Free-Riding On Tax Credits For Home Insulation In France: An Econometric Assessment Using Panel Data.

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ABSTRACT

This econometric study assesses the efficiency of the income tax credit system introduced in France in 2005 on investment decisions for household retrofits, focusing on insulation measures. A logit model with random individual effects is estimated using an unbalanced panel of 23,879 households surveyed over the period 2002-2011. An estimation in difference is performed to identify the impact of the policy. The tax credit is found to have had no significant effect during the first two years, suggesting a latency period related to inertia in households' investment decisions, possibly due to the complexity of the tax credit scheme. The tax credit had an increasing, significant positive effect from 2007 to 2010, before slightly decreasing in 2011. This is in line with changes in the tax credit rates, suggesting a correlation with the level of subsidy. Defined as the situation in which the subsidized household would have invested even in the absence of the subsidy, free-ridership progressively decreased over the period, was lower for insulation of opaque surfaces (roofs, walls, etc.) than for insulation of windows. The estimated average proportion of free-riders varies between 40% and 85% after 2006. In addition, we assess the potential bias caused by time-varying unobservable variables and conclude that our estimates of the impacts of the policy are conservative.

Introduction[1]

In the current context of climate change and given the weight of the residential sector in industrialized countries' energy use and CO2 emissions, the promotion of energy efficiency investments in the existing building stock is a major issue in climate policy. This sector is all the more targeted as it is considered one of the sectors with the highest energy savings potential (Levine & al. 2007), although this potential has been questioned (Allcott & Greenstone 2012). Consequently, incentives such as income tax credits have been introduced in many countries to encourage households to invest in energy-efficient retrofitting of their dwellings. In some countries the first wave of tax credit implementation occurred in the 1970's, in the post oil-crisis period, and led to a first group of empirical studies, mainly dealing with the US tax credit system from 1977 to 1986.

Among all the barriers to action faced by households who want to retrofit their dwellings (Jakob 2007), the presence of market imperfections may provide justification for instruments such as tax credits. Called "investment inefficiencies" by Allcott and Greenstone (2012), these market failures mainly refer to imperfect information and may cause households not to undertake privately profitable investments in energy efficiency. Moreover, in the case of negative externalities related to

Acknowledgement:
Results and interpretations based on the ADEME TNS-SOFRES «Maitrise de l'énergie» survey, are those of the author and do not reflect the opinion of ADEME or TNS-SOFRES. I wish to thank Philippe Quirion, Laurent Meunier, Amélie Mauroux, François-Charles Wolff, Erwan Gautier and Nicolas Jacquemet for helpful discussions and comments

[1] Abbreviations in the article: CIDD stands for *Credit d'Impôt Développement Durable* (Sustainable Development Tax Credit), which is the French name of the tax credit scheme studied; EcoPTZ stands for *Eco Prêt à Taux Zéro* (Interest-Free Loan for Environmentally-Friendly Projects), which is the French name of the currently-available zero interest rate loan.

fossil fuels and the political difficulties of implementing first-best solutions such as Pigouvian taxes[2], energy efficiency policies might be a reasonable second-best substitute (Allcott & Greenstone 2012). Such policies can also address behavioral failures, even if they are imperfect when consumers are heterogeneous (Gillingham & Palmer 2013).

In public economics, policy assessment occurs relative to social welfare, in a framework of cost-benefit analysis taking into account all the significant direct and indirect effects of the policy on the economy and society. Empirical papers however tend to adopt a cost-effectiveness perspective due to the limitations of empirical cost-benefit analysis, which Ientile & Mairesse write is "as difficult as it is ambitious" (2009).

In order to measure cost-effectiveness, we first have to assess the extent to which households respond to the policy. There is no consensus in the literature, in particular regarding studies of the first US tax credit scheme: results differ depending on data and methodology. Dubin and Henson (1988) studied the scheme for the 1979 tax year, using fiscal data aggregated by Internal Revenue Service (IRS) district and audit class. They assessed the tax credit's effects on both the probability of declaring energy conservation investment and the amount of expenditure, and found no significant incentive effects (1988). Neither did Walsh (1989) using micro data from the 1982 Residential Energy Consumption Survey, nor Cameron (1985) using a nested logit model. On the other hand, using micro panel data covering 1979/1981, Hassett and Metcalf (1995) found a significant positive incentive effect of the tax credit on the likelihood of performing energy-efficiency improvements. However, they could not assess free-ridership,[3] which is defined as behavior occurring "when the agents targeted by the policy take the incentives but would have made the investment anyway" (Alberini et al. 2014)

Free-ridership has to be taken into account to avoid overstating a policy's efficiency in terms of additional energy savings. Moreover, free-ridership leads to a net social cost in the presence of administrative costs (to attract, to monitor, etc.).[4] Public revenues could have been allocated to other expenditure and subsidies may cause price distortions and have anti-redistributive effects. To our knowledge, Joskow and Marron (1992) were the first to discuss free-ridership in the literature related to domestic energy conservation. They conducted a meta-analysis by reviewing evaluations of demand-side management (DSM) programs implemented by U.S. utilities, in which estimates of free-ridership varied between 4% and 55%. Recent literature studying subsidies implemented to trigger domestic energy efficiency investment has focused on the assessment of free-ridership. Using a discrete choice model on German cross-sectional data, Grösche and Vance (2009) designated potential free-riders as those whose estimated marginal willingness to pay for a particular retrofit option is higher than the observed investment cost without subsidy, and found the proportion of free-riders approached 50%. Using the same database, Grösche, Schmidt, and Vance (2013) applied a more flexible discrete choice model to generate predicted choice probabilities for each retrofit option. They found that, as the size of the subsidy increases, the share of program funds allocated to free-riders decreases even as the overall cost of the program increases. Using discontinuity analysis regression to examine the adoption of energy efficient appliances, Boomhower & Davis (2014) found similar results. Alberini et al. (2014) studied the effects of an Italian tax credit implemented in 2007. Taking into account geographical heterogeneity, they found that the tax credit made the rate of window replacement increase by 37 to 40 percent in colder climates. They also found that increased free-ridership is more likely in the case of heating system replacement than window replacement.[5] Mauroux (2012) studied the French tax credit, called CIDD, implemented in 2005 in order to trigger households' investment in energy conservation and renewable energy equipment in their dwellings.

[2] A Pigouvian tax is intended to correct a market imperfection generating a negative externality and does so by being set equal to the externality, such as a carbon tax.

[3] The term of "windfall gains" could be more appropriate in order not to emphasize households' "intention to free-ride" but the use of the terms "free-riding, free-rider, or free-ridership" is the most common in energy efficiency literature.

[4] Such welfare loss is theoretically formalized by Boomhower & Davis (2014).

[5] A possible explanation is that heating system replacement only happens when the old equipment breaks down beyond repair.

The author analyzed the effect of the 2006 reform, which increased the CIDD rate from 25% to 40% for investments in old buildings after a recent housing transfer using fiscal data over the period 2006/2008. Her results suggested the presence of significant free-ridership: around two thirds of the CIDD beneficiaries would have applied for the subsidy even without the reform. The effect of the reform was also found to increase over time. In these two papers however, free-ridership assessment was not complete as data did not provide the share of subsidized retrofits on the whole of energy-efficiency retrofitting investments.

In this paper, we assess the same French income tax credit (CIDD) as Mauroux (2012). Our approach in this paper is first to assess the impact of the CIDD on energy-saving investments on the extensive margin at the time of its introduction in 2005. The extensive margin corresponds to the number of retrofit investments that were triggered by the implementation of CIDD, in other words the effect of CIDD on the probability of retrofitting. Second, the paper assesses how the effect of the CIDD evolved over the period 2005/2011. Third, those estimations enable an assessment of the proportion of free-riders and what individual and housing characteristics influence free-riding. An unbalanced panel of individual data coming from the "Energy Management" (EM) annual survey conducted over the period 2002/2011 and dedicated to households' energy-efficiency investments in their dwellings is used since behavior-based estimates are more reliable than self-reports (Malm 1996). In the absence of a control group, a difference estimator relying on time and policy-design change is performed, as in Alberini et al.(2014). This estimation focuses on insulation measures (windows, walls, roofs, etc.).[6] Control variables are included in the model and a test for pre-trends over the period 2002/2004 is conducted in order to avoid ascribing to CIDD effects that are due to exogenous unobserved time-varying variables. We also include individual effects to control for unobserved time-constant variables.

Our results suggest a significant and positive effect of CIDD on householders' investment decisions but with a lag of two to three years depending on the category of retrofits. After the initial lag, the estimated average marginal effects of CIDD rise progressively, especially in 2009, before slightly decreasing in 2011. These changes are consistent with actual changes in the tax credit rates and with the slowness of the investment decision-making process. As regards the assessment of free-riders, the estimated share of free-riders among CIDD beneficiaries varies between 40% and 85% in years for which the effect of CIDD was significant. This is consistent with the range of values found in the literature and confirms that free-riding is an important phenomenon. Free-ridership is found to have decreased gradually over the period, to be lower for measures relating to opaque surface insulation than those related to glazed surface insulation.

In section 2 we first review the French context and describe the tax credit scheme being studied. Section 3 presents the data, the variables and descriptive statistics. Econometric methods are explained in section 4. Section 5 presents the results, which are discussed in section 6, with conclusions in section 7.

Description Of The French Context And Tax Credit Scheme[7].

The residential sector consumed 30% of the total French energy supply in 2011 (in final energy),[8] mainly for space heating and hot water. The French policy package called "Grenelle de l'Environnement" (voted in 2009) aims at cutting energy consumption in the existing building stock by at least 38% by 2020, compared to the 2008 level.

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[6] Information on other retrofitting investments, such as efficient heating systems and equipment producing renewable energy, is too scanty to introduce them in the analysis, as discussed below **Erreur ! Source du renvoi introuvable.**.

[7] This review of the French tax credit scheme is based on information from several Official Tax Bulletin publications (BO n°147, September 2005; BO n°183, May 2006; BO n°88, July 2007; BO n°38, April 2009; BO n°65, June 2009; BO n°77, August 2010; BO n°84, December 2011) and public reports or publications (Mauroux et al. 2010), (Pelletier 2011), (Mauroux 2012).

[8] Source: "Le bilan énergétique de la France en 2011" http://www.developpement-durable.gouv.fr/IMG/pdf/LPS130.pdf

The French tax credit scheme CIDD started in 2005.[9] The tax credit was initially implemented for the period from 2005 to 2009 and was extended until 2015. The purchase of energy efficient equipment and materials for main dwellings[10] is eligible for income tax credits. All households, regardless of their level of income, can apply for the CIDD tax credit.[11] The tax credit subsidy is capped at 8,000€ for a one-person dwelling, 16,000€ for a two-person dwelling (with an additional allowance of 400€ per child) for a period of five consecutive years.

Eligible investments include both energy conservation measures, such as opaque and glazed surface insulation[12] and heating system improvements,[13] and renewable energy systems, such as wood-heating appliances, photovoltaic panels, solar heaters and domestic wind turbines. Renewable energy production systems and heat pumps are eligible for all types of buildings, whereas insulation measures and other heating system improvements are only eligible for buildings more than two years old. The tax credit rates range from 15 to 50% of investment cost and are specific to each category and are based on energy performance criteria. Changes in the tax credit rates, as well as in energy performance eligibility criteria, result from a compromise between the aim of targeting the most energy-efficient systems, the desire to limit public expenditure, and lobbying from the supply side.[14] Whereas the tax credit base has generally only subsidized material costs of measures, a reform in 2009 included labor costs of installation for the insulation of opaque surfaces. A further amendment occurred in 2011 where the tax credit was cut by 10% due to the economic crisis and concerns about the public deficit.

According to statistics from the "Energy Management" (EM)[15] survey on households' intentions to apply for the available economic incentives,[16] French households have benefited from CIDD far more than from other contemporary instruments.[17] Since 2005, more than half of the households investing each year in retrofitting their homes have used the CIDD, this proportion having reached nearly 70% since 2007, whereas less than 7% of them used other subsidies over the same period. Moreover, according to the same survey, CIDD is widely known (56.9% of households were aware of it in 2005, steadily increasing to 85.2% in 2009) and has been considered by households as the most decisive incentive since 2006 (see **Erreur ! Source du renvoi introuvable.**). Due to its success, CIDD has led to large public expenditures: 985 M€ in 2005, 1.9 Bn€ in 2006, 2.2 Bn€ in 2007, 2.8 Bn€ in 2008, 2.6 Bn€ in 2009, 1.96 Bn€ in 2010 and 1.1 Bn€ in 2011.[18]

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[9] Earlier legislation allowing fiscal deductions already existed (since 2001 for thermal insulation material) but did not specifically target energy efficiency renovations and its scope was not comparable with that of CIDD: public expenses were around ten times lower (http://www4.minefi.gouv.fr/budget/plf2004/somble04.htm), due to lower level of subsidies and a lower proportion of beneficiaries, especially for insulation measures (according to households' declarations in the EM survey).

[10] The Tax Credit had only subsidized owner-occupiers and tenants but in 2009 it was extended to landlords renting their dwellings.

[11] For households who pay income tax, the CIDD takes the form of an income tax reduction. For households who do not pay income tax, the CIDD tax credit is converted into a direct payment proportional to the amount of income tax one would save for a similar measure.

[12] Opaque surface insulation refers to the insulation of the attic, the walls (indoor or outdoor) or the floor (or a combination of different types of insulation) while glazed surface insulation refers to the installation of more energy-efficient windows and/or shutters.

[13] Heating system improvements are: the installation of heating regulation systems (thermostatic valves, heat cost allocators, ambient thermostat, programming equipment) and the installation/replacement of energy efficient heating systems (boilers, heat-pumps).

[14] Heat-pumps are a good example: air-air heat-pumps were only eligible between 2006 and 2008 whereas thermodynamic heat-pumps for water heating started to be eligible in 2010.

[15] The Energy Management survey is supervised by the French Agency for Environment and Energy Management (ADEME) and conducted by the French market research institute TNS-Sofres. More information in section 3.

[16] In this paper, households' declared intentions to apply for the different economic incentives are used to determine the proportion of corresponding beneficiaries, which means assuming that the proportion of applicants who would not be subsidized is negligible.

[17] Available subsidies include regional or local subsidies, national subsidies delivered by the ANAH (National Housing Agency), for which the modalities can vary with income, retrofitting performance, etc.

[18] Data from the Public Finances general Directorate (DGFiP). Public expenses (in million €) for opaque and glazed insulation were

After the implementation of CIDD, another economic instrument was created. When households invest in a combination of at least two retrofitting measures taken from an options list, an interest-free loan (known as EcoPTZ) could have been combined with CIDD for the same investment since 2009 (except in 2011) but has been used much less than CIDD.[19] A total of 70,933 EcoPTZ were issued in 2009 (resp. 78,484 in 2010 and 40,755 in 2011), while by contrast, more than 1 million households have benefited from CIDD every year since 2006. In the case of insulation measures, EcoPTZ has benefited households much less than CIDD: the proportion of investors intending to apply for CIDD was 49.1% and 84.5% for opaque and glazed surface insulation respectively whereas the proportion of investors intending to apply for EcoPTZ was 3.1% and 3.3% for opaque and glazed surface insulation respectively.

Data

The data used in this paper come from the annual EM) survey,[20] which provides detailed information on the retrofitting decision process, retrofit options, the characteristics of households and dwellings, and on the subsidies they received. We use data collected from 2002 to 2011[21] and treat this as an unbalanced panel.[22] Over the period 2002/2011, 23,879 households were surveyed with an average turnover rate between two successive years of 49%. The number of annual observations goes from 6,148 households in 2005, to 8,498 in 2009. Every year, households are asked about their residential energy consumption and the investments they have or have not made, in order to improve the energy efficiency of their dwelling. A first questionnaire provides data on socio-economic variables, housing information (type of building, heating energy source, building date, etc.), and information about dweller's situation (occupation status, move-in date). Those who have invested in retrofitting their home during the last year (7-12% each year) answer a second questionnaire to provide information on retrofitting categories, investment costs, means of payment, the economic or non-economic incentives investors have benefited from (including tax credit), as well as other pieces of qualitative information such as their motivation, personal context, satisfaction, etc. In this second questionnaire, up to four items from the list of possible retrofits are reviewed.

Figure 1 shows retrofitting rates in the main dwellings among all homeowners for all the main retrofitting categories. Retrofitting categories are here accounted for separately, even if the same households have undertaken several measures belonging to different categories. As for the installation or replacement of standard heating systems with non-renewable energy, we do not observe any trend. This suggests that CIDD would only potentially impact the decision to invest at the intensive margin (leading to choose more energy-efficient equipment), since the retrofitting rate seems unresponsive to the introduction of CIDD. Unfortunately, as explained below **Figure 1** this cannot be properly measured as the data do not provide the precise energy performance characteristics of each system. No increasing trend appears for heating regulation/ventilation systems either. We cannot say anything for equipment producing renewable energy as the series start in 2005. An exception could be wood stove installation or replacement (observed since 2000), whose installation rate seems to slightly increase after 2005 but statistical tests cannot be performed due to limited sample size and low rates of installation.

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estimated at 518 in 2005, 741 in 2006, 948 in 2007, 811 in 2008, 902 in 2009, 417 in 2010 and 363 in 2011 mainly for windows (CGDD 2012).

[19] This has been mainly due to the reluctance of the banking sector to propose such loans (Pelletier 2011). Eligibility criteria have also been tightened.

[20] The datasets are not in open access. Any researcher who wants to use the data has to sign a convention with ADEME and TNS-SOFRES. Contact the author for more information.

[21] The survey has been conducted since 2000 but we restricted the sample to the period 2002/2011 for the econometrics because some explanatory variables such as Individual Preferences are unavailable for 2000 and 2001. Robustness checks run over 2000/2011 do not change the results.

[22] Annual recruitment is carried out by TNS-Sofres to ensure representation of all socio-economic profiles after the departure of households wishing to leave the survey. Attrition will be discussed in section 5.

Focusing on insulation measures, **Figure 1** shows investment rates separately for opaque and glazed surface insulation.[23] Investment rates for both insulation types follow similar changes, which indicate some correlations between these retrofitting measures and the necessity to study them all together. We do not see any particular trend for either before 2005. After 2005, we see a slight increase until 2008, especially for glazed surface insulation, then a peak in 2009 and a decline thereafter. This suggests that there was a differentiated effect during two sub-periods of the implementation of CIDD's: 2005/2008 and 2009/2011. Finally, the average CIDD rate for all insulation measures shown on the right axis of **Figure 1** seems correlated with the retrofitting rates for insulation, especially from 2007. The peak in 2009 is due to the reform relating to the inclusion of labor costs, and shows a large increase in the tax credit rate.[24]

Econometric Methodology.

We aim to determine the impact of the CIDD tax credit on the probability of investing. In the absence of a control group or any appropriate exogenous variable to identify the impact of the CIDD, the identification strategy relies on the comparison of the dependent variable before and after the CIDD introduction.

Let $\hat{\Delta}_0$ be the "naive" difference estimator:

$$\hat{\Delta}_0 = \overline{I_{it}^{CIDD_t=1}} - \overline{I_{it}^{CIDD_t=0}}$$

with I_{it} the dependent variable, i.e. the retrofitting investment decision, $\overline{I_{it}^{CIDD_t=1}}$ and $\overline{I_{it}^{CIDD_t=0}}$ the empirical mean of I_{it} respectively before and after the implementation of CIDD. Let $CIDD_t$ be a dummy variable equal to one after the implementation of CIDD and zero before. $\hat{\Delta}_0$ captures the average effect of the introduction of CIDD on the dependent variable and is identified by the marginal effect of $CIDD_t$ on I_{it} and is unbiased if all unobserved explanatory variables are constant over time (Crépon & Jacquemet 2010). Therefore, in order to avoid ascribing to CIDD effects that are due to exogenous unobserved time-varying variables, the model implementing the difference estimator Δ has to include all the relevant variables that are likely to change over time. Second, the eventual presence of trends in unobservable potential time-varying variables is checked over the period before the implementation of CIDD. Third, temporal changes in the tax credit rate will be integrated in the model in a second step to improve the identification.

To estimate the effect of CIDD on the probability of investing, the difference estimator Δ is implemented in a random effect (RE) dichotomous logit model,[25] as follows:

$$P(I_{it} = 1 \mid CIDD_t, X_{it}, u_i) = \frac{e^{\alpha + \sum_{t=2002}^{2004} \gamma_t T_t + \sum_{t=2005}^{2011} \delta_t CIDD_t + \beta X'_{it} + u_i}}{1 + e^{\alpha + \sum_{t=2002}^{2004} \gamma_t T_t + \sum_{t=2005}^{2011} \delta_t CIDD_t + \beta X'_{it} + u_i}}$$

with $P(I_{it} = 1)$ the probability of investing in retrofitting for household i at time t, $(T_t)_{t=2002,..,2004}$ the annual dummies referring to the period before the introduction of CIDD,

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23 We use "window" with an extensive meaning of all glazed surfaces.

24 Considering that labor costs represent at least 30% of the total cost (based on the EM survey over the period 2008/2011, since no data were available making the distinction between labor and material costs before 2008, labor costs as a percentage of total costs go from 32% for roofs to 39% for ceilings), this reform is equivalent to an increase of at least 50% in the tax credit rate.

25 The conditional fixed effects logit model is not used since it is estimated only on individuals having variation in the outcome, which excludes too many observations. Indeed, among the 23,879 households surveyed over 2002/2011, only 2,674 households are observed for at least two years and have variation in the outcome as regards retrofitting investments in opaque and glazed surface insulation (1,425 considering only retrofitting investments in opaque surface insulation).

$(CIDD_t)_{t=2005,..,2011}$ are the annual dummies referring to the period after the implementation of CIDD,[26] and u_i a random individual effect. $X_{it} = (x_{1it},...,x_{kit})$ are the exogenous observed covariates.

These explanatory variables are selected on the basis of the literature on household investment modeling in residential energy. The basics of those models consist of calculating the return on retrofitting investment by comparing initial cost with future economic savings in a cost-benefit analysis, in which technological, socio-economic and contextual constraints can interact. The socio-demographic variables influencing the investment decision in the model are the Annual income of the household, the Socio-professional category,[27] the Family size, the Age of the head of the household and the move-in-date. As regards the status of occupation, we restrict the analysis to homeowners.[28]

In order to capture changes in individual preferences about the environment and the economic context, possibly linked to either macroeconomic or social changes, we also include data on households' main concerns. In the EM survey, households are asked every year to rank, in order of importance, their concerns about environmental (e.g. pollution, climate change, renewable energy…) and economic issues (unemployment). Environmental concern and Economic concern are included as dummy variables equal to one if the household has identified pollution, and, respectively, unemployment, as one of the main concerns. The Building completion date, the Building type (single or multi-family buildings),[29] the Dwelling size (surface area in square meters) and the Heating energy sources are the home characteristics variables included in the model to describe the energy performance and the level of energy consumption, conditioning the profitability of the investment.

We include the average heating energy price determined on the basis of the main energy source declared by each household (electricity, gas, fuel, wood, district heating and a mix between electricity and wood).[30,31] Dwellings heated by wood and district heating have been omitted from the sample in the econometrics estimation since energy prices have only been available since 2003 for these two energy sources. The regional Heating degree days (HDD)[32] and the Location Category are used to represent the climatic and spatial characteristics of the dwelling.

Contrary to a linear model, the difference estimator Δ is not directly derived from the estimated coefficients δ but from the marginal effects of $CIDD_t$ on $P(I_{it} = 1 \mid X_{it}, u_i)$:

$$\frac{\partial P(I_{it} = 1 \mid X_{it}, u_i)}{\partial CIDD_t} = \delta_t (1 - P(I_{it} = 1 \mid X_{it}, u_i)) P(I_{it} = 1 \mid X_{it}, u_i).$$

In order to estimate Δ, we compute the average of all the individual marginal effects.

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[26] We make the CIDD dummy interact with annual dummies in order to allow for temporal heterogeneity in the effect of CIDD.

[27] Distinguishing between a Business category (in a wide sense including company directors, farmers and shopkeepers), Professionals (including liberal professionals and executive managers), Employees and the Inactive.

[28] Indeed, the question in the EM survey about retrofit investment is ambiguous in the case of tenants since it is not clear what answer a tenant of a dwelling in which retrofitting has been undertaken by the owners should give, which can lead to potential measurement bias. Moreover, even if tenants were potentially concerned by the program, statistics show that CIDD has only impacted home-owners.

[29] New buildings and buildings other than single-family homes or multi-family buildings are also omitted from the sample.

[30] From statistics produced by the French Ministry of Ecology. http://www.statistiques.developpement-durable.gouv.fr/energie-climat/r/industrie-1.html?tx_ttnews[tt_news]=21083&cHash=fb5b458ff78e44f761db201e5f4a2641.

[31] The heating energy price variable is introduced as a rate of variation in the regression. Otherwise, it would capture differences between energy sources to a greater extent than changes in the price of each source of energy. At year y, the energy price variation variable is the growth rate between y-4 and y-1. We notably assume a certain inertia in the decision-making process, which is why there is a lag in the prices considered and why the growth rates considered are calculated over several years. We choose the specification maximizing the log-likelihood. Other specifications have been tested giving the same results (not reported in the paper but available on request). Even if the EM survey provides data on households' energy bills, we chose not to use it due to the number of missing values and the fact that we do not know if the reported energy bills correspond to the pre or post-retrofitting period for households who retrofitted during the previous year.

[32] From statistics produced by the French Ministry of Ecology. http://www.statistiques.developpement-durable.gouv.fr/energie-climat/r/statistiques-regionales.html?tx_ttnews. Heating degree day (HDD) is a measurement based on the gap between outside temperatures and a comfortable inside temperature. The heating requirements for a given structure at a specific location are considered to be directly proportional to the number of HDD.

Temporal variations in the tax credit rates are then added in a second model specification to test if the CIDD effect is correlated with the tax credit rate.

From those estimates, we derive the share of free-riders. It should be recalled that free-riding is defined as the situation in which the subsidized household would have undertaken the energy saving investment even in the absence of the subsidy. The free-riders share is defined as: $FRS = \frac{Invest_{Subsidized} - \hat{\Delta}}{Invest_{Subsidized}}$ where $Invest_{Subsidized}$ is the total number of renovations for which an incentive was requested. $Invest_{Subsidized}$ can be broken into two components: $\hat{\Delta}$, the renovations for which an incentive was requested and where the availability of the incentive was critical for the decision to do the renovation; and $Invest_{Subsidized} - \hat{\Delta}$, the number of investments for which an incentive was claimed, but the household would have made the renovation anyway. $Invest_{Subsidized} = \alpha_{CIDD} * \tau_{R}$, with τ_R the retrofitting rate among owner-occupiers and α_{CIDD} the proportion of retrofitters applying for CIDD, assuming that the measurement error caused by identifying households benefiting from CIDD with those applying for it can be ignored.[33] FRS confidence intervals are computed with the delta method.

Results

Table 1 shows the logit estimates over the period 2002-2011[34] for all the insulation measures. The table provides estimates for logit models with (column 3) and without (column 2) random individual effects (RE) plus a preliminary logit model without any covariate except the policy variable interacted with the year dummies (column 1).

The estimated marginal effects of the control variables reveal significant determinants of the investment decision. As regards household variables, being relatively wealthy has a positive impact on the retrofit decision. Professionals, Employees (and to a minor extent the Inactive) are more likely to invest than the Business category (including company directors, farmers and shopkeepers). The family size variable is insignificant. The age of household head variable was dropped due to correlation between covariates. Households having recently moved in also invest significantly more in energy efficiency.

Environmental preferences have a significant positive effect on the investment decision whereas the economic concerns variable is insignificant. As regards variables relating to the dwelling, households living in old buildings and/or in single-family homes are more prone to invest than those living in more recent and/or multi-family buildings. Larger surface area, which implies higher energy consumption for the same behavior in respect of energy use, significantly increases the probability of investing. As for the energy price variation variable, its effect is positive though insignificant. Regarding geographic patterns, households living outside Paris, and in particular in small cities or in rural areas, invest more in energy efficiency. The regional average heating degree days (HDD) variable, also positively correlated with energy consumption, impacts positively though insignificantly on the retrofit decision.

As regards the effect of CIDD, it should first be recalled that we use a difference estimator. The insignificance of annual dummies before 2005 confirms the absence of a temporal trend before the implementation of CIDD, which is a necessary condition for this estimation method. Then, after a three-year latency period (2005-2007) with no significant effect, the effect of CIDD on the investment decision starts to be significantly positive in 2008 at the 10% level. This positive effect strongly increases after 2009: becoming significant at the 1% level, it goes from 0.8 percentage points in 2008 to 3.1 in 2009 decreasing to 2.5 percentage points in 2010 and 1.5 percentage points in

[33] More accurate information is unavailable.
[34] 2001 has been omitted from the sample since a few variables were not available for that year.

2011.

First, the results reveal an initial latency period of two or three years with no significant effect, suggesting the existence of some inertia in households' response to the policy. This could first be due to the intrinsic temporality of such an investment decision, known to be a long process.[35] Second, we find an increasing, positive effect on the probability of retrofitting, especially from 2009, although with a decrease in the positive effects at the end of the period. Third, the increase in the positive effect in 2009 may be linked to the reform carried out in that year (the addition of the installation expenditure to the tax credit base in 2009 for opaque surface insulation measures). In this case, the CIDD effect acted as a price shock, as households' awareness of CIDD did not change much in the meantime.[36] Finally, the decreasing trend in the positive effect of CIDD at the end of the period can be related to the decrease in the CIDD rate for glazed insulation.[37] This suggests that the effect of CIDD is sensitive to the level of subsidy.

Comparing columns 1 and 2 with column 3 in both samples, the introduction of the covariates and the RE in the logit models changes the coefficients, mainly lowering the magnitude of the average marginal effects of the CIDD and other covariates.

Annual estimates of the share of free-riders (FRS) along with their confidence intervals are presented in **Table 2**, in addition to annual statistics on τ_R (the retrofitting rate among owner-occupiers), α_{CIDD} (the share of retrofitters applying for CIDD) and households' declarations about free-ridership provided in the EM survey. It does not provide estimates of the proportion of free-riding for those years for which the estimated marginal effect of CIDD was not significant, suggesting that free-riding would have been ubiquitous during these years. As regards all insulation measures, annual rates of free-riding decrease from 85% in 2008 to 61% in 2010, with a new increase to 70% in 2011.

When focusing on opaque surface insulation, annual rates of free-riding rates steadily decrease from 77% in 2007 to 42% in 2011. Estimates indicate that free-riding is more significant in the case of glazed surface insulation than opaque surface insulation. We remark that households' intentions to benefit from CIDD also decline at the end of the period, probably linked to the fact that more and more potential CIDD beneficiaries had already undertaken works and also to the decrease in subsidy rates. The percentage of households having benefited from CIDD and declaring themselves as free-riders decreased from 61.4% in 2006 to 52.4% in 2010 before going up again to 61.8% in 201138. Statistics for opaque surface insulation follow the same trend: from 66.9% in 2006 to 48.7% in 2010 and rising to 65.1% in 2011. Compared to our estimates, rates of declared free-riding display the same decreasing trend until 2010, with a new increase in 2011, but are lower in magnitude.

Discussion and conclusion.

This paper assesses the effects on households' retrofit investments of the most prominent incentive implemented in France: the CIDD tax credit introduced in 2005. Focusing on glazed and opaque surface insulation measures, we use an unbalanced panel of individual data from the EM annual survey over the period 2002/2011 in order to estimate the effects of CIDD on the extensive

[35] The average maturation period of a renovation project is more than 6 months, according to the OPEN[35] database, even more for a project including insulation measures (OPEN 2008).

[36] On the basis of the EM survey, the proportion of households surveyed only once that were aware of CIDD is 56.9% in 2004, 62.9% in 2006, 76% in 2007, 79.4% in 2008, 85.2% in 2009 and 83.4% in 2010.

[37] The fact that households can only benefit once from a CIDD subsidy over a five-year period can also contribute to a diminishing effect of CIDD in the long run too. Indeed, the CIDD subsidy being capped for a period of 5 consecutive years (see section 2), households having invested at the beginning of the CIDD implementation period (2005), or households having reached the subsidy cap, were no longer eligible in 2011, which might have contributed to the 2011 decrease in CIDD effects.

[38] The question did not exist in 2005.

margin of French households' retrofit investments. In the absence of a control group, we use a difference estimator in a random individual effect dichotomous logit model.

Results reveal a significant positive effect of CIDD on the probability of investing in retrofitting, though after an initial latency period of two or three years with no significant effect, and further suggest that the effect of CIDD is sensitive to the level of subsidy. Accordingly, the estimated annual proportion of free-riders among CIDD beneficiaries has globally decreased over the period: from 85% in 2008 to 61% in 2010 (70% in 2011), from 77% in 2007 to 42% in 2011 when focusing on opaque surface insulation (after quasi-ubiquitous free-riding over the period 2005/2007). Therefore, free-riding is an important phenomenon, higher for insulation of glazed surfaces than for opaque surfaces.

After being cautious about explanatory variable selection and conducting successful pre-trend tests, some uncertainties still remain as regards the difference estimator's ability to capture CIDD effects exclusively. In particular, unobserved time-varying factors linked to macroeconomic shocks, especially related to the economic crisis of 2008, still potentially exist. We have been careful to introduce individual subjective declarations in order to capture changes in environmental preferences and the economic conjuncture but other crisis-related time-varying factors could remain unobservable, such as budget and liquidity constraints, precautionary saving, etc. Assuming that the economic crisis would have had a negative, immediate, and temporary effect as regards insulation measures, this means that our CIDD effect estimates are likely underestimated after 2008 and especially in 2009.

Even though the difference estimation might not eliminate all sources of bias, the difference estimation is the only applicable method to assess the CIDD effect using our data in the absence of a control group or any appropriate exogenous variable to identify the effect of CIDD. Further steps could be the estimation of a structural choice model, but this would require using other data.

In terms of policy implications, the existence of inertia in households' response to the policy invites the implementation of consistent and simple tax credit design, accompanied by good communication. The sensitivity of households' response to the level of subsidy suggests that increasing the level of subsidy while strengthening the eligibility requirements would trigger more additional private investment for the same level of public expenditure. The heterogeneity found in the FRS also suggests targeting subsidies towards groups where the number of likely free-riders is low.

Tables

Table 1. RE logit's estimated marginal effects for opaque & glazed surface insulations

	logit (1)		logit (2)		logit RE (3)	
Variables	M.E.	S.E.	M.E.	S.E.	M.E.	S.E.
Annual dummies (ref:2002)						
2003	0.002	(0.0065)	0.001	(0.0062)	0	(0.0046)
2004	-0.004	(0.0069)	-0.002	(0.0067)	-0.006	(0.0045)
CIDD dummy*2005	0.001	(0.0069)	0.002	(0.0068)	0	(0.0048)
CIDD dummy*2006	-0.001	(0.0067)	-0.002	(0.0063)	-0.004	(0.0045)
CIDD dummy*2007	0.012*	(0.0066)	0.011*	(0.0065)	0.006	(0.0046)
CIDD dummy*2008	0.01	(0.0067)	0.013*	(0.0066)	0.008*	(0.0047)
CIDD dummy*2009	0.037***	(0.0073)	0.043***	(0.0074)	0.031***	(0.0054)
CIDD dummy*2010	0.027***	(0.0072)	0.038***	(0.0075)	0.025***	(0.0053)
CIDD dummy*2011	0.008	(0.0066)	0.018***	(0.0066)	0.015***	(0.005)
Environmental concerns			0.006*	(0.0034)	0.005**	(0.0024)
Economic concerns			-0.001	(0.0034)	0	(0.0024)
HDD			0	(0.006)	0.005	(0.0043)
Energy price variation			0.008	(0.0102)	0.008	(0.0075)
Dwelling size			0.001**	(0.0005)	0.001**	(0.0004)
Building completion date *(ref : < 1974)*						
1975/1988			-0.027***	(0.0045)	-0.022***	(0.0033)
1989/last year			-0.087***	(0.0033)	-0.065***	(0.0029)
Multi-family housing *(ref: single-family home)*			-0.041***	(0.0044)	-0.031***	(0.0029)
Annual income of the dwelling *(ref : <18500 euros)*						
18500 /36 300 euros			0.01**	(0.0046)	0.01***	(0.003)
>36 300 euros			0.007	(0.0057)	0.008**	(0.0038)
Move in date *(ref : < 3 years)*						
3 / 10 years			-0.071***	(0.0076)	-0.062***	(0.0067)
> 10 years			-0.095***	(0.0078)	-0.082***	(0.007)
Category of city *(ref : Parisian agglomeration)*						
> 20.000 inhabitants			0.004	(0.0059)	0.008**	(0.0037)
<20.000 inhabitants / rural			0.008	(0.0062)	0.009**	(0.004)
Socio-professional category *(ref : Entrepreneur)*						
Managers			0.029***	(0.0092)	0.023***	(0.006)
Employees			0.026***	(0.0091)	0.018***	(0.006)
Inactive			0.021**	(0.0091)	0.014**	(0.0058)
Family size *(ref : 1 person)*						
1 couple			0.008*	(0.0048)	0.004	(0.0035)
>2 persons			0.01	(0.0063)	0.004	(0.0041)
sigma_u					1.111	0.047
rho					0.273	0.017
Nb of observations	36367		36367		36367	
Nb of individuals	13116		13116		13116	
Log likelihood	-12411.527		-11714.13		-9432.6265	

*(resp. ** and ***) significant at 10% level (resp. 5% and 1%).

col (1): logit estimates without covariates; (2) logit estimates; (3) RE logit estimates

Table 2. Free-ridership estimation.

All retrofit incl. Insulation (opaque and glazed surfaces)							
	2005	2006	2007	2008	2009	2010	2011
Observed retrofitting rate*	6.77	6.59	8.22	7.99	10.91	9.61	7.8
Observed CIDD recourse rate**	62.88	67.57	67.52	68.46	74.29	73.43	64.79
Estimated CIDD M.E.	0	-0.004	0.006	0.008	0.031	0.025	0.015
Standard errors	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Estimated FRS	-	-	-	0.85	0.62	0.65	0.7
FRS 95% Confidence interval	-	-	-	[0.69 - 1]	[0.49 - 0.75]	[0.5 - 0.79]	[0.51 - 0.9]
Declared FRS***	-	61.4	56.2	48.8	55.1	52.4	61.8
(N)****	-	255	310	335	425	398	275

Opaque Insulation							
	2005	2006	2007	2008	2009	2010	2011
Observed retrofitting rate*	2.91	2.83	3.7	3.51	4.93	4.6	3.89
Observed CIDD recourse rate**	.	29.96	36.29	39.37	48.83	42.02	39.95
Estimated CIDD M.E.	0.001	-0.001	0.003	0.004	0.013	0.011	0.009
Standard errors	0.002	0.002	0.002	0.002	0.003	0.003	0.002
Estimated FRS	-	-	0.74	0.68	0.48	0.43	0.43
FRS 95% Confidence interval			[0.45 - 1]	[0.4 - 0.97]	[0.27 - 0.68]	[0.18 - 0.69]	[0.13 - 0.73]
Declared FRS***	-	66.9	60.6	60.1	58.3	48.7	65.1
(N)****	-	123	169	142	227	224	167

(*) the renovation rate for insulation in % among occupying homeowners, (**) the % of households having invested in retrofitting who apply for CIDD, (***) % of CIDD beneficiaries stating that CIDD had no effect on their decision, (****) Number of respondents to the question "What was the CIDD effect on your decision to retrofit?"

Note : Confidence intervals are computed with the delta method.

Figures

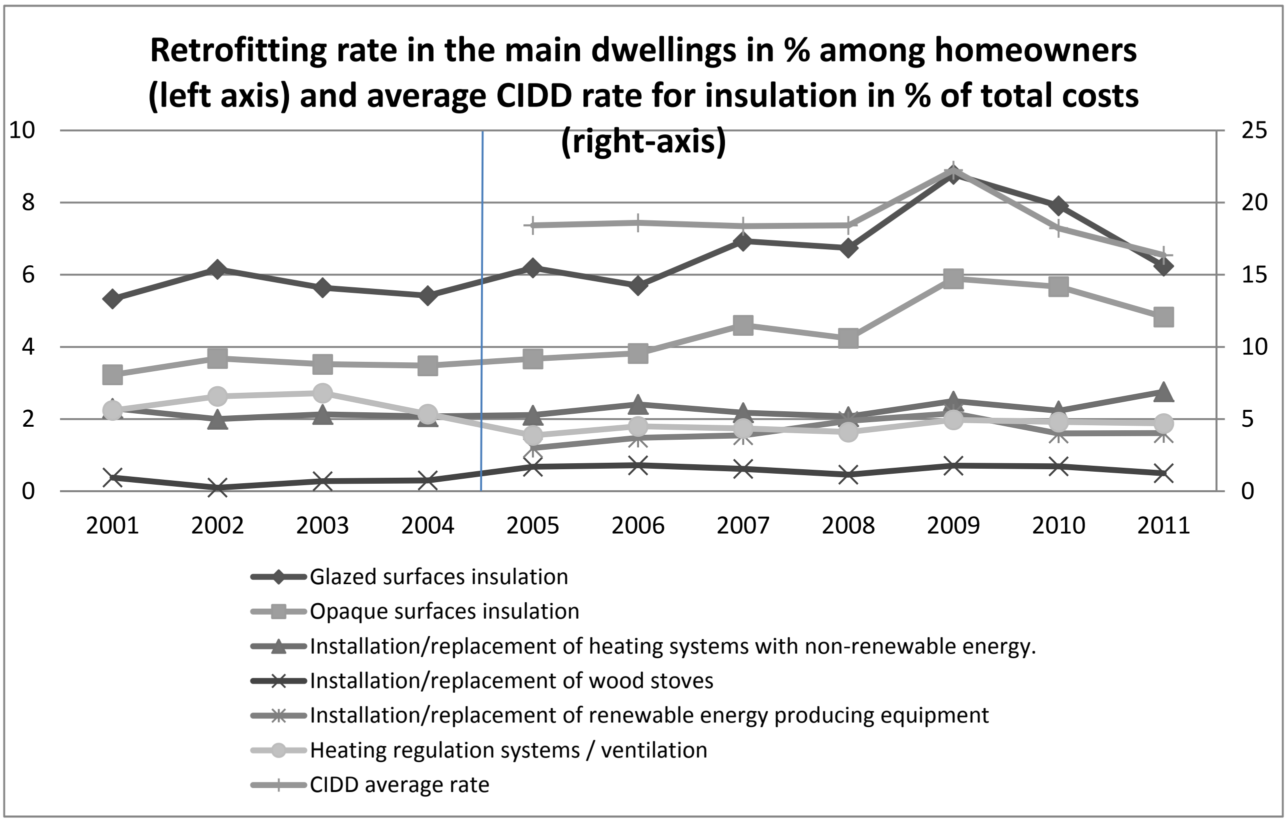

Figure 1. Retrofitting rate in % among occupying homeowners.

Note: Data are inappropriate to estimate the CIDD effect on retrofit measures other than opaque and glazed surface insulation. As for the category “installation/replacement of heating systems with non-renewable energy”, we do not observe the energy performance of each system, on which CIDD eligibility is based[39]. As for “heating regulation/ ventilation systems” and “installation/replacement of wood stoves”, the sample size cannot provide robust statistics given their low retrofitting rates. Equipment producing renewable energy and heat-pumps are excluded from the analysis since the EM survey does not mention these systems in the list of retrofitting options before the introduction of CIDD. The average CIDD rate is weighted by the market shares of the different types of insulation and takes into account the repartition between material and labor costs for each type of insulation (based on statistics from the EM survey over 2009/2011).

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