On the added value of utility-sponsored energy efficiency subsidies: Insights from the French White Certificates program, Phase III*

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Abstract

Since 2006, French energy suppliers provide subsidies for home energy retrofits to comply with an energy efficiency, or "White Certificate," obligation. The alleged advantage of utility-sponsored programs, compared to the public counterparts with which they often overlap, is in leveraging the private information energy suppliers may possess about energy efficiency potentials, allowing them to save energy more cost-effectively. We challenge this hypothesis and assess the value private funding adds to public funding. In a regression discontinuity design, we exploit two geographical discontinuities in subsidy amounts that prevailed during the third phase of the program (2015-2017). Comparing outcomes across the high- versus middle-subsidy border, we find that a 1% increase in subsidy amounts induced a 1.16% higher take-up. The effect only holds in three out of eight specifications, however. We moreover fail to identify a significant elasticity across the middle- versus low-subsidy border. In subsample regressions, we find that take-up was strong for insulation measures, which rank first in the cost-effectiveness merit order. These results together imply that the program's third phase was effective qualitatively, but not quantitatively. This suggests that energy suppliers could fulfill their obligation by merely free riding on overlapping programs – a mechanism we confirm in complementary microsimulations.

1 Introduction

Improving the energy efficiency of residential buildings is a priority for public policy, owing to the multiple benefits it entails – CO_2 emissions reductions, fuel poverty alleviation, improved energy security, and, as is increasingly noted, reduced exposure to cold-related illness (Dervaux et al., 2022; Roberdel et al., 2025). In high-income countries, these benefits have primarily been sought after through subsidy programs for home energy retrofits (Kerr and Winskel, 2020). Subsidies are indeed an adequate tool to address at once several market and behavioral frictions hindering energy efficiency investment – the climate change externality, credit constraints, the landlord-tenant dilemma, coordination failures in multi-family housing, and present bias (Vivier and Giraudet, 2024). In addition, subsidies tend to receive stronger political support from both consumers and the renovation industry than does pricing CO_2, the textbook remedy to the climate change externality (van der Ploeg, 2025).

While most energy efficiency subsidy programs are publicly funded, they coexist in many countries with utility-sponsored programs. The International Energy Agency (IEA) has recorded 143 national government spending programs on energy-efficient building as of 2025 and 49 utility-funded energy efficiency programs in 24 countries as of 2020.[1] Utility-funded programs usually derive from an energy efficiency obligation imposed

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[1] Sources: IEA's Policies Database, as of February 6, 2025, and (IEA, 2020)

on energy suppliers (thus referred to as the "obligated parties"), known in Europe as White Certificate programs (Bertoldi et al., 2010; Giraudet and Finon, 2015; Rosenow et al., 2019). Just like publicly-funded programs are ultimately paid by households as taxpayers, utility-sponsored ones are paid by ratepayers, for utilities are allowed to pass-through compliance costs onto their retail prices. The rationale for adding utility funding to the public policy portfolio is twofold. On allocative grounds, it is expected to leverage the private information energy suppliers may possess about end-use patterns, which allows them to identify energy saving opportunities most cost-effectively. On more practical grounds, leveraging private money makes utility-sponsored programs highly palatable to budget-constrained governments.

France is perhaps where public and private funding for home energy retrofits have been most deeply intertwined, with questionable results. Public funding has been deployed gradually with VAT reductions in 1999, tax credits in 2005, zero-interest loans in 2009 and low-income subsidies in 2010. Meanwhile, a white certificate program called *Certificats d'économies d'énergie* (CEE) was introduced in 2006. The obligation ever since has primarily been fulfilled through subsidies for home energy retrofits. Importantly, the CEE subsidies target the same measures as do the other programs, and all can be claimed together to support the same investment. This creates room for energy suppliers to free ride on public spending. Indeed, the CEE program places an obligation on ends, not means. Energy suppliers only have to collect invoices as proofs of supporting a measure, without having to report on the amount paid to the beneficiary. An upper bound of this amount is nevertheless provided by the market price of certified energy savings (the so-called "white certificates"), which can be traded among obligated parties. Interviews with stakeholders have revealed that obligated parties managed to fulfill their obligation during the first phase of the program (2006-2009) by merely advertising for the tax credit program, leading to a low compliance cost of €4 per lifetime discounted megawatthour saved (MWh_{LD}) (Giraudet et al., 2012). Notwithstanding the limitations of the approach, these results give little support for the information leverage hypothesis, thus challenging the added value of private funding. The first phase, however, was meant to be experimental. Since then, the obligation has been tightened every three or four years. Meanwhile, funding increased to the point that, now in Phase V, the program involved €3 billion in 2023 – just as much as the amount the government spent on overlapping programs that year.

Did the CEE program become more additional past this experimental phase? Specifically, did it trigger additional investment, and one that qualitatively differs from that induced by the presumably less well-targeted government stimulus? To answer this question, we focus on the third phase of the program, spanning from 2015 to 2017. This period uniquely features an exogenous variation in subsidy amounts which we can exploit in a regression discontinuity design (RDD). This window of opportunity is delineated by the lack of publicly available data prior to 2015 and new provisions undermining the discontinuity from 2018. During this period, the CEE subsidies remained low compared to their public counterparts owing to a white certificate price at its lowest, in turn due to a target that was arguably little stringent. Our focus on Phase III is therefore demanding in terms of identifying additionality.

The discontinuity we are interesed in is geographical. Generally speaking, each measure eligible to the program is entitled certified energy savings based on ex ante engineering calculations. Albeit undisclosed, subsidy amounts can be backed up by multiplying the certified savings (in MWh_{LD}) by the market price of white certificates (in €/MWh_{LD}), supposed to reflect marginal compliance cost. Crucially for our analysis, certified savings are differentiated across three climate zones partitioning France's mainland territory – H1, the coldest zone, H2, of intermediate climate, and H3, the warmest. An investment undertaken in the warmer zone will thus be eligible to a larger subsidy than one undertaken in a neighboring city from a colder zone, despite their shared climate making their profitability similar. These climate zones are separated by two borders, which can be exploited in RDD under reasonable assumptions.

In our preferred specification grouping municipalities in 5-km bins within a 55 km bandwidth, we find a 25% increase in the number of subsidies taken in H1 compared to H2, statistically significant at the 10% level. Given the 22% higher incentive offered in zone H1 on average, this estimate yields a 1.16 elasticity of take-up with respect to subsidy amounts. The effect does not survive, however, in alternate specifications involving different geographical controls, bandwidth and binwidth, and imputation procedures for missing data. Meanwhile, we fail to detect a statistically significant effect in any of the four specifications at the H2-H3 border, despite a bigger incentive differential there (+47% in H2). Looking at individual measures separately, we find substantial heterogeneity. Attic and roof insulation, the most common measures with approximately 30% of total take-up, entail significantly higher take-up in H2 than in H3. The next most frequent measures, window insulation (19%), high-performance boiler (14%) and wood furnace (9%) exhibit no significant effect across either border. Other measures are found to be significant – wall insulation across H1-H2 and floor insulation across H2-H3 – but with a cumulative market share of 9%, their importance is marginal. Importantly, this pattern of actions mirrors the cost-effectiveness merit order, and more so than do public programs. This suggests that the program qualitatively helped identify the best opportunities.

These results together suggest that the program's third phase was only marginally effective at supporting additional home energy retrofits – not quantitatively, but qualitatively. How then could the obligation be fulfilled regardless? One hypothesis is that obligated parties continued to free ride on overlapping programs, as they did in the first phase. To test this hypothesis, we run microsimulations using Giraudet et al. (2021)'s model of the French housing sector. We find that 91% of the white certificate production could be achieved at zero price, simply by collecting invoices attached to non-subsidized measures (66%) and those attached to overlapping subsidies (25%). The 9% gap was closed with a €4/MWh$_{\mathrm{LD}}$ price. Such a lack of additionality provides strong support for the free-riding hypothesis, casting doubts on the added value of the program compared to its public counterparts. This is all the more concerning that the program is the main vehicle by which France reports on its energy savings effort in compliance with the European Energy Efficiency Directive. Failing to acknowledge interactions with other programs thus creates a risk of double counting.

It is important to emphasize that our results only apply to the 2015-2017 period, which was characterized by low CEE prices. Things drastically changed when the obligation was doubled in 2018, causing prices to soar, which the government responded to by applying bonuses to insulation and heat pump measures. As a result, subisidies were much larger, which was found to have a significant effect on energy savings (Wald and Glachant, 2023) and job creation (Cohen et al., 2024). In other words, the program became *quantitatively* impactful. We argue, however, that it then ceased to be *qualitatively* impactful, for actions were now driven by a public signal – the bonus system set by the government – rather than any of the obligated parties' expertise. This regime shift therefore did not dissipate the doubts we raise about the added value of delegating part of the energy efficiency effort to energy suppliers.[2]

Our paper contributes to three strands of literature. The overarching one is the vast empirical literature on energy efficiency subsidies – e.g., Hassett and Metcalf (1995); Houde and Aldy (2017); Alberini et al. (2016), to name only a few. This literature has primarily focused on quantifying inframarginal participation, or "free-riding" (Boomhower and Davis, 2014; Giraudet, 2020). References for France include Nauleau (2014); Risch (2020); Mauroux (2014) evaluating the tax credit program and Eryzhenskiy et al. (2023) evaluating the zero-interest rate program. We contribute to this literature with an original RDD framework that provides a credible estimation of take-up. The more specific strand we contribute to is the emerging empirical literature on white certificate programs, focused for the most part on the French case. This includes Giraudet et al. (2012) evaluating the first phase based on interviews with stakeholders, Chlond et al. (2023) evaluating the 2014-2016 period based on survey data, Giraudet et al. (2021) assessing the 2015-2018 period based on microsimulations, Darmais et al. (2024) assessing distributional impacts post-2016 based on microsimulations,

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[2] In addition, the bonus system widened the performance gap between predicted and real energy savings, raising further concerns that using the program to report on energy saving efforts may be a flawed approach (Wald and Glachant, 2023).

Wald and Glachant (2023) assessing induced energy savings past 2016 using the program data and Cohen et al. (2024) assessing induced job creation post-2016 using business data. Our contribution here is to estimate induced take-up in a highly credible approach. It is closest to Wald and Glachant (2023), who use the same dataset to study a different outcome – energy savings – at a later period – Phase IV, which no longer features the discontinuity we exploit. Our investigation of mechanisms moreover relies on Giraudet et al. (2021)'s microsimulation framework. Lastly, and importantly, by comparing public and private subsidies for energy efficiency, our analysis more broadly relate to the question of private versus public funding that has for instance been studied in relation to insurance (Charpentier, 2024).

The remainder of the paper is as follows. Section 2 provides some background on the White Certificates programs and their public counterparts. Section 3 introduces the dataset. Section 4 presents the empirical strategy. Section 5 presents the results. Section 6 discusses the results and investigates a possible mechanism. Section 7 concludes.

2 Background

2.1 The French White Certificate program[3]

One of the oldest experiences with White Certificate Obligations, and the largest to date, the *Certificats d'économies d'énergie* (CEE) was introduced in 2006. The program imposes energy efficiency obligations on suppliers of all types of fuels – electricity, natural gas, fuel oil and, since 2010, gasoline – in proportion to their retail sales. Energy savings can in turn be achieved in all sectors — residential buildings, commercial buildings, agriculture, industry, and transport. Obligations are tradable, allowing a party short of their target to purchase savings from one with excess supply.

The program was introduced in a peculiar context of energy market liberalization in the European Union and wide political support for market-based instruments in climate policy (Quirion, 2021). In this spirit, the program has placed an obligation on ends, not means. Obligated parties are asked to provide evidence of their triggering action – e.g., invoice proving a certain measure was installed – without having to disclose the cost incurred – e.g., the subsidy granted to the beneficiary. They are entitled energy savings certificates on each supported measure, based on ex ante engineering calculations expressed in lifetime discounted kilowatthour savings (hereafter $\mathrm{kWh}_{\mathrm{LD}}$).[4] The so-called "white certificates" can be traded among obligated parties, their price reflecting marginal compliance costs. Moreover, in the aforementioned market environment, obligated parties are free to pass through compliance costs onto retail energy prices. The instrument thus hybridizes energy efficiency subsidies with energy taxes, allowing energy savings to be generated with moderate price effects compared to the pure forms of each tool (Giraudet and Quirion, 2008). Obligated parties can be discharged from their obligation upon paying a €15 fee on every missing $\mathrm{MWh}_{\mathrm{LD}}$, which places an upper bound on the white certificate price.

Delegating energy saving efforts to private bodies whose business is to sell energy may seem contradictory. The rationale is to leverage their knowledge of energy consumption patterns, inferred from their large customer databases, which puts them in a unique position to identify the most cost-effective energy savings options. The cost recovery provision in turn ensures incentive compatibility, thus overcoming any contradiction. Another concern is that free competition might encourage suppliers to promote energy savings by their competitor's customers, thereby discarding the superior information they have about their own customers. This threat is however mitigated by the trading provision, which restores incentives to target the most cost-effective options (Giraudet et al., 2020).

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[3] Complete information can be found in (ecologie.gouv, 2024)

[4] The discount rate is 4%. The lifetime varies with the measure considered, from 16 years for heating systems to 35 years for insulation measures.

The obligation target has been tightened every three or four years, from 54 TWh_{LD} in the first phase (2006-2009) to 850 TWh_{LD} in the third phase we will be most interested in (2015-2018) and 3,100 TWh_{LD} in the ongoing fifth phase (2022-2025). Meanwhile, the white certificate price has varied within a narrow range of €2 to €4/MWh_{LD} during the first ten years of the program, before rising sharply at the outset of Phase IV in 2018 and remaining within the €6-8/MWh_{LD} range since then. These changes are depicted in Figure 1. Over the years, residential buildings have consistenly been the main delivery sector, contributing as much as 83% savings in Phase I and as little as 50% in Phase III. These figures together imply €75 million annual spending in the residential sector in Phase I, €425 million in Phase III and a tentative €2.7 billion in Phase V.

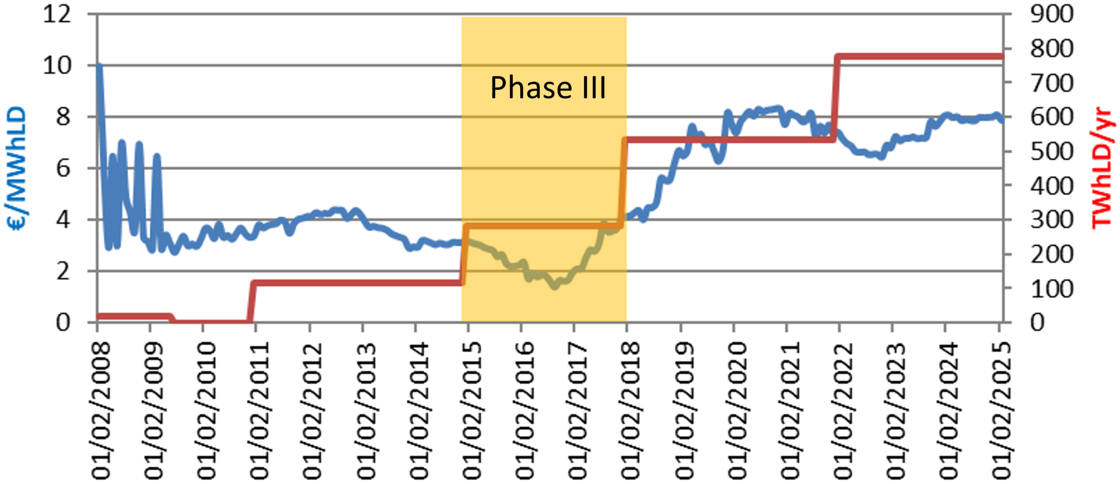

Figure 1: Coevolution of the market price (left axis) and the annual target (right axis)

A central feature of the program is its heavy reliance on standardized energy savings.[5] Each measure is entitled certificates based for instance on the number of windows installed or wall surface insulated. The calculations result from collaborative work by engineers from the French Energy Management Agency (ADEME) and industry representatives.[6]

Although subsidy amounts are not disclosed, an upper bound can be approximated for each measure by multiplying the number of certificates (in MWh_{LD}) by the white certificate price (in €/MWh_{LD}). An obvious caveat with the standardized savings approach is the gap that might arise with real savings, also known as the performance gap in the energy efficiency literature. A recent study comparing the real savings induced by the program to certified ones in Phase IV concludes to a 60% discrepancy (Wald and Glachant, 2023) – an order of magnitude similar to that found in energy efficiency investments in general (e.g., Christensen et al. (2023)).

Crucially for our analysis, certificate provisions are differentiated by climate zones. They are higher in colder zones for heating-related measures (heating systems, insulation) and the other way around for renewable systems (solar water heaters). Three climatic zones partition France's mainland departments (the second-tier subnational jurisdiction) – H1, the coldest, spanning the northwest; H2, of intermediate climate, spanning most of the southeast; and H3, the warmest, covering the Mediterranean coast. Table 5 details energy saving calculations for the key measures supported in Phase III. On average, ex ante savings are 22% higher in H1 than in H2, where they are in turn 47% higher than in H3. As will be further detailed, this

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[5] Non-standardized measures can also be undertaken, with specific calculations. These measures tend to be much bigger in size – e.g., renovation projects at the neighborhood scale. They however weigh little in total saving.

[6] `https://www.ecologie.gouv.fr/sites/default/files/documents/Catalogue%20fiches%20version%20actualis%C3%A9e%2066%C3%A8me%20arr%C3%AAt%C3%A9.pdf`

discontinuity provides the basis for our identification strategy.

In this paper, we focus on the period that ran from January 2015 to March 2018, which covers Phase III of the program (Jan 2015-Dec 2017) and extends slightly beyond. This time window is delineated by data availability on the one hand and a policy change undermining our identification strategy on the other – which will be further detailed shortly. Notwithstanding, the 2015-2018 period is interesting to study in at least two respects. First, the price of white certificates varied within a particulary low range – €3/$\mathrm{MWh_{LD}}$ on average, with an all-time low of €1.41 reached in September 2016. This made the benefit offered by the program quite low compared to that offered by overlapping ones. Second, Phase III saw the introduction of a sub-obligation specifically targeting low-income households, with a separate market. Eligible households are identified as belonging to the first two quintiles of the income distribution. White certificates are doubled for households of the first quintile, with subsidies expected to be doubled as well. Three regimes therefore prevail – the top 60% of the income distribution get subsidies based on the baseline price, the 20%-40% group gets subsidies based on the fuel-poor price and the first quintile gets twice the latter amount. Introduced in 2016, the fuel-poor sub-obligation added 150 $\mathrm{TWh_{LD}}$ to the 700 $\mathrm{TWh_{LD}}$ baseline obligation, hence a total obligation of 850 $\mathrm{TWh_{LD}}$ in Phase III. Prices in the two separate markets have not significantly differed, suggesting the sub-obligation was not binding (Darmais et al., 2024).

From the historical low reached in September 2016, the price of white certificates sharply increased at the prospect of a near doubling of the obligation starting 2018. They matched their historical high of €4/$\mathrm{MWh_{LD}}$ at the onset of Phase IV and continued to increase thereafter, thus entering uncharted territory. The industry raised concerns that soaring costs would impair their ability to comply, prompting the regulator to take action. The government responded with a comprehensive bonus system multiplying the value of certificates by a factor of 4 to 6. Such currency devaluation had the expected effect of containing the price increase (IGF, 2020). Meanwhile, it induced energy suppliers to expand subsidies, which stimulated job creation in the renovation industry (Cohen et al., 2024). The real savings associated with each measure did not increase accordingly, however, which caused the performance gap to widen. Lastly, and importantly, the boosted certificates were evened across climatic zones, preventing us from applying our identification strategy. Our results are therefore only valid for a given time frame. We think, however, that many of our insights carry over to the later period, as we will further develop upon discussing the results.

2.2 Overlapping programs

The CEE program has been coexisting with a number of public programs deployed at the national scale, including reductions in value-added tax (VAT) introduced in 1999, tax credits introduced in 2005, zero-interest rate loans introduced in 2009 and subsidies targeting low-income households introduced in 2010. [7] Further detail on overlapping programs can be found in Appendix A of this paper. The CEE subsidies stand out from this diversified portfolio as the only per-unit ones, all others being ad valorem. Expressed in ad valorem terms, their rate was particularly low during the 2015-2018 period, due to a low white certificate price. As the selection of works eligible under the various programs largely overlap, many households benefited from multiple programs at the same time. Statistics are lacking, however, to assess the extent of this overlap. A survey conducted between 2014 and 2016 indicates that 40% of investors claimed no subsidy, 46% claimed one only, 10% claimed two and 4% claimed three or more (ADEME, 2018). Specifically, 45% of households had benefited from the VAT reduction, 11% from CITE, 8% from CEE, 8% from *Habiter mieux* and 5% from EPTZ. Altogether, this coexistence of multiple instruments creates an incentive for obligated parties to free ride and claim certificates for measures that were supported by another funding program, thus challenging identification of their effect.

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[7] In addition, a carbon fee has been imposed since 2014 on residential fossil fuel consumption (natural gas and fuel oil). The rate rose from €7/$\mathrm{tCO_2}$ in 2014 to €44.60/$\mathrm{tCO_2}$ in 2018 and has remained at that rate since then.

Alongside public national programs, 5% of respondents in the ADEME 2014-2016 survey had benefited from local programs (ADEME, 2018). As of today, 560 local energy efficiency subsidy programs exist in France, mostly deployed at the subdepartmental level.[8] These programs are little studied and their total cost is unknown. In any case, since our identification strategy is based on a geographical discontinuity that overlaps with regions and departments, it is important to have them in mind. In the data section, we check they are not an issue.

3 Data

3.1 Program data

We use the program data collected by the French Ministry of Ecological Transition (*Ministère de la Transition Écologique*).[9] The dataset records all CEE measures supported from 2015, specifying their code, the certified energy savings, the municipality identifier where they were taken, whether they applied to an apartment or a house and whether they benefited a low-income household. In line with the principle that cost information needs not be disclosed under an obligation placed on ends, as opposed to means, no information is reported about the subsidy amount given to beneficiaries. An upper bound can nevertheless be derived from multiplying the certified savings with the certificate price. In addition, the data contain no information about subsidy beneficiaries (e.g., income, age, etc.) beyond whether they qualify as low-income (however imprecisely, see below). Lastly, there is no one-to-one mapping between measures and dwellings. Several measures could have been undertaken in the same dwelling without it being acknowledged in the data. In turn, some measures in multi-family units contain a number of elementary actions (e.g., several hundred windows installed) that far exceeds that which could reasonably be envisaged for a single dwelling, suggesting they were undertaken in multiple dwellings at once.

In an attempt to disaggregate multi-dwelling measures into individual dwellings, we implement an imputation procedure based on available characteristics, such as whether the measure was undertaken in a single-family home. For some measures, such as window replacement, the procedure is straightforward – we use aggregate statistics (e.g., the average number of windows per house in France) and divide the requests accordingly. It is more tedious with measures like insulation, which are quantified in square meters. Detailed explanations about the imputation process are provided in section H. In any case, since the database lacks an identifier for dwellings or households, this imputation is inherently imprecise. Another implication of bundling multi-dwelling measures is the imprecision that follows regarding the low-income status of their beneficiary. Indeed, if at least one dwelling in a bundle qualified, then the entire bundle is assigned the same status. To improve robustness, we employ two different imputation procedures to estimate the number of dwelling-measure pairs, creating two separate samples for our analysis.

With this, we constructed a panel dataset covering the period from January 2015 through March 2018. The end date coincides with the introduction of the *coup de pouce* bonus system. As detailed earlier, this provision applied irrespective of climate zones, thus undermining our identification strategy. Note, however, that our period of interest includes a pilot version of the *coup de pouce* system launched in early 2017.[10] Since it covered fewer measures and was restricted to low-income households, we consider this pilot to so limited as to be inocuous to our identification strategy.

After removing observations with incomplete data and excluding measures that either lack climate zone

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[8] We thank Odile Dubois-Joye from ANIL for communicating this information to us.

[9] The data are made available through the *Centre d'Accès Sécurisé aux Données* (CASD). The same dataset is used by Wald and Glachant (2023) to study the impact of Phase IV on energy savings.

[10] https://www.ecologie.gouv.fr/sites/default/files/documents/2017.02.23%20-%20Coup%20de%20pouce%20CEE-PM.pdf

variation in subsidy amounts[11] or have reverse incentives with higher subsidies in warmer climate zones,[12] together representing approximately 1% of the dataset, we are left with 1,429,168 residential CEE measures in mainland France. After aggregating measures at the municipality-year level, which will serve as our unit of analysis, our dataset contains 132,576 observations covering 33,144 municipalities.

3.2 Complementary data

We match the program data with socio-economic, technical and meteorological data. The data needed to aggregate program data at the municipality level are provided by the FILOCOM database (File of Housing by Municipalities), jointly assembled by the Ministry of Ecological Transition (SDES office) and the Ministry of Economics and Finance (DGFiP office).[13] The dataset also allows us to create control variables at the municipality level, such as municipality size (number of households), average household income, dwelling construction period, cadastral rental value, number of floors, dwelling type (single-/multi-family), distribution of income categories (top 60%, bottom 20-40%, bottom 20%), ownership type (individual or legal entity), presence of central heating, residential status (primary or secondary residence), occupancy type (owner-occupied or rental), and the number of minors per dwelling.

As detailed above, our identification strategy relies on exogenous variation in implied subsidy amounts based on the geographical location. The underlying certificate provisions are computed using the technical documentation provided by the Ministry of Ecological Transition (DGEC office).[14] The geographical coordinates of municipalities are obtained from (data.gouv, 2023). To control for climatic variations, we compute heating degree days (HDD) using daily temperature data from French meteorological stations. A common proxy for heating needs, HDDs are computed here using the COSTIC method, with temperature inputs from Météo France.[15]

4 Empirical strategy

4.1 Identification

As previously discussed, certificate provisions, which serve as the basis for implied subsidies, vary systematically based on dwelling characteristics – dwelling type, size, heating fuel – and, most crucially for our analysis, across climate zones. As illustrated in Fig. 2, mainland France is divided into three climate zones named H1, the coldest, H2, and H3, the warmest.

H1 covers the major part of eastern France, except the southernmost part. It combines maritime, continental and montainous climates (including the Vosges, Jura and most of the Alps and Massif Central ranges). H2 covers the major part of western France, with a thin band expanding east in the south. It is essentially maritime with significant montainous parts – most of the Pyrénées, plus part of the Massif central and a small part of the Alps. H3 covers the southern coast. It is purely mediterranean with some montainous

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[11] This includes: thermodynamic water heater with storage (BAR-TH-148); comprehensive renovation of a residential building (BAR-TH-145), which relies a more detailed climate zone variation than the one used in our analysis; collective solar water heater (BAR-TH-102)

[12] Individual solar water heater (BAR-TH-101)

[13] We use the 2017 edition made available through CASD. https://www.casd.eu/en/source/file-of-housing-by-municipalities/

[14] https://www.ecologie.gouv.fr/politiques-publiques/operations-standardisees-deconomies-denergie. The website was accessed in January 2023.

[15] https://meteofrance.com/ and https://www.costic.com/ressources/dju. The weather data include daily average temperatures from all French meteorological stations for the period of 2011 to 2020 and the geographical coordinates for each station. The heating period is considered from October 1st to May 20th, with a threshold of 18 degrees Celsius. Using the daily average temperatures, we sum all the degree differences below 18 degrees during the heating period for each station and year separately. These are then averaged over the period from 2011 to 2020 to obtain the final HDD measure for each station. Finally, we associate each municipality with the closest meteorological station.

parts from the Alps and Pyrénées. We will refer to the climate zones as “colder” vs. “warmer” in pairwise comparisons – H1 as opposed to H2 and H2 as opposed to H3.

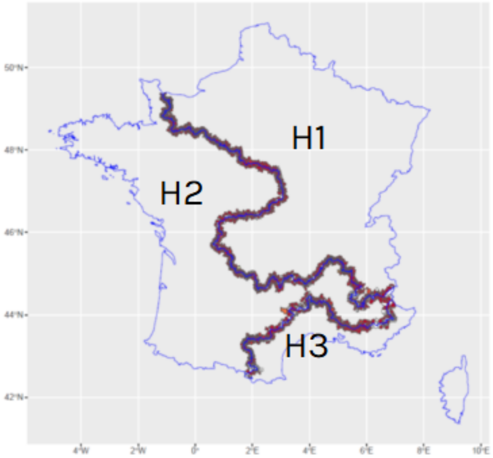


Figure 2: Climate Zones in Metropolitan France

The climate zone borders follow those of departments, the second-tier local jurisdiction in France. Importantly, they do not actually follow clear climatic divides. The continuity of climate across these borders, contrasted with the discontinuity in certificate provisions, is crucial to our identification strategy. In this context, dwellings with identical characteristics in two neighboring municipalities located on either side of the border will presumably receive a different subsidy – higher in the colder zone – despite having similar heating needs, implying the two renovation projects should be incentivized in the same way. This setup enables us to employ a regression discontinuity design (RDD) to study the impact of CEE subsidies.

4.2 Assumptions

Our RDD is conditional on a set of assumptions.

- **Varying subsidy amounts around borders.** Remember that subsidies are not reported in the dataset, but inferred from the market price of white certificates, multiplied by the certificate provision associated with each measure. In practice, competing obligated parties use an internal price to design their subsidies, necessarily lower than the market price, which reflects the marginal compliance cost. Since certificate provisions vary across borders, so too should subsidy amounts. This is however conditional on obligated parties applying a single internal price regardless of the climate zone. To check whether this is the case, we did some data scraping on the online simulators made available online by energy suppliers for consumers to gather the subsidies they would be offered. We found that subsidy amounts differ across climate zones in proportions that exactly match the differences in certificate provisions, implying internal prices do not vary within obligated parties. Moreover, even though internal prices do vary across obligated parties, as they should, we expect no systematic bias in the distribution of these variations across regions.

- **Identical prices before subsidies around borders.** In turn, for our RDD to be valid, the differing subsidy amounts should effectively lead to differing renovation prices after subsidy. Otherwise, an even price after subsidy across borders would reveal some adjustment of their margins by renovation contractors. We believe this is the case because of the widespread online disclosure of contractor service prices, which makes price differences easily noticeable, especially in small geographical units like neighboring departments, where consumers and contractors are quick to adjust to any discrepancies.

In addition, our identification strategy rests on a set of more classical assumptions (Hahn et al., 2001; Lee and Lemieux, 2010):

- **No sorting around climate zone borders.** We assume individuals do not strategically relocate to colder climate zones to benefit from higher subsidies. This is motivated by the small variation in benefit implied by the discontinuity, which is in the hundreds of euros, hence negligible compared to the average value of property in France (around €200,000).
- **Local randomization near the climate zone borders and continuity of outcome and control variables.** We expect that municipalities near the cutoff are similar in unobserved and observed characteristics, allowing us to attribute any differences in outcomes to the treatment effect. We also assume that the outcome and control variables remain continuous with respect to the running variable across its range, except at the cutoff for the outcome variable. To verify these assumptions, we test the balance of covariates around the climate zone borders. Table 1 presents the results of t-tests, comparing municipalities within a 5 km range on either side of the climate zone border. Approximately half of the tested characteristics are balanced across the two sides of the border at the 10% significance level. Importantly, one of the key covariates in our analysis, HDD, shows no significant difference across the border, which supports our approach. However, the share of houses compared to apartments differs significantly, which could influence energy efficiency investment decisions, as dwelling type may strongly affect uptake. It is nevertheless encouraging that other important drivers of energy efficiency investments, such as the share of owner-occupied dwellings, the share of primary residences, and average household income, are balanced, further supporting the validity of our approach.

Table 1: Covariates Balance: t-test

Covariate	Bandwidth	H1-H2		H2-H3	
		p-value	t-statistic	p-value	t-statistic
HDD	5/5	0.261	16.80	0.808	10.23
avg annual household revenue in 000s euros		0.420	0.18	0.424	-0.27
nb of households in municipality		0.001	89.08	0.007	436.17
share of houses		0.001	-0.03	0.067	0.01
share of "very modest" households		0.096	-0.01	0.003	-0.02
share of "modest" households		0.442	-0.00	0.048	-0.01
avg nb of minors per dwelling		0.294	-0.01	0.779	0.00
avg cadastral rental value in euros		0.001	88.99	0.024	107.46
share of dwellings with central heating		0.005	0.02	0.014	0.03
avg number of floors		0.001	0.09	0.088	-0.02
comfort ranking: partial comfort		0.082	-0.01	0.010	-0.02
comfort ranking: full comfort		0.006	0.01	0.025	0.02
share of primary residences		0.545	-0.00	0.852	-0.00
share of secondary residences		0.638	0.01	0.849	-0.00
share of owner-occupied dwellings		0.918	-0.01	0.136	0.01
share of tenant-occupied dwellings		0.693	-0.01	0.127	-0.01
share of construction period before 1946		0.135	-0.01	0.071	0.02
share of construction period from 1946 to 1970		0.090	0.00	0.605	0.00
share of construction period from 1971 to 1973		0.120	0.00	0.001	0.00
share of construction period from 1974 to 1982		0.055	0.00	0.336	-0.00
share of construction period from 1983 to 1989		0.010	0.00	0.001	-0.01
share of construction period from 1990 to 2000		0.256	0.00	0.881	-0.00
share of construction period from 2001 to 2005		0.587	0.00	0.529	0.00

Note: bandwidth of 5km on each side of the climate zone border

4.3 Model

We leverage exogenous discontinuity in certificate provisions to estimate the effect of the program on the uptake of renovation measures. Our main outcome variable is the count of measures undertaken in a given year in a given municipality, which is a proxy of investment on the extensive margin – an imprecise one, due to the absence of a one-to-one mapping between measures and renovation projects. In complementary analysis, we also consider the total certificate provision, which captures the extensive and intensive margins combined.

Our running variable is the shortest distance to the climate zone border, with the borders acting as cutoffs. With three climate zones, we will conduct two separate analyses – one for the border between H1 and H2 and another one for H2 and H3. In each case, the colder zone represents the treated group, presumably receiving a higher subsidy.

We use a quasi-Poisson regression to estimate the treatment effect with the following regression discontinuity (RD) model with covariates

$$\log(E(Y_i)) = \beta_0 + \mathbf{X}_i\boldsymbol{\beta} + \epsilon_i, \tag{1}$$

where Y_i represents the outcome with a quasi-Poisson distribution, $E(Y_i)$ the expected value of Y_i, β_0 the intercept, $\mathbf{X}_i$ a vector of covariates described above, $\boldsymbol{\beta}$ the vector of coefficients for the covariates, and ϵ_i is the error term. The variance of Y_i is given by $Var(Y_i) = \phi E(Y_i)$, with ϕ representing the dispersion parameter, accounting for overdispersion relative to the Poisson model.

4.4 Specifications

Table 2: Parameters of specifications: Number of subsidies

Specification	**Outcome variable**	**Sample**	**Geo-difference control**	**Scope**
1	Number of subsidies	Imputation 1	HDD	55km bandwidth, 5km binwidth
2		Imputation 2		
3		Imputation 1	Border segments	
4		Imputation 2		
5		Imputation 1	HDD	Cattaneo and Vazquez-Bare (2017)'s bandwidth and binwidth
6		Imputation 2		
7		Imputation 1	Border segments	
8		Imputation 2		

Note: The options in blue are our preferred specification (specification 1)
Details regarding imputation 1 and imputation 2 are available in the annex
Optimal bins were determined using the ES setting

In our preferred specification, we consider the distance to the border within a bandwith of 55 kilometers (km) and divide it into bins of 5 km-width. These bins serve as our explanatory variables. To disaggregate multi-dwelling measures into single-dwelling ones, we use the imputation procedure described earlier. Lastly, we control for HDDs to ensure comparability between municipalities that are geographically distant. HDDs are weighted using a triangular kernel over the length of the bandwidth.

We use seven alternative specifications combining alternate criteria, as summarized in Table 2. Specifications 5 to 8 rely on binwidths and bandwiths optimally determined with state-of-the-art methods, such as Calonico et al. (2015) for bandwith selection and Cattaneo and Vazquez-Bare (2017)'s mean square error minimization for binwidth and bandwith sizes. The resulting bandwidths are quite narrow (between 20 to 30 km), potentially limiting statistical power, hence our use of a larger bandwidth in our preferred specification. Specifications 2, 4, 6 and 8 rely on an alternative imputation procedure, where dwellings with an unusually large surface have been excluded from the sample. Lastly, in Specifications 3, 4, 7 and 8 we use a spatial

RD approach inspired by Dell (2010). Each border is divided into ten segments, and each municipality is associated with its corresponding border segment. We then estimate the treatment effect in the same way as we do in our preferred specification, save for omitting the HDD variable. This spatial RDD approach is rather standard in studies like ours where the explanatory variable is geographical, but with the larger bandwidths that we use, we believe HDD might control more precisely for potential climatic differences than do border segments.

In all specifications, the bin immediately adjacent to the border on the control side serves as the reference group, while the coefficient for the bin just across the border on the treatment side is interpreted as the treatment effect.

5 Results

5.1 Visual analysis without controls

As a preliminary check, we examine the RDD graphs based on raw values, not yet adjusted for the predetermined characteristics of the municipalities and other relevant factors. Figure 3 displays the number of measures using Calonico et al. (2015)'s evenly-spaced (ES) bin widths. Municipalities from the treatment group are located on the right-hand side of the cutoff, with positive distance values. We observe a slight discontinuity between the values of the bins adjacent to the border, with treated municipalities exhibiting a higher number of measures. Trends however appear to have opposite directions in the treatment and control groups. We will perform further visual analysis later after controlling for municipality-level characteristics.

5.2 Preliminary analysis with climate zone dummies

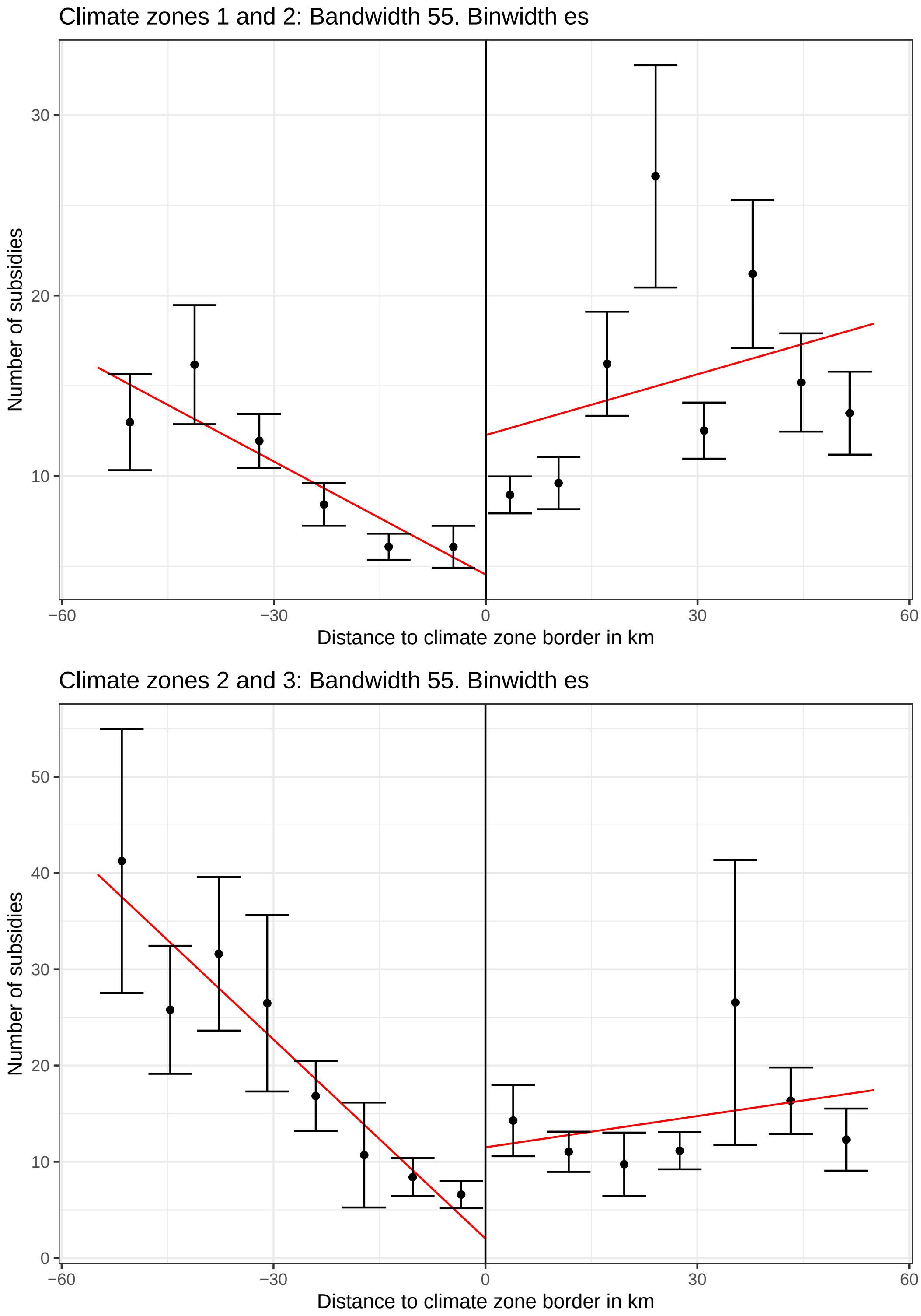
Another preliminary check consists of investigating whether the number of measures is correlated with climate zones. To do so, we run the quasi-Poisson model with climate zones as a categorical control variable, using the whole sample, whereas the RDD focuses on subsamples around the borders. The results in section C show a significantly smaller number of measures in H3 than in H2, after controlling for various municipality and measures characteristics. There is no significant difference between zones H1 and H2. These findings are consistent with the design of the program, which features a greater subsidy differential around the H2-H3 border than around the H1-H2 border. Therefore, if an effect is to be observed, it is more likely to be between H2 and H3, which is the case here.

5.3 RDD results

Figure 4 discloses the RDD coefficients at both borders under different specifications. The detailed results can be found in Section D. The RD results are framed as a percentage effect using the average marginal effects estimated from the quasi-Poisson regression results. In our preferred specification, we find 25% more measures in H1 than in H2, significant at the 10% level. In contrast, we find no significant effect at the H2-H3 border, despite a bigger differential in certificate provisions there. In alternative specifications, the H1-H2 effect turns non-significant and the H2-H3 effects remain non-significant. The disappearance of the H1-H2 effect may be due to the lower statistical power implied by the narrower bandwidth in Specifications 5 to 8. The detailed results can be found in Section F.

The more pronounced effect at H1-H2, despite a smaller certificate provision differential there, goes against the previous findings established with climate zone dummies. It may be due to different reasons. Our imputation procedure may have introduced inaccuracies. Alternatively, the municipal-level statistics we use (e.g., property size) may not adequately control for the characteristics of subsidy recipients. The discrepancy

Figure 3: Number of subsidies delivered. Aggregated on municipality level



Specification 1. Values grouped using Cattaneo and Vazquez-Bare (2017) evenly-spaced binwidths, displaying 95% confidence intervals

Table 3: Comparison of CEE program's effect size and incentives: number of subsidies

measure			H1-H2			H2-H3		
code	**name**	**share (%)**	**Δ effect (%)**	**Δ incentive (%)**	**elasticity**	**Δ effect (%)**	**Δ incentive (%)**	**elasticity**
BAR-EN-101	Attic or roof insulation	30.3	**36.4**	**21.8**	1.67	**35.7****	**47.1**	0.76
BAR-EN-104	Window or patio door with glazed surface insulation	18.6	**2.2**	**22.8**	0.1	**5.6**	**49.3**	0.11
BAR-TH-106	High-efficiency boiler	13.5	**-15.1**	**18.3**	-0.83	**-36.9**	**38.4**	-0.96
BAR-TH-112	Independent wood heating appliance	8.7	**5.8**	**22.3**	0.26	**2.8**	**50.3**	0.06
BAR-EN-102	Wall insulation	5.1	**40.4****	**22.0**	1.83	**21.2**	**49.2**	0.43
BAR-EN-103	Floor insulation	3.5	**89.7**	**21.0**	4.26	**127.1****	**51.6**	2.46
total		100.0	**25.0***	**21.6**	1.16	**5.1**	**47.0**	0.11

Note: Effect size and incentive are calculated within a 55 km bandwidth on each side of the border (specification 1).
“Δ effect in %” refers to the RDD effect size relative to the average number of subsidies in the control group (55km bandwidth).
RDD effect size is reported with signif. codes: ***: 0.01, **: 0.05, *: 0.1
“Δ incentive %” refers to the percentage difference in adjusted CEE values (in MWh CUMAC) delivered between the treatment and control groups.
Elasticity is calculated by dividing “Δ effect in %” by “Δ incentive %”

might also stem from the general instability of results in the bins used to assess treatment effects. To see this, we plot the bin coefficients (fig. 5), representing the average marginal treatment effects in our preferred specification of the quasi-Poisson model. We see that even where a significant treatment effect was identified, the coefficients for adjacent bins display erratic behavior, with the trends appearing volatile. These robustness checks confirm that the effects we are trying to identify are weak at best.

5.4 Heterogeneity by measure

Next to overall results, we run the regressions on measures sub-samples to investigate heterogeneity. We focus on the six most frequent measures among those varying certificate provision by climate zone. This includes four insulation measures (for roof, window, floor and wall) and two heating system measures (high-efficiency boiler and wood furnace), together covering 80% of realizations. The results are displayed in Table 3 for our preferred specification.

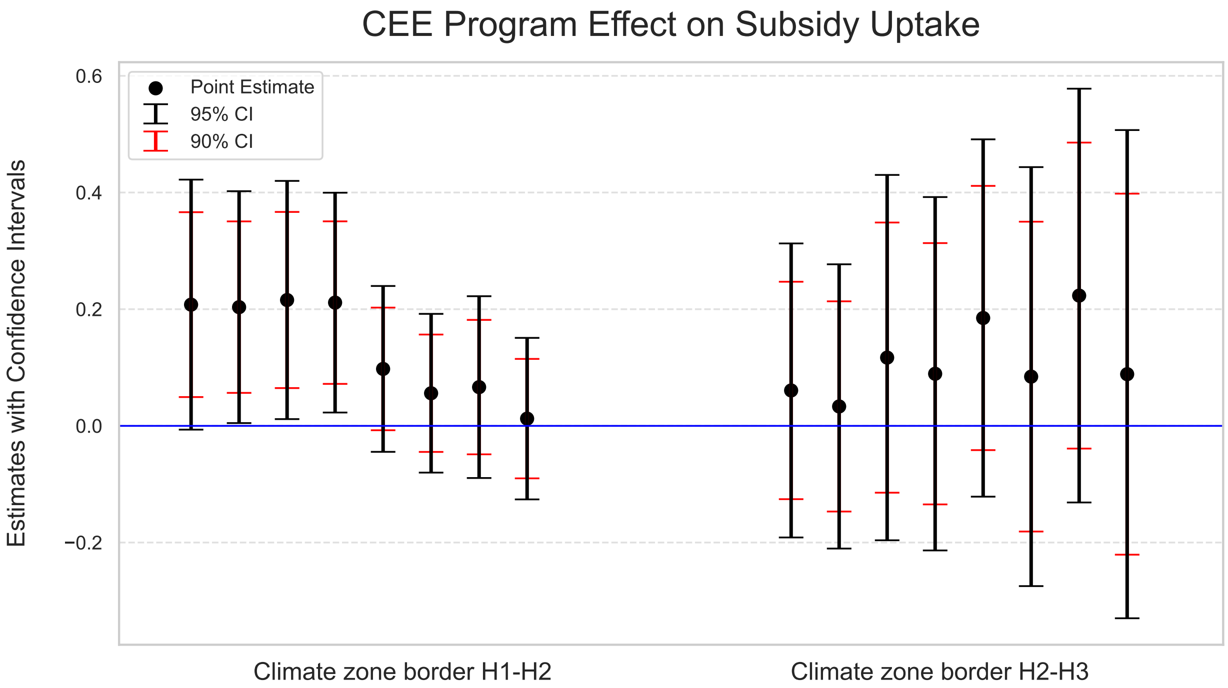
Looking at the H1-H2 border, we find a 40% higher take-up for wall insulation in H1, significant at the 5% level. Albeit important, this effect must be put into perspective given the low fraction of the underlying measure in aggregate outcomes – 5%. Other measures do not exhibit significant results. The analysis is more conclusive at the H2-H3 border. Take-up is 36% higher for roof insulation in H2, and 127% higher for floor insulation, in both cases significant at the 5% level. The former finding is noteworthy given that the measure weighs 30% in total achievements.

5.5 Implied elasticities

In Table 3, we compute elasticities by dividing the percentage effect estimated in our preferred specification by the percentage variation in certificate provision across borders. We find a 1.16 overall elasticity at the H1-H2 border, where the effect was found to be significant. This means that a 1% increase in the implied benefit increased take-up by 1.16%. The elasticity is only 0.11 at the H2-H3 border, but the effect was non-significant anyway. Elasticities vary widely across measures. To mention only those whose effect was significant, elasticities are 1.8 for wall insulation at the H1-H2 border, 0.76 for roof insulation at H2-H3 and 2.5 for floor insulation at H2-H3.

If financial criteria were the only determinants of choice, then every euro of profitability would be valued the same by decision-makers and elasticities would be similar across measures. Our finding that they aren't is

Figure 4: Comparison of specifications



Note: Specifications 1-8

revealing of unobserved choice determinants. For instance, unlike other insulation measures, floor insulation does not have the same appeal in cold and warm zones. Specifically, it is less warranted in warm zones, where a non-insulated floor provides cooling service in the summer. While this aspect is not accounted for in how certificate provisions are calculated, the fact that households respond much more strongly to it in H2 than in H3 suggests it drives part of the decision.

6 Discussion

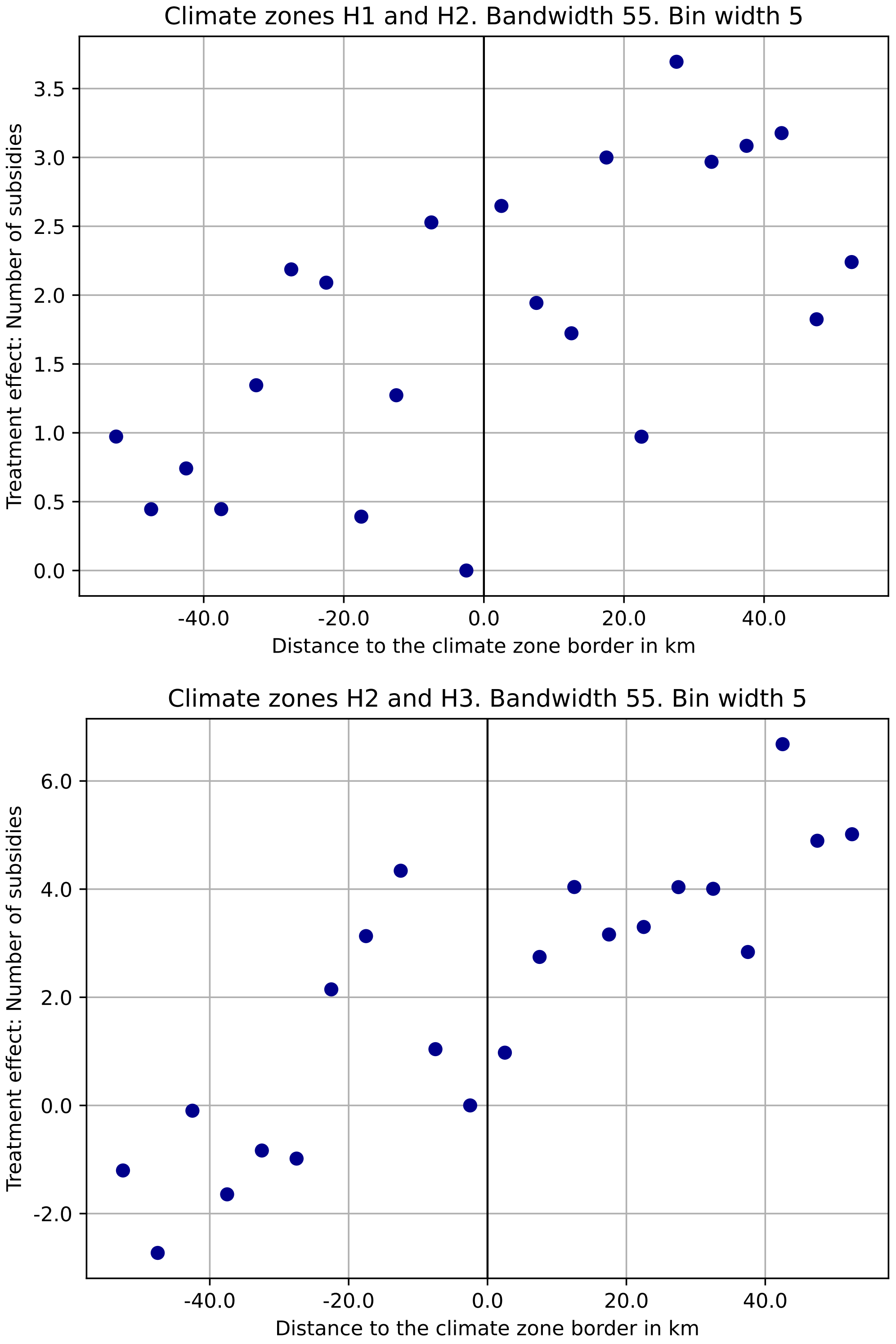
6.1 Heterogeneity by income category

Section G presents the results of the same analysis applied to the "very low income" sub-sample, with H2 serving as the reference climate zone. Overall take-up is higher in H1 than in H2, and higher in H2 than in H3, in both case significant at the 10% level. Again, the magnitude of the effect is larger at the H1-H2 border, despite a smaller incentive differential there. The results are qualitatively similar with the "low income" sub-sample, except that the H2-H3 effect is not significant. These results should nevertheless be interpreted with caution, since we lack precise information on how many subsidies were allocated to each income group in multi-dwelling measures.

6.2 Comparison with the CITE program

We now compare the pattern of CEE measures with those achieved under the main public counterpart over the same period, namely the CITE program, as described by Domergue and Vermont (2018). As depicted in Figure 7, the two patterns are in sharp contrast, with a much higher fraction of roof, wall and floor insulation measures under the CEE program, whereas the CITE program heavily targets window insulation.

Figure 5: Coefficients of the RD model



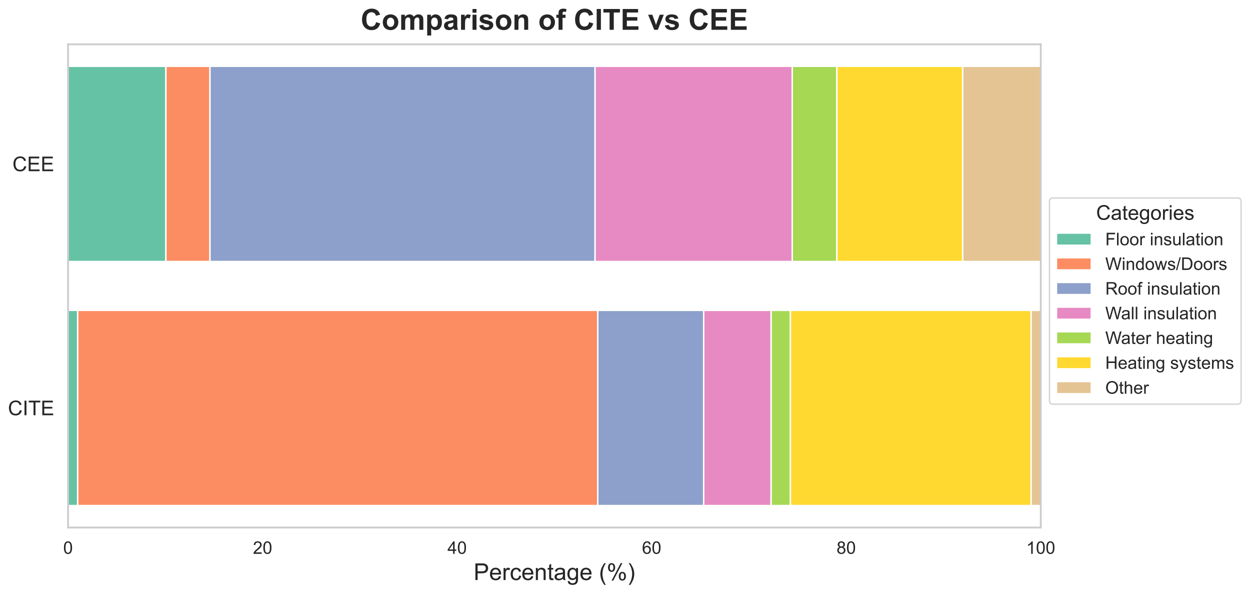
Climate zones H1 and H2. Bandwidth 55. Bin width 5

Climate zones H2 and H3. Bandwidth 55. Bin width 5

Coefficients representing the number of subsidies in each bin relative to the control bin

Importantly, the CEE pattern much more closely aligns with the cost-effectiveness merit order elicited by Camilier-Cortial et al. (2017) for France. This goes to suggest that the CEE program is more effective than the CITE at identifying the best opportunities. While this qualitatively gives support to the information leverage hypothesis, it should not overlook the fact that the quantitative impact of the program is extremely low.

Figure 6: Measure category breakdown



CEE: share of certificates delivered in 2015 to March 2018; CITE: share of funds delivered in 2015 to 2016 (Domergue and Vermont, 2018)

6.3 Investigating the free-riding hypothesis

Our results so far suggest that the program had a significant impact on renovation take-up qualitatively, but not quantitatively. Still, obligated parties managed to fulfill their obligation. This suggests that they claimed certificates for measures whose invoices they managed to collect without needing to actively subsidize them. In other words, they free rode on renovation triggered by other means, including overlapping subsidy programs.

To investigate this free-riding hypothesis, we run microsimulations comparing the impact of the program with and without overlapping programs. We use Giraudet et al. (2021)'s Res-IRF model, which features endogenous renovation processes responding to energy prices and energy efficiency policy signals. We model the program as an energy efficiency subsidy coupled with an energy tax. The subsidies are computed using certificate provisions (averaged across climate zones since the model is national in scope) multiplied by a white certificate price scenario. The taxes are computed using the same price scenario and applying it to the "kWhWh$_{\text{LD}}$ certificate to produce by kWh sold" ratio inherent in the obligation.[16] We model both standard and low-income certificates, assuming the same price for both (so the bonus applying to very low-income households is the only additional signal). The tax component has an effect on investment through the renovation decision processes encapsulated in the model, equivalent to a price-elasticity of energy demand of -0.23 in the short term and -0.35 in the long run (Giraudet et al., 2021).

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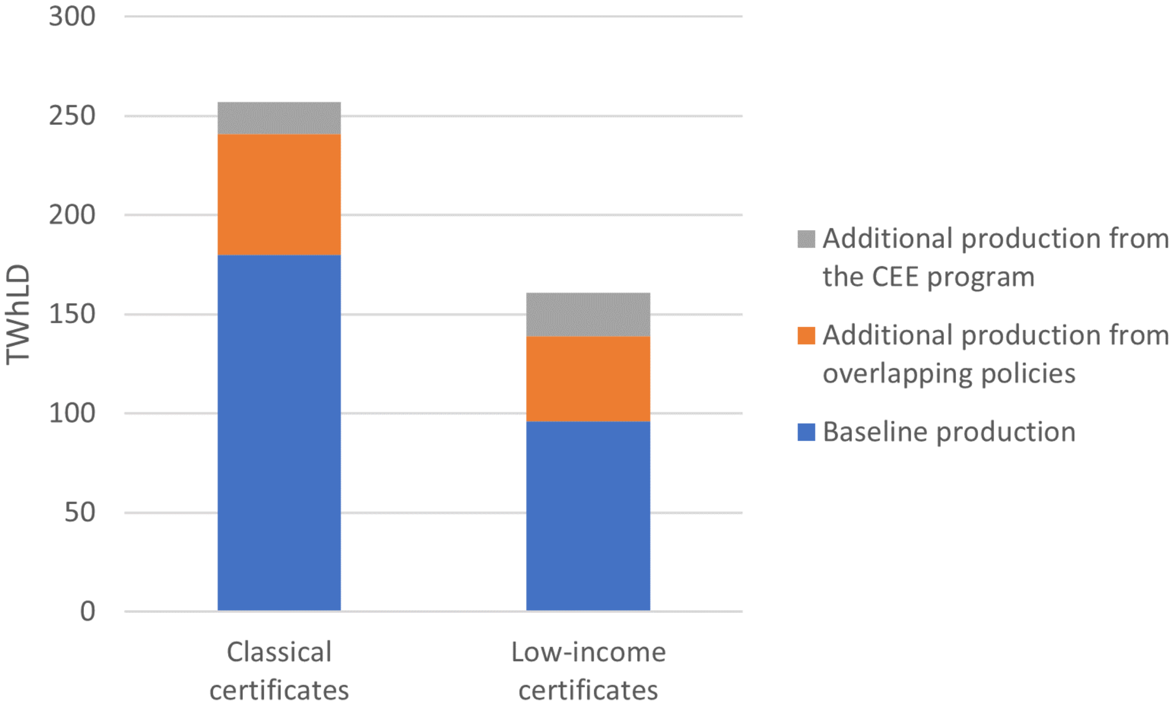
[16] Since we only model the residential sector while the program is all-encompassing, there is no closure between total spending amount and total tax proceeds.

Assuming a white certificate price of €4/MWh$_{\mathrm{LD}}$– the upper bound of that which prevailed during Phase III – we run three different scenarios: one with no policy; one with all policies but the CEE, i.e., CITE, VAT and EPTZ (cf. Section A); and one with all policies, including the CEE. The first two scenarios capture white certificate production when energy suppliers are allowed to collect invoices and claim thoses measures without having to actively subsidize them. In other words, this what happens when the white certificate price is zero. The third scenario captures the additional effect of a non-zero white certificate price.[17] Importantly, we assume that households claim all the benefits they are entitled to. Lastly, CEE benefits are capped so the total benefits cannot exceed 100% of investment cost.

We find that, taking together the classical and low-income certificate production, 276 TWh$_{\mathrm{LD}}$ were achieved under no policy, i.e., through natural renovation turnover and heating system replacement. Public policies added 104TWh$_{\mathrm{LD}}$ to this, hence a total of 380 TWh$_{\mathrm{LD}}$. On top of that, a €4Wh$_{\mathrm{LD}}$ price only added 38 TWh$_{\mathrm{LD}}$. In other words, 91% of the total production was achieved at zero white certificate price. This gives strong support to the free-riding hypothesis.

Figure 7: Microsimulations of white certificate production and its attribution under Phase III



7 Conclusion

The French CEE program involves utility-sponsored subsidies for home energy retrofit that can be combined with public subsidies. We assess the value Phase III of the program added to its contemporaneous public counterparts and estimate the implied elasticities in a regression discontinuity design exploiting geographical variation in incentive provisions.

We find that, overall, the effectiveness of the program was very low. Overall impact is significant at only one of the two borders, in only three out of eight specifications. In this most favourable specification, a

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[17] Alternatively, we could have proceed as follows: (i) no policy; (ii) CEE only; (iii) all policies, including CEE. The CEE effect captured with (ii) would however be devoid of interactions with other policies, and as such overstated.

1% increase in incentive induced a 1.16% higher take-up in CEE measures. Such an almost undetectable impact can be explained by the low white certificate price that prevailed at that time, making the implied subsidy amounts very small. In turn, this low price can be explained by the design of the program, which allows energy suppliers to claim certificates without having to disclose the means involved. Under these circumstances, and as long as the target is not binding, energy suppliers can free ride on other programs and advertise for them instead of granting subsidies themselves. This is confirmed in microsimulations showing that, under the assumption that each measure supported by the CEE program was jointly supported by public subsidies, 91% of the target of Phase III could be achieved at a zero white certificate price.

Looking more qualitatively at the pattern of measures, we find that the program had a significant impact on a handful measures that rank pretty high in the cost-effectiveness merit order – attic, wall and floor insulation. These impacts, however, are not consistent across climate zones and not highly robust. Still, this pattern of actions is more skewed towards the most cost-effective measures than that associated with public subsidy programs. This tentatively suggests that the program was effective at identifying the best renovation opportunities.

Only valid for a given time frame, our results overall suggest the program was effective qualitatively, but not quantitatively. One could expect from this that a tighter target would increase the white certificate price, hence subsidy amounts, thereby making the program fully additional, both quantitatively and qualitatively. The fourth phase of the program that started in 2018 confirms the first part but casts doubts on the second one. The tightening of the target indeed caused prices to soar. Prompted to act by energy suppliers, the government responded by introducing a bonus system boosting certificate provisions. This intervention had the expected effect of containing the price increase. In addition, it changed the pattern of actions in a way that closely matched the pattern of bonuses designed by the government. This indicates that the role of the government was more important in steering actions than that of energy suppliers. This does not mean that the program was quantitatively ineffective – it was, in particular when it comes to job creation (Cohen et al., 2024). But this essentially resulted from a government impetus, rather than from energy suppliers leveraging private information.

Altogether, the limited value utility-sponsored subsidies qualitatively add to public subsidies calls for merging the two systems, such as into the sort of "one-stop shop" promoted by the European Commission (Pardalis et al., 2025). In this case, the same amount of private funding would be sollicited, but instead of having energy suppliers granting subsidies themselves, they would contribute the same amount to a public-private fund which would redistribute subsidies.

Further research includes assessing the impact of Phase III on energy consumption, as in (Wald and Glachant, 2023), in a two-stage framework where our take-up estimates serve as an instrument. Given the very limited effect we already find, however, we do not expect energy savings to be significant. Another important question to study is the pass-through between white certificate prices and energy suppliers' subsidies. This calls for systematically collecting subsidy data. Lastly, white certificate programs are meant to create two-sided markets in which energy suppliers as a platform connecting customers with renovation contractors (Giraudet and Finon, 2015). In this context, the expected added value of the program is to stimulate the relationship between energy suppliers and contractors. While we have focused on the demand side of this two-sided market, it is important to also study the supply side.

Appendices

A Overlapping national programs

We provide below some background on overlapping national programs, focusing on the conditions that prevailed during the 2015-2018 period. Further detail can be found in Giraudet et al. (2021); Chlond et al. (2023).

Introduced in 1999, the VAT reduction first applied to all types of retrofit works. It was restricted in 2014 to a selection of energy-related works, making it a proper energy efficiency subsidy. The rate was taken down to 5.5% for eligible works, against 10.0% for non-energy-related works and 20.0% for all other types of goods. It can thus be considered an ad valorem subsidy with a flat rate of 14.5% when assessed against the regular 20% rate or 4.5% when assessed against the specific 10% rate, which arguably provides a more relevant benchmark. This benefit is available to all households without any income restriction. Assessed against the 20% default rate, as the government typically does, the implied public cost was about €1-1.5 billion per year over the 2015-2017 period (IGF, 2020), and only one third of this when assessed against the 10% benchmark.

The tax credit program was introduced in 2005 under the *Crédit d'impôt pour le développement durable* (CIDD) name and rebranded *Crédit d'impôt pour la transition énergétique* (CITE) in 2014. Available to all households without income restrictions, it consists of a refund on income taxes in return to investment in a selection of energy-related works.[18] The refund is proportional to the cost of the underlying measure, making it an ad valorem subsidy. While the rate was initially differentiated according to the measure – from 10% for window replacement to 50% for heat pumps – it became fixed at 30% for all measures in 2014. This single rate prevailed until the program was merged into MPR in 2020. Over the 2015-2018 period, the program benefited on average 1.3 million households per year, for a total public cost of €1.9 billion per year. This policy has been the most studied empirically, with a focus on the earlier periods. Using panel data on household renovation investment, Nauleau (2014) found inframarginal participation in the program to be in the 60% to 80% range from 2007 to 2010. This result was confirmed by Mauroux (2014) in a difference-in-differences framework using fiscal data and by Risch (2020) in a temporal regression discontinuity framework using the same dataset as Nauleau. Risch (2020) additionnally finds a significant 22% effect on the intensive margin of investment.

The zero-intest green loan program or *Eco-prêt à taux zéro* was introduced in 2009. It allows households to borrow money for free to invest in a selection of energy-related works. Accessible without income restrictions, loans are capped at €30,000, to be repaid over a maximum period of 15 years. Banks are compensated by the government for forgone revenue on each loan. By giving back interests that would otherwise be proportional to the amount borrowed, the program can be interpreted as an ad valorem subsidy, however with important qualifications. First, the implied subsidy rate varies across time – due to fluctations of the market interest rate – and space – since different borrowers would typically be charged different interest rates. Second, the rate is non-linear, as several measures need to be combined for the project to be eligible. Using panel data on household renovation investment and an eligibility restriction to newer buildings, (Eryzhenskiy et al., 2023) find that eligibility to the program significantly increased investment by 22% on the extensive margin, especially for low-income households, and 3% on the intensive margin. These effects however vanished after two years into the program. Over the 2015-2018 period, participation was particularly low, with annual beneficiaries in the 19,000 to 24,000 range and a low public cost varying between €110 million in 2015 and €51 million in 2018 (PLF).

Lastly, in 2010, the government launched the *Habiter Mieux* program, involving subsidies specifically

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[18] Low-income households who qualify for income tax exemption receive a direct payment.

targeting fuel-poor households, identified as belonging to the bottom 30 % of the income distribution. Granted by ANAH, the French Housing Agency, the subsidies are primarily ad valorem with a 50% rate, to which smaller per-unit bonuses can be added. Over the 2015-2018 period, the program benefited between 40,000 and 50,000 households per year, for an annual cost of about €240 million (CC, 2018).

Since 2014, the CEE, CITE and EPTZ programs are subject to eco-conditionnality – to get subsidies, households need to hire contractors certified with a label *Reconnu garant de l'environnement* (RGE).

In 2020, the tax credit and low-income subsidy programs were merged into a single program called *MaPrimeRénov'* (MPR).

B Share of measures

Table 4: Share of certificates delivered by measure in the CEE data

Measure Code	**Measure name (French)**	**Measure name (English)**	**Volume of CEE delivered (%)**
BAR-EN-101	Isolation des combles ou toitures	Attic or Roof Insulation	38.5
BAR-EN-102	Isolation des murs	Wall Insulation	19.4
BAR-EN-103	Isolation d'un plancher	Floor Insulation	11.2
BAR-TH-106	Chaudière individuelle à haute performance énergétique	High efficiency boiler	7.6
BAR-TH-115	Isolation d'un réseau hydraulique de chauffage	Insulation of a heating hydraulic network	5.4
BAR-TH-131	Isolation d'un réseau hydraulique d'eau chaude sanitaire	Insulation of a domestic hot water hydraulic network	4.4
BAR-EN-104	Fenêtre ou porte-fenêtre complète avec vitrage isolant	Window or patio door with glazed surface insulation	4.2
BAR-EN-105	Isolation des toitures terrasses	Insulation of flat roofs	2.2
BAR-TH-107	Chaudière collective haute performance énergétique	High-efficiency collective boiler	1.7
BAR-TH-107-SE	Chaudière collective haute performance énergétique	High-efficiency collective boiler	
	avec contrat assurant la conduite de l'installation	with a maintenance contract ensuring system operation	1.6
BAR-TH-112	Appareil indépendant de chauffage au bois	Independent wood heating appliance	1.4
BAR-TH-127	Ventilation Mécanique Contrôlée simple flux hygroréglable	Hygro-adjustable single-flow Mechanical Ventilation System	0.9
BAR-TH-104	Pompe à chaleur de type air/eau ou eau/eau	Air-to-water or water-to-water heat pump	0.5
BAR-TH-129	Pompe à chaleur de type air/air	Air-to-air heat pump	0.5
BAR-TH-137	Raccordement d'un bâtiment résidentiel	Connection of a residential building	
	à un réseau de chaleur	to a district heating network	0.3
BAR-TH-113	Chaudière biomasse individuelle	Individual biomass boiler	0.2
BAR-TH-110	Radiateur basse température pour un chauffage central	Low-temperature radiator for central heating	0.1
BAR-TH-155	Ventilation hybride hygroréglable	Hygro-adjustable hybrid ventilation	0.1
BAR-EN-108	Fermeture isolante	Insulating closure	0.1
BAR-TH-125	Système de ventilation double flux autoréglable	High-performance self-regulating	
	ou modulé à haute performance	or modulated double-flow ventilation system	0.1
BAR-TH-116	Plancher chauffant hydraulique à basse température	Low-temperature hydronic underfloor heating	0.1
BAR-TH-150	Pompe à chaleur collective à absorption	Collective absorption heat pump	
	de type air/eau ou eau/eau	of the air-to-water or water-to-water type	0.1
BAR-TH-159	Pompe à chaleur hybride individuelle	Individual hybrid heat pump	0.1
			Total 100% **378,853,803,217 kWh CUMAC**

Table 5: Measure certificate values for 100 square meter house in kWh CUMAC

Measure Code	**Measure Name**	**H1**	**H2**	**H3**	**H1 vs H2**	**H2 vs H3**
BAR-EN-101	Attic or Roof Insulation	150000	120000	80000	+25%	+50%
BAR-EN-102	Wall Insulation	240000	200000	130000	+20%	+53.85%
BAR-EN-103	Floor Insulation	460000	380000	250000	+21.05%	+52%
BAR-TH-106	High efficiency boiler	46900	39600	28500	+18.43%	+38.95%
BAR-TH-115	Insulation of a heating hydraulic network	280000	225000	150000	+24.44%	+50%
BAR-TH-131	Insulation of a domestic hot water hydraulic network	375000	360000	325000	+4.17%	+10.77%
BAR-EN-104	Window or patio door with glazed surface insulation	82000	67000	45000	+22.39%	+48.89%
BAR-EN-105	Insulation of flat roofs	220000	180000	120000	+22.22%	+50%
BAR-TH-107	High-efficiency collective boiler	N/A	N/A	N/A	N/A	N/A
BAR-TH-107-SE	High-efficiency collective boiler with a maintenance contract ensuring system operation	N/A	N/A	N/A	N/A	N/A
BAR-TH-112	Independent wood heating appliance	29600	24200	16100	+22.31%	+50.31%
BAR-TH-127	Hygro-adjustable single-flow Mechanical Ventilation System	42900	35100	23400	+22.22%	+50%
BAR-TH-104	Air-to-water or water-to-water heat pump	79900	65400	43600	+22.17%	+50%
BAR-TH-137	Connection of a residential building to a district heating network	96300	81400	58600	+18.32%	+38.98%
BAR-TH-113	Individual biomass boiler	142300	116400	77600	+22.26%	+50%
BAR-TH-110	Low-temperature radiator for central heating	8500	7000	4550	+21.43%	+53.85%
BAR-TH-155	Hygro-adjustable hybrid ventilation	N/A	N/A	N/A	N/A	N/A
BAR-EN-108	Insulating closure	13000	10000	6900	+30%	+44.93%
BAR-TH-125	High-performance self-regulating or modulated double-flow ventilation system	46100	37700	25100	+22.28%	+50.2%
BAR-TH-116	Low-temperature hydronic underfloor heating	30000	25000	16000	+20%	+56.25%
BAR-TH-150	Collective absorption heat pump of the air-to-water or water-to-water type	N/A	N/A	N/A	N/A	N/A
BAR-TH-159	Individual hybrid heat pump	104800	88800	64400	+18%	+37.94%

Example of certificate values for a 100 square meter house heated with combustible fuel, having 10 windows, 5 single heaters or one central heater, and 10 insulating closures. Additional conditions: "Insulation of a heating hydraulic network" and "Insulation of a domestic hot water hydraulic network" refer to 50 meters of network insulated. "Hygro-adjustable single-flow Mechanical Ventilation System" refers to a Low-energy Controlled Mechanical Ventilation type B. "High-performance self-regulating or modulated double-flow ventilation system" refers to a self-regulating double-flow ventilation system. Individual hybrid heat pump has a seasonal energy efficiency (η_S) of $130 \leq \eta_S < 140$.

C Model: Number of subsidies and climate zones

Table 6: Number of subsidies and whole climate zones. Quasi-Poisson regression

Dependent Variable:	number of CEE subsidies allocated
Model:	(1)
Variables	
heating degree days	$2.09 \times 10^{-5*}$
	(8.47×10^{-6})
climate zone H1	0.1586
	(0.0855)
climate zone H3	-0.2215***
	(0.0345)
avg annual household revenue in 000s euros	-0.0039
	(0.0061)
share of houses among all dwellings	0.6034***
	(0.0589)
share of 'high precarity' subsidies	1.151***
	(0.1463)
share of 'precarity' subsidies	1.124*
	(0.3690)
avg number of minors per dwelling	-0.3760
	(0.3611)
avg cadastral rental value in euros	$-4.78 \times 10^{-5*}$
	(1.82×10^{-5})
share of dwellings with central heating	0.7041
	(0.3304)
avg number of floors	-0.1087***
	(0.0105)
share of secondary residences	-0.9777**
	(0.1907)
share of dwellings with landlord-tenant dilemma	0.0598
	(0.1830)
nat. logarithm of nb of households in municip.	Yes
construction periods	Yes
share of households without income category reported	Yes
share of comfort ranking: no comfort or partial comfort	Yes
Fixed-effects	
year	Yes
Fit statistics	
Observations	132,576
Squared Correlation	0.74341

Clustered (year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Quasi-Poisson regression.

Variables refer to municipality-level aggregations.

Reference categories: control bin -5km; share of apartments among all dwellings; share of 'classic' subsidies; share of dwellings not owned by natural person; share of dwelling without central heating; share of primary residences; share of dwellings whose owners do not have an incentive to renovate; share of dwellings constructed after 2005

Bandwidth value refers to the distance from each side of the border

D RD model: Number of subsidies delivered

D.1 Results. All specifications

Table 7: RD results. Climate zone border H1-H2

Dependent Variable:	number of CEE subsidies allocated							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
Treatment bin	0.2078*	0.2035**	0.2157**	0.2113**	0.0976	0.0559	0.0664	0.0124
	(0.0673)	(0.0624)	(0.0641)	(0.0592)	(0.0447)	(0.0428)	(0.0490)	(0.0435)
Avg annual household revenue in 000s euros	-0.0042	-0.0031	0.0027	0.0027	-0.0060	-0.0048	-0.0014	-0.0005
	(0.0069)	(0.0062)	(0.0052)	(0.0050)	(0.0039)	(0.0037)	(0.0044)	(0.0040)
Share of houses among all dwellings	0.6491**	0.6574**	0.3688	0.3184	0.7656**	0.7294**	0.2241	0.1222
	(0.1396)	(0.1595)	(0.2089)	(0.2124)	(0.1688)	(0.1561)	(0.3312)	(0.3363)
Share of 'high precarity' subsidies	1.160***	1.164***	1.115***	1.130***	1.102***	1.085***	1.016***	1.024***
	(0.1301)	(0.1339)	(0.1171)	(0.1229)	(0.1093)	(0.1012)	(0.0623)	(0.0663)
Share of 'precarity' subsidies	0.8418*	0.8690*	0.6830	0.7213	0.9998**	1.024**	0.8952*	0.9472*
	(0.3384)	(0.3606)	(0.3931)	(0.4180)	(0.3112)	(0.3150)	(0.3316)	(0.3352)
Avg number of floors	-0.0297	-0.0346	-0.0963**	-0.0984*	0.0448	0.0328	-0.0381	-0.0462
	(0.0241)	(0.0280)	(0.0301)	(0.0333)	(0.0296)	(0.0323)	(0.0270)	(0.0283)
Share of secondary residences	-0.4710**	-0.4136**	-0.2947	-0.2956	-0.4454*	-0.4328*	-0.1125	-0.1971
	(0.1257)	(0.1232)	(0.2277)	(0.2414)	(0.1811)	(0.1739)	(0.2448)	(0.2402)
other treatment and control bins	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
heating degree days	Yes	Yes	No	No	Yes	Yes	No	No
nat. logarithm of nb of households in municip.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of minors per dwelling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg cadastral rental value in euros	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
construction periods	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of households without income cat. reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of comfort ranking: no or partial comfort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of dwellings with central heating	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of floors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of tenant-occupied dwellings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed-effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Segments	No	No	Yes	Yes	No	No	Yes	Yes
Fit statistics								
Observations	31,024	31,000	31,024	31,000	10,316	10,100	10,316	10,100
Squared Correlation	0.80938	0.80659	0.82884	0.82314	0.72088	0.71732	0.73547	0.72941

Clustered (year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Quasi-Poisson regression.

Table 8: RD results. Climate zone border H2-H3

Dependent Variable:	number of CEE subsidies allocated							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
treatment bin	0.0607	0.0333	0.1170	0.0893	0.1849	0.0844	0.2233	0.0886
	(0.0792)	(0.0766)	(0.0984)	(0.0952)	(0.0962)	(0.1128)	(0.1114)	(0.1315)
natural logarithm of number of households	1.055***	1.061***	1.017***	1.022***	1.032***	1.050***	1.062***	1.079***
	(0.0235)	(0.0248)	(0.0200)	(0.0220)	(0.0267)	(0.0269)	(0.0182)	(0.0169)
avg annual household revenue in 000s euros	0.0011	0.0015	-0.0003	0.0002	0.0061**	0.0066**	0.0033	0.0038
	(0.0017)	(0.0017)	(0.0027)	(0.0026)	(0.0016)	(0.0015)	(0.0019)	(0.0018)
share of houses among all dwellings	0.8431*	0.7473*	0.0489	0.0214	0.8271	0.7462	-0.1076	-0.1428
	(0.2956)	(0.2864)	(0.1712)	(0.2021)	(0.3817)	(0.3487)	(0.1950)	(0.1714)
share of 'high precarity' subsidies	1.317***	1.330***	1.333***	1.356***	1.306***	1.293***	1.274***	1.258***
	(0.1170)	(0.1146)	(0.1244)	(0.1210)	(0.2068)	(0.1915)	(0.1718)	(0.1597)
share of 'precarity' subsidies	1.416**	1.467**	1.260*	1.317*	1.447**	1.521**	1.503**	1.554**
	(0.4239)	(0.4424)	(0.4888)	(0.4975)	(0.3722)	(0.3809)	(0.3858)	(0.4000)
avg number of floors	-0.1518	-0.1707	-0.1105	-0.1219	-0.1471	-0.1672	-0.2120	-0.2240*
	(0.0819)	(0.0819)	(0.0745)	(0.0764)	(0.0817)	(0.0732)	(0.1033)	(0.0943)
share of secondary residences	-0.6810**	-0.5100*	-0.5450**	-0.4252*	-0.7132*	-0.5655	-0.5829	-0.4842
	(0.1174)	(0.1703)	(0.1048)	(0.1383)	(0.2389)	(0.2919)	(0.2678)	(0.2965)
other treatment and control bins	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
heating degree days	Yes	Yes	No	No	Yes	Yes	No	No
nat. logarithm of nb of households in municip.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of minors per dwelling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg cadastral rental value in euros	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
construction periods	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of households without income cat. reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of comfort ranking: no or partial comfort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of dwellings with central heating	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of floors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of tenant-occupied dwellings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed-effects								
year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
segments	No	No	Yes	Yes	No	No	Yes	Yes
Fit statistics								
Observations	12,392	12,384	12,392	12,384	6,128	6,172	6,128	6,172
Squared Correlation	0.86517	0.86276	0.87725	0.87402	0.89017	0.89096	0.89907	0.89773

Clustered (year) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

E RD model: Adjusted volume of CEE delivered

To further examine the impact of the subsidy program, we employ an alternative outcome variable: the adjusted volume of certificates. This measure accounts for the total volume of certificates distributed, normalized according to climate zone and income level, ensuring comparability across groups. Specifically, we recalibrate all cumulative amounts received by households as if they had been granted under climate zone H2 as a classical (rather than precarity-based) subsidy.

In this analysis, we exclude municipalities with zero subsidies in a given year to focus on areas where households actively applied for CEE subsidies. Consequently, the interpretation of the results differs slightly from the main analysis.

Our findings diverge from those of the main analysis. While no significant effect is observed at the H1-H2 climate zone border, we do detect an impact at the H2-H3 border. Compared to the primary results, the absence of an effect at H1-H2—despite previously identifying a difference in the number of subsidies received—suggests that renovation projects undertaken in H2 may be more substantial than those in H1. Similarly, at the H2-H3 border, the results indicate that households in H2 likely engaged in larger-scale renovations than those in H3.

Table 9: Adjusted volume of certificates delivered. Linear regression. Climate zone border H1-H2

Dependent Variable:	adjusted volume of certificates allocated							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
Treatment bin	208,379.4	278,006.7	168,447.4	261,005.0	518,775.0	527,319.2	493,526.6	482,309.0
	(326,702.5)	(261,034.4)	(363,973.3)	(285,984.5)	(357,486.5)	(366,018.7)	(375,145.5)	(338,712.9)
Avg annual household revenue (000s euros)	1,577.8	-8,354.5	-24,181.8	-21,793.1	1,834.2	1,024.1	6.767	-5,117.1
	(22,982.7)	(16,557.1)	(27,150.5)	(21,293.2)	(10,733.6)	(9,200.0)	(12,377.3)	(10,256.2)
Share of houses among dwellings	-4,765,654.7*	-2,305,840.2	-11,222,879.5*	-6,595,304.3*	-2,427,720.1	-1,281,371.0	-8,934,080.1*	-6,802,984.5
	(1,524,415.8)	(1,083,811.5)	(2,884,279.5)	(2,104,283.5)	(937,062.9)	(745,825.3)	(2,532,300.4)	(2,546,578.8)
Share of 'high precarity' subsidies	1,648,312.8	1,335,889.1*	0.6	1.54×10^{10}	1,564,277.0**	1,326,545.2**	1.66×10^{10}	0.8
	(576,353.4)	(332,517.5)	(2.18×10^{10})	(2.7×10^{10})	(363,155.8)	(239,399.5)	(2.37×10^{10})	(2.73×10^{10})
Share of 'precarity' subsidies	256,660.2	571,539.9*	-0.1	0.4	432,083.6	604,210.8	-1.5×10^{10}	1,387,092,321.3
	(288,479.2)	(162,996.2)	(1.62×10^{10})	(0.1)	(376,167.5)	(250,388.0)	(2.05×10^{10})	(2.12×10^{10})
other treatment and control bins	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
heating degree days	Yes	Yes	No	No	Yes	Yes	No	No
nat. logarithm of nb of households in municip.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of minors per dwelling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg cadastral rental value in euros	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
construction periods	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of households without income cat. reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of comfort ranking: no or partial comfort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of dwellings with central heating	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of floors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of tenant-occupied dwellings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed-effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Segments	No	No	Yes	Yes	No	No	Yes	Yes
Fit statistics								
Observations	19,671	19,642	19,671	19,642	7,783	8,312	7,783	8,312
R^2	0.26755	0.27708	0.29816	0.28959	0.28260	0.27032	0.30437	0.28524
Within R^2	0.26527	0.27188	0.28959	0.28959	0.27767	0.26295	0.29513	0.27315

Clustered (year) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 10: Adjusted volume of certificates delivered. Linear regression. Climate zone border H2-H3

Dependent Variable:	adjusted volume of certificates allocated							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
treatment bin	1,422,235.8**	642,096.6	1,547,635.4**	759,608.2	1,436,894.2**	1,014,190.7**	1,307,376.0**	1,047,477.9*
	(302,452.4)	(232,434.4)	(316,371.7)	(267,783.8)	(247,461.2)	(223,654.5)	(241,628.5)	(256,136.9)
avg annual household revenue in 000s euros	20,420.8*	10,808.1*	14,447.5	7,018.1	12,649.8*	3,098.4	11,509.2*	5,293.8*
	(5,277.6)	(2,586.3)	(5,121.5)	(4,433.2)	(3,631.6)	(2,742.0)	(2,911.7)	(1,290.4)
share of houses among all dwellings	6,547,483.4**	4,975,918.0**	3,760,160.9**	3,067,621.8*	6,147,331.5**	4,288,917.1**	1,568,185.8	1,341,845.2*
	(860,332.8)	(1,092,308.6)	(816,433.4)	(750,894.4)	(1,145,789.2)	(924,736.9)	(706,695.7)	(433,694.8)
share of 'high precarity' subsidies	2,705,630.7	1,720,177.2*	8.24×10^{10}	7.54×10^{10}	2,256,770.5	1,484,035.1	4.54×10^{10}	2.99×10^{10}
	(1,241,028.9)	(489,798.4)	(6.47×10^{10})	(6.55×10^{10})	(1,351,768.0)	(559,917.2)	(3.83×10^{10})	(4.12×10^{10})
share of 'precarity' subsidies	1,520,991.1***	1,917,055.9**	-0.7	4.52×10^{10}	1,629,495.6*	1,871,321.0*	-5.54×10^{10}	4.09×10^{10}
	(131,751.7)	(349,642.2)	(2.86×10^{10})	(4.55×10^{10})	(443,574.2)	(510,863.4)	(9.59×10^{10})	(3.77×10^{10})
other treatment and control bins	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
heating degree days	Yes	Yes	No	No	Yes	Yes	No	No
nat. logarithm of nb of households in municip.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of minors per dwelling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg cadastral rental value in euros	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
construction periods	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of households without income cat. reported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of comfort ranking: no or partial comfort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of dwellings with central heating	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
avg number of floors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
share of tenant-occupied dwellings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed-effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Segments	No	No	Yes	Yes	No	No	Yes	Yes
Fit statistics								
Observations	7.642	7,630	7.642	7,630	4,159	3,522	4,159	3,522
R^2	0.22701	0.29960	0.23775	0.31934	0.25558	0.35082	0.26308	0.31747
Within R^2	0.22602	0.29619	0.22492	0.29759	0.25467	0.34612	0.24420	0.29018

F Comparison of CEE program's effect size and incentives. Outcome: nb of subsidies delivered. Specification 2

Table 11: Comparison of CEE program's effect size and incentives: number of subsidies. Specification 2

measure			H1-H2			H2-H3		
code	**name**	**share (%)**	**Δ effect (%)**	**Δ incentive (%)**	**elasticity**	**Δ effect (%)**	**Δ incentive (%)**	**elasticity**
BAR-EN-101	Attic or roof insulation	30.3	**36.3**	**21.8**	1.66	**33.4****	**47.1**	0.71
BAR-EN-104	Window or patio door with glazed surface insulation	18.6	**2.2**	**22.8**	0.1	**5.6**	**49.3**	0.11
BAR-TH-106	High-efficiency boiler	13.5	**-15.1**	**18.3**	-0.83	**-37.0**	**38.4**	-0.96
BAR-TH-112	Independent wood heating appliance	8.7	**5.8**	**22.3**	0.26	**2.8**	**50.3**	0.06
BAR-EN-102	Wall insulation	5.1	**44.3*****	**22.0**	2.01	**47.9**	**49.2**	0.97
BAR-EN-103	Floor insulation	3.5	**96.1**	**21.0**	4.57	**153.7****	**51.6**	2.98
total		100.0	**24.3****	**21.6**	1.13	**2.8**	**47.0**	0.06

Note: Effect size and incentive are calculated within a 55 km bandwidth on each side of the border (specification 1).
"Δ effect in %" refers to the RDD effect size relative to the average number of subsidies in the control group (55km bandwidth).
RDD effect size is reported with signif. codes: ***: 0.01, **: 0.05, *: 0.1
"Δ incentive %" refers to the percentage difference in adjusted CEE values (in MWh CUMAC) delivered between the treatment and control groups.
Elasticity is calculated by dividing "Δ effect in %" by "Δ incentive %"

G Model: Subsidies and climate zones

G.1 Outome: Number of 'high precarity' and 'precarity' subsidies delivered and climate zones

G.1.1 Specification 1

Table 12: Number of "high precarity" subsidies and whole climate zones. Quasi-Poisson regression

Dependent Variable: Model:	 (1)
Variables	
heating degree days	$-3.06 \times 10^{-5*}$
	(1.2×10^{-5})
share of households in 'very modest' category	0.6793**
	(0.2021)
share of households in 'modest' category	1.147*
	(0.4224)
climate zone H1	0.4620**
	(0.1243)
climate zone H3	-0.4436**
	(0.1137)
share of houses among all dwellings	0.2631
	(0.2844)
avg number of minors per dwelling	0.3187
	(0.2959)
avg cadastral rental value in euros	2.58×10^{-5}
	(1.62×10^{-5})
share of dwellings with central heating	1.817*
	(0.6398)
avg number of floors	-0.1543**
	(0.0383)
share of secondary residences	-1.324***
	(0.2058)
share of dwellings with landlord-tenant dilemma	1.453
	(0.6218)
avg. annual household revenue in 000s euros	Yes
nat. logarithm of nb of households in municip.	Yes
construction periods	Yes
share of households without income category reported	Yes
share of comfort ranking: no comfort or partial comfort	Yes
Fixed-effects	
year	Yes
Fit statistics	
Observations	132,576
Squared Correlation	0.37509

Clustered (year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Quasi-Poisson regression.

Variables refer to municipality-level aggregations.

Reference categories: control bin -5km; share of apartments among all dwellings; share of 'classic' subsidies; share of dwellings not owned by natural person; share of dwelling without central heating; share of primary residences; share of dwellings whose owners do not have an incentive to renovate; share of dwellings constructed after 2005

Bandwidth value refers to the distance from each side of the border

Table 13: Number of “precarity” subsidies and whole climate zones. Quasi-Poisson regression

Dependent Variable: Model:	number of CEE “precarity” subsidies allocated (1)
Variables	
heating degree days	4.32×10^{-5}
	(5.62×10^{-5})
share of households in ’very modest’ category	-0.3233
	(0.5794)
share of households in ’modest’ category	2.913^{**}
	(0.7161)
climate zone H1	0.1559^{**}
	(0.0394)
climate zone H3	-0.2128
	(0.1654)
share of houses among all dwellings	0.3966
	(0.4723)
avg number of minors per dwelling	0.0963
	(0.1706)
avg cadastral rental value in euros	4.85×10^{-5}
	(5.07×10^{-5})
share of dwellings with central heating	1.700
	(1.694)
avg number of floors	-0.2102
	(0.1160)
share of secondary residences	-1.164
	(1.032)
share of dwellings with landlord-tenant dilemma	0.8756
	(0.7050)
avg. annual household revenue in 000s euros	Yes
nat. logarithm of nb of households in municip.	Yes
construction periods	Yes
share of households without income category reported	Yes
share of comfort ranking: no comfort or partial comfort	Yes
Fixed-effects	
year	Yes
Fit statistics	
Observations	132,576
Squared Correlation	0.30880

Clustered (year) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*
Quasi-Poisson regression.
Variables refer to municipality-level aggregations.
Reference categories: control bin -5km; share of apartments among all dwellings; share of ’classic’ subsidies; share of dwellings not owned by natural person; share of dwelling without central heating; share of primary residences; share of dwellings whose owners do not have an incentive to renovate; share of dwellings constructed after 2005
Bandwidth value refers to the distance from each side of the border

G.1.2 Specification 2

Table 14: Number of “high precarity” subsidies and whole climate zones. Quasi-Poisson regression. Specification 2

Dependent Variable:	number of “high precarity” CEE subsidies allocated
Model:	(1)
Variables	
heating degree days	-3.13×10^{-5}
	(1.42×10^{-5})
share of households in ’very modest’ category	0.6623^{*}
	(0.2083)
share of households in ’modest’ category	1.422^{*}
	(0.4552)
climate zone H1	0.4911^{**}
	(0.1271)
climate zone H3	-0.3961^{**}
	(0.1114)
share of houses among all dwellings	0.2524
	(0.3150)
avg number of minors per dwelling	0.3461
	(0.3184)
avg cadastral rental value in euros	1.88×10^{-5}
	(1.9×10^{-5})
share of dwellings with central heating	2.105^{*}
	(0.6706)
avg number of floors	-0.1677^{**}
	(0.0409)
share of secondary residences	-1.197^{***}
	(0.1654)
share of dwellings with landlord-tenant dilemma	1.607^{*}
	(0.6162)
avg. annual household revenue in 000s euros	Yes
nat. logarithm of nb of households in municip.	Yes
construction periods	Yes
share of households without income category reported	Yes
share of comfort ranking: no comfort or partial comfort	Yes
Fixed-effects	
year	Yes
Fit statistics	
Observations	132,500
Squared Correlation	0.36475

Clustered (year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Quasi-Poisson regression.

Variables refer to municipality-level aggregations.

Reference categories: control bin -5km; share of apartments among all dwellings; share of ’classic’ subsidies;
share of dwellings not owned by natural person; share of dwelling without central heating;
share of primary residences; share of dwellings whose owners do not have an incentive to renovate;
share of dwellings constructed after 2005

Bandwidth value refers to the distance from each side of the border

Table 15: Number of “precarity” subsidies and whole climate zones. Quasi-Poisson regression. Specification 2

Dependent Variable:	number of “precarity” CEE subsidies allocated
Model:	(1)
Variables	
heating degree days	5.02×10^{-5}
	(5.78×10^{-5})
share of households in ’very modest’ category	-0.3831
	(0.5781)
share of households in ’modest’ category	3.112**
	(0.7498)
climate zone H1	0.1747**
	(0.0386)
climate zone H3	-0.1731
	(0.1567)
share of houses among all dwellings	0.3953
	(0.4801)
avg number of minors per dwelling	0.1275
	(0.1807)
avg cadastral rental value in euros	4.7×10^{-5}
	(5.38×10^{-5})
share of dwellings with central heating	1.838
	(1.750)
avg number of floors	-0.2245
	(0.1174)
share of secondary residences	-0.9785
	(1.006)
share of dwellings with landlord-tenant dilemma	1.029
	(0.6976)
avg. annual household revenue in 000s euros	Yes
nat. logarithm of nb of households in municip.	Yes
construction periods	Yes
share of households without income category reported	Yes
share of comfort ranking: no comfort or partial comfort	Yes
Fixed-effects	
year	Yes
Fit statistics	
Observations	132,500
Squared Correlation	0.30850

Clustered (year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Quasi-Poisson regression.

Variables refer to municipality-level aggregations.

Reference categories: control bin -5km; share of apartments among all dwellings; share of ’classic’ subsidies; share of dwellings not owned by natural person; share of dwelling without central heating; share of primary residences; share of dwellings whose owners do not have an incentive to renovate; share of dwellings constructed after 2005

Bandwidth value refers to the distance from each side of the border

H Details on the imputation procedure

Two imputation patterns were applied to determine the number of dwelling-measure combinations in the case where the column `NbLogements` (number of dwellings) was empty or column `nb_operation` (number of operations) had a value greater than 1, indicating that the observation represented more than one dwelling-measure combination.

General Imputation Pattern

A consistent approach was used when measure volumes depended on various units, such as the number of heaters, and other factors. The following rules were applied:

- Heaters:
    - Apartments: The number of heaters was divided by 5 to estimate the number of individual dwellings.
    - Houses: We assumed an average of 7 windows per house, and the values were rounded accordingly.
- For the measure BAR-TH-148, values for apartments were divided by 2 to estimate the appropriate count.

Imputation 1

- For measures where subsidy amounts were calculated based on the isolated surface area, the number of dwellings was estimated by assuming an average dwelling size of 120 square meters.

Imputation 2

- For measures where subsidy amounts were calculated based on the isolated surface area, observations with a surface area above 220 square meters were excluded from the dataset.

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