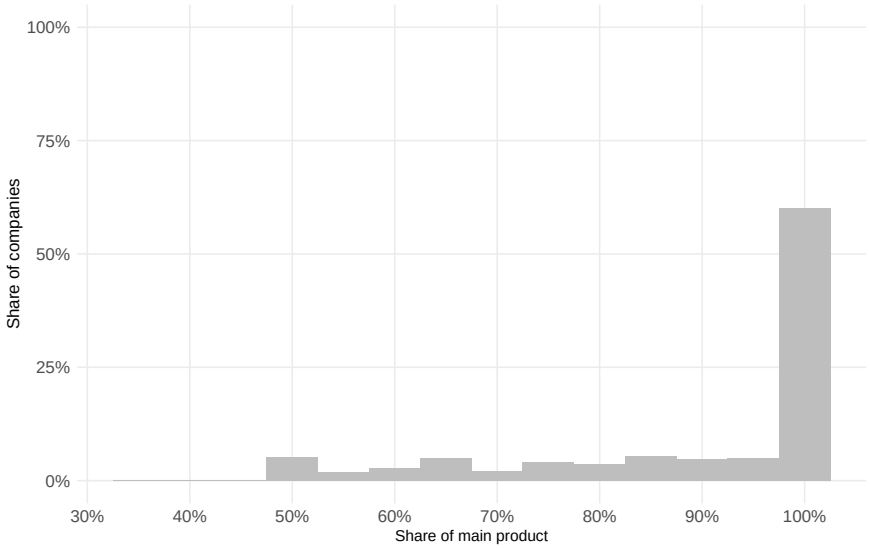
(b) MO-INT



(c) INT-SUP

Note : This figure presents the observed density of MPR files by distance to the income threshold, for each of the three income thresholds. The sample for estimation pools all observations at less than 2.000€of one of the 61 selected discontinuities. Income threshold is normalized to zero. Differential in discontinuity at the threshold is interpreted as a differential in take-up.

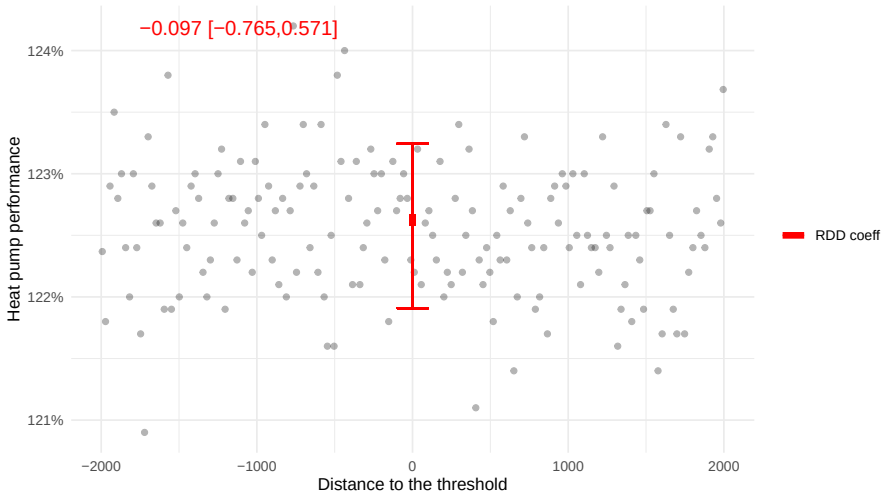
Figure 27: Distribution of share of main quality level in total heat pump activity



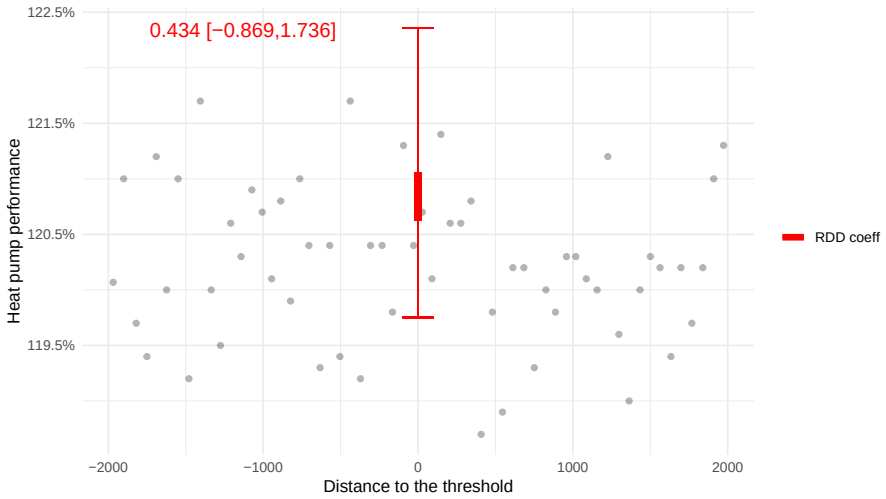
Note : For each active RGE firm in the sector of heat pumps, we compute the share of activity (number of MPR-CEE files) by coefficient of performance – quality – level. The distribution of this share for the main quality level is then computed across all firms.

Figure 28: RD results – coefficient of performance

(a) Firms with at least two qualities



(b) Firms with at $>$ 25% of activity in other quality



Note : This figure presents the RD coefficient on coefficient of performance of heat pumps, using two different sample selections. In the first panel, files are selected if related firms have performed installation of at least to quality levels of heat pumps. In the second panel, other quality levels (other than main one) need to represent at least 25% of all files of the firm.