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# How Effective Are Energy-Efficiency Incentive Programs? Evidence from Italian Homeowners

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# How Effective Are Energy-Efficiency Incentive Programs? Evidence from Italian Homeowners

By

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## Abstract

We evaluate incentives for residential energy upgrades in Italy using data from an original survey of Italian homeowners. In this paper, attention is restricted to heating system replacements, and to the effect of monetary and non-monetary incentives on the propensity to replace the heating equipment with a more efficient one. To get around adverse selection and free riding issues, we ask stated preference questions to those who weren't planning energy efficiency upgrades any time soon. We argue that these persons are not affected by these behaviors. We use their responses to fit an energy-efficiency renovations curve that predicts the share of the population that will undertake these improvements for any given incentive level. This curve is used to estimate the $CO_2$ emissions saved and their cost-effectiveness. Respondents are more likely to agree to a replacement when the savings on the energy bills are larger and experienced over a longer horizon, and when rebates are offered to them. Reminding about $CO_2$ (our non-monetary incentive) had little effect. Even under optimistic assumptions, the cost-effectiveness of incentives of size comparable to that in the Italian tax credit program is generally not favorable.

**Keywords:** Energy-efficiency incentives; Free riding; Adverse selection; Stated Preferences; $CO_2$ emissions reductions; $CO_2$ emissions reductions supply curves; residential energy consumption.

**JEL Classification:** Q41 (Energy: Demand and Supply; Prices); Q48 (Energy: Government Policy); Q54 (Climate; Natural Disasters; Global Warming); Q51 (Valuation of Environmental Effects).

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## 1. Introduction and Motivation

In recent years, many countries have implemented policies that offer incentives to encourage residential energy-efficiency upgrades. These typically include certain home renovations (such as insulation and new windows) and equipment (such as high-efficiency heating and cooling systems, and selected appliances). A major goal of these policies is to reduce the emissions of greenhouse gases associated with electricity generation and energy use in the home. Additional benefits include diminished reliance on fuel imports and reduced pressure on highly congested grids. Support for these policies is motivated by their large potential, as buildings account for some 30-40% of all energy use, and alleged low or even negative cost (Levine et al. 2007; Choi Granade et al., 2009).

Despite the extensive reliance on these systems, little is known about their effectiveness at reducing energy use and the associated greenhouse gas emissions. Assessing incentive programs is inherently difficult because of adverse selection issues (people replace equipment at the end of its life; Sandler, 2012), free riding (people may install thermal integrity measures, but would have anyway, even in the absence of the incentives) and because these programs are likely to attract persons who are more productive at reducing energy use (Joskow and Marron, 1992). Unless these factors are appropriately accounted for, evaluations will typically overstate the effectiveness of the programs (Joskow and Marron, 1992; Boomhower and Davis, 2013).

Evaluating incentive programs requires answering three key, and related, questions. The first is how responsive households are to the incentive amount: In other words, by how much must the incentive be raised to result in the desired number of energy efficiency adoptions?

Second, what is the reduction in energy use (and associated carbon emissions) that can be correctly ascribed to the program? Third, what is the cost (to households, taxpayers, and other parties) per unit of energy or carbon emissions avoided, and how does that compare with that of alternate policies?

Despite the extensive reliance on residential energy efficiency incentives, the evidence about the first question is mixed and inconclusive (Walsh, 1989; Hassett and Metcalf, 1995; Boomhower and Davis, 2013). Identifying the energy use reductions that can be correctly be attributed to incentive programs--the second key question above—is even more challenging. An important concern is free riding, which occurs when the economic agents targeted by the policy take the incentives, but would have done the home renovations or appliance replacements anyway. Blumstein (2010) and Vine et al. (2001) discuss the difficulty of recognizing free riders, and other studies have used a variety of approaches to estimate the shares of free riders in incentive-based programs (Joskow and Marron, 1992; Malm, 1996; Grosche and Vance, 2009; Boomhower and Davis, 2013). In practice, some studies simply assume free ridership away, others assume that the impact of free riders cancels out with other behavioral responses (Haberl, Adensam and Geissler, 1998), and others yet assume that a specific percentage of the program participants are free riders (e.g., Allaire and Brown, 2012).

Ignoring free riders overstates the cost-effectiveness of an incentive program—the third key question above—sometimes to a staggering extent (Joskow and Marron, 1992). Hartman (1988) establishes that the average conservation truly attributable to an audit program is only 39% of the savings calculated based on a naïve comparison between participants and non-participants. Waldman and Ozog (1996) study a specific “demand side management” (DSM) program and estimate that it only accounts for 71% of total energy conservation; the rest would have happened regardless. In Loughran and Kulik (2004) DSM expenditures are found to have reduced electricity usage by at a cost per kWh that exceeds the price charged to consumer.

In contrast, Gillingham and Palmer (2013) and Blumstein (2010) discuss free drivers, namely persons who do not avail themselves of the incentives offered by a program, but choose to make energy-efficiency purchases because their awareness has been raised by the existence of the program. Alberini, Banfi and Ramseier (2013) report that climate change concerns and $CO_2$ emissions are important drivers of Swiss homeowners' decisions to undertake energy efficiency upgrades, at least as reported in a stated preference survey, and Ramseier (2013) finds that energy consultants exert an important influence in the nature and extent of actual energy efficiency home renovations in five cantons in Switzerland.

In this paper we report the results of a study where we gathered both revealed and stated-preference data from a sample of Italian homeowners. The survey was conducted in May-June 2013 through computer-assisted web interviews. Tax credits to help defray the cost of energy efficiency home renovations have been available to Italian homeowners since the beginning of 2007. Until recently, specified energy efficiency upgrades on existing homes and buildings, including heating system replacements, insulation, and new windows, qualified for 55% tax credits on the purchase and installation costs. From June 6, 2013 to December 31, 2013 (June 30, 2014 for renovations in communal parts of apartment blocks), the tax credits were temporarily increased to 65% of the purchase and installation costs.

The Italian Renewable Energy Agency (ENEA) reports that hundreds of thousands of tax credit claims have been filed every year since the inception of the program. Unfortunately, the Agency does not make the individual claim data available (ENEA, 2009, 2010, 2011; Alberini, Bigano and Boeri, 2014), which prevents us from studying the reasons for the energy-efficiency renovations and the responsiveness to the size of the incentives themselves. We circumvent this problem by developing a survey questionnaire to gather information about upgrades covered by the tax credits, their costs and characteristics. The questionnaire was administered on-line to a representative sample of Italian homeowners.

Since adverse selection and free riding are likely to be pervasive in the presence of energy-efficiency upgrades funded through incentives, in this paper we deploy a somewhat different approach to getting around this problem and getting a “clean” estimate of the cost-effectiveness of the program. Specifically, we query a group of people that is arguably unaffected by these behaviors—those who weren’t planning to change their heating equipment, or do any other energy efficiency upgrades any time soon—to study their responsiveness to potential savings, the life span of the investment, and the size of the incentive. With these persons, we use stated preference questions. Our study design randomly assigns savings, equipment lifetimes and incentives to these persons, making the setting similar to that of a randomized controlled trial. We likewise use random assignment to a specific treatment—the reminder that more energy-efficient equipment reduces $CO_2$ emissions—to examine the importance of “public good” considerations (Kotchen and Moore, 2007; Kotchen, 2009; Jacobsen et al., 2012).

We use the responses to our hypothetical questions to fit an energy-efficiency renovations curve that predicts the share of the population that will undertake these improvements for any given level of the incentive. Combined with information about $CO_2$ emissions and the likely remaining life of the equipment to be replaced, this curve is used to estimate the $CO_2$ emissions saved and their cost-effectiveness.

Briefly, we find that the responses to our survey questions are internally valid. Respondents are more likely to agree to a heating equipment replacement when the savings on the energy bills are larger and experienced over a longer horizon, and when rebates are offered to them. Each $100 increase in the incentive amount raises the likelihood of replacing the heating system at the stated conditions by 3 percentage points. The reminder about $CO_2$ emissions reductions and climate change, however, had little effect. Even under optimistic assumptions about energy and emissions savings, and the remaining life of the equipment to be replaced, the cost-effectiveness of incentives of size comparable to that in the Italian tax credit program is generally not favorable.

The remainder of this paper is organized as follows. Section 2 provides background about energy efficiency incentives in Italy. Section 3 presents theoretical considerations. Section 4 describes methods and study design. Section 5 presents the econometric model. Section 6 describes the data. Section 7 reports on estimation results, and section 8 concludes.

## 2. Policy Background

Effective February 19, 2007, a national law allowed homeowners to deduct from their income taxes up to 55% of the expenses incurred to implement certain types of energy efficiency renovations or source of renewable energy in existing homes.[2] (Earlier legislation in place since 1998 allowed deductions for renovations--36% of expenses--but did not target energy efficiency renovations.)

These include the replacement of the heating system, windows and doors; attic and wall insulation; the entire building envelope, and hot water solar panels. Photovoltaics are specifically excluded because they are addressed by other laws and programs. Applications for the tax credits

[2] Caps of €30,000, €60,000, and €100,000 per residential unit apply, depending on the type of renovation.

must be accompanied by a professional engineer's certification of the renovations and estimated energy savings. After 2007, the law was amended, in that changes were made to the number of years over which the tax deductions can be spread.

The Italian Renewable Energy Agency (ENEA, 2008, 2009, 2010) reports that there were 106,000 filings for the tax deduction for tax year 2007, 248,000 for tax year 2008 and 237,000 for tax year 2009. These documents also calculate the cost-effectiveness of the emissions reductions made possible by the energy savings attributed to these renovations (assuming no free riding). ENEA (2010) reports that in 2009, 49% of the filings were for window and door replacement, 30% for heating system replacement, 15% for thermal solar panels, 4% for attic, ceiling or floor insulation, and 2% for "vertical wall" insulation.

## 3. Theoretical Considerations

Decisions about energy-using capital (or home renovations that improve the thermal integrity of the dwelling) and energy usage are usually represented assuming a two-stage utility maximization process. In the first stage, the household chooses the level of consumption of other goods and the desired level of "energy services" (e.g., thermal comfort). In the second stage, the household chooses the combination of capital stock $K$ and energy use $E$ that minimizes expenditure for any given level of energy services. At the optimum, the slope of the isoquant representing the possible combinations of capital and energy for any given technology is equal to the ratio of capital and energy prices.

Figure 1 depicts a possible set of isoquants and isocost lines. The technology represented in isoquant S2 is more efficient than that in isoquant S1, since the former uses less energy at any given level of capital. At a given initial level of prices, the hypothetical household represented in

Figure 1 selects optimal point A. Subsidies or tax credits expressed as a percentage of the price of capital change the isocost line, which becomes steeper and has a higher K-intercept. This results in optimum B, which uses more capital and less energy than A.

It can be shown that the first order conditions for the private optimum imply that households energy-saving home renovations to the point where the marginal benefit from the investment (the marginal willingness to pay for thermal comfort) is equal to the private marginal cost of the investment. On aggregating the individual households' demand functions, one obtains the market demand for home renovations, which is the solid downward sloping line in Figure 2. The private-optimum number of renovations is $Q_1$.

Using energy, however, generates externalities (such as emissions of conventional pollutants and $CO_2$ associated with power generation, excessive load on the grid, dependence on foreign imports of fuel, etc.), and so the social marginal benefit is the dashed line in Figure 2. The social optimum is Q*, which is clearly greater than $Q_1$.

Offering a tax credit on the cost of energy-efficiency investments lowers the marginal cost of the investment (dashed flat line in Figure 2), but if households cannot be forced to internalize the externalities associated with energy production and use, the final outcome will be at point C, and those households that would have done the renovation at the initial, unsubsidized cost level—the free riders—will simply pocket the amount of money corresponding to the area of rectangle DFAE.

In this paper, we collect information from the households who received incentives, and we focus on estimating the slope of the line from A to C: In other words, we seek to establish how many more adoptions of energy-efficient technologies can be attained with each subsequent increase in the subsidy. We also seek to establish whether reminders about the importance of reducing $CO_2$ emissions get people to internalize the social benefits of energy-efficient technologies.

## 4. Study Design

*A. Questionnaire and Study Design*

We gathered extensive information about recent and potential future energy efficiency upgrades through a survey of Italian homeowners. The questionnaire collected information about the structural characteristics of the respondent's home, fuels used, and energy costs. It also inquired about hot water solar panels (a form of no-emissions renewable energy), heating equipment, appliances such as refrigerators and washing machines, and measures that improve the thermal integrity of the home (insulation and new windows). For each of these devices, we elicited information about the existing equipment, including make and model, year of installation, capacity and energy efficiency rating.

For heating equipment bought in 2007 (the date of inception of the tax credit policy) or later, for example, we asked how much it cost, whether a government rebate or tax credit was applied to that purchase, and how much that was. If the equipment was older, we asked the respondent if he or she planned to replace it within the next five years. If not, we further asked respondents whether they would replace it within five years at a cost of €2000, if doing so resulted in R% savings in the energy bills over the subsequent T years. R and T were varied at random across respondents. R ranges between 10 and 40%, whereas T ranges between 13 and 25 years.

Those respondents who were willing to make the purchase within the next five were asked if they would make the purchase within the next three years. Those who declined were offered a hypothetical rebate (ranging from €100 to €1000 for heating equipment) to see if that was sufficient to change their minds. A summary of the structure of these hypothetical questions is depicted in figure 3. Half of the respondents were also told that changing the equipment would reduce greenhouse gas emissions, to see if this would encourage them to make the (hypothetical) investments. Respondents were assigned at random to the variant of the questionnaire that reminded them about $CO_2$ emissions.

The questionnaire also elicited the respondent's attitude about conservation and energy efficiency. The last section of the survey instrument asked questions about the respondent's socio-demographic and economic circumstances.

*B. Survey Administration*

The survey questionnaire was administered via internet to a sample drawn from the panel of consumers assembled in Italy by IPSOS, an international survey firm. Respondents were recruited among persons who own homes built before or in 2000 and live in them, and were placed into one of three possible groups: i) those who had done one or more energy-efficiency renovations between 15 and 6 years before the survey, ii) households who have done energy-efficiency improvements in the previous 5 years, and iii) households who haven't done energy-efficiency improvements in 15 or more years.

We gathered a total of 3025 completed questionnaires between May and June 2013. The geographical distribution of the sample mirrors that of the population.

*C. Follow-up Surveys*

Since information about the monthly usage of electricity and gas in Italian households is generally limited, we developed a follow-up questionnaire that was administered in alternate months to a total of 200 participants in the main survey—100 each month—from July to December 2013. Like the main survey questionnaire, the follow-up questionnaire is self-administered on-line. We used it to inquire about electricity and gas consumption and expenditures from the most recent utilities bills, and about any changes in the stock of energy-using equipment and appliances. We use this information to check whether our main survey sample is similar to the Italian population in terms of residential energy consumption.

**5. Econometric Model**

In this paper we wish to estimate an "energy efficiency uptake curve" that predicts the share of the public that will do energy efficiency renovations at any given subsidy level. Attention is restricted to heating equipment. We exploit our study design, focusing on the people that are the least likely to be engaging in free riding or adverse selection—namely those homeowners who do not plan to replace their heating system any time soon.

We posit that a homeowner will accept a subsidy if the offered incentive *X* is greater than his or her "reservation incentive" $S^*$. We do not observe a person's exact $S^*$; however, based on the responses to the hypothetical upgrade questions we know whether it is above or below a certain value.

In the simplest specification of our econometric model, we let $S_i^* = \alpha + \varepsilon_i$, where ε is normally distributed with mean zero and variance $\sigma^2$ and α is the mean and median reservation subsidy, namely the figure that must be offered so that 50% of the population accepts it. The econometric model is thus

(1) $$\Pr(\text{Renovation}) = \Pr(S_i^* \le X_i) = \Pr(\varepsilon_i / \sigma \le -\alpha / \sigma + (1/\sigma) \cdot X_i) = \Phi(-\alpha / \sigma + X_i / \sigma),$$

where $\Phi(\ )$ denotes the standard normal cdf.

Equation (1) is a probit model with the intercept and a single regressor, namely the rebate amount offered to the respondent. In practice, the survey responses provide information sufficient to specify an interval-data model. Consider for example respondents who do not plan to replace their boiler or furnace in the next five years, would not replace it at the initial conditions stated in the questionnaire (i.e., €2000 price and specified savings R% over a given equipment lifetime T), but would change it if a rebate of €X was made available to them. The incentive that must be offered to these persons is thus comprised between 0 and €X. Had these persons declined the €X incentive, then the "ideal" subsidy would be greater than €X. Had these persons accepted to replace their heating system even without a rebate, their subsidy would thus be zero, or less.[3]

We thus amend equation (1) to obtain an interval-data model, where each person's contribution to the likelihood function is the probability that his or her unobserved $S^*$ lies between the lower and upper bounds we infer from his or her responses. Formally, this is

(2) $$\Phi(-\alpha / \sigma + X_i^U / \sigma) - \Phi(-\alpha / \sigma + X_i^L / \sigma),$$

where $X^L$ and $X^U$ denote the lower and upper bound, respectively.

Economic theory suggests that the expectation of $S^*$ should depend on the attractiveness of the hypothetical "heat replacement package" **z**, may be affected by the direct reminder of the $CO_2$ emissions associated with heating (dummy TREAT), and may also be affected by individual or household characteristics **w**:

(3) $$S_i^* = \alpha + \mathbf{z}_i \boldsymbol{\beta} + TREAT \cdot \gamma + \mathbf{w}_i \boldsymbol{\delta} + \varepsilon_i .$$

[3] We remind the reader that these replacements are hypothetical.

In alternate specifications, **z** includes i) the percentage savings R and the lifetime T of the equipment (which are exogenously assigned to the respondent), or ii) the savings on the heating bills, which we compute based on i) and on the heating bills reported by the respondent in the survey.

Once the coefficients in (1) - (3) are estimated, we use them to construct the curve that predicts the share of the population that will do a renovation at specified conditions for each incentive amount *X*. We then combine this curve with information about energy consumption and $CO_2$ emissions to compute the expected $CO_2$ emissions reductions associated with each incentive amount, and the cost effectiveness of these emissions reductions.

## 6. The Data

We collected a total of 3025 completed “wave 1” questionnaires. After we eliminated duplicate questionnaires we were left with a usable sample size of N=3015 questionnaires. Our first order of business is to determine whether the respondents, who were interviewed on-line and were recruited from the IPSOS panel of consumers in Italy, are reasonably representative of the population.

On comparing the characteristics of the 200 participants in the follow-up surveys with the original 3015 respondents, it appears that the former are very similar to the latter in terms of house size, type and age, fuels used, and in terms of respondent age, education, family status and income. The 200 follow-up subjects did report information about their electricity and other fuel consumptions, and their energy consumption is similar to that of the population of residential customers in Italy. Based on this evidence and on the similarity of the 200 follow-up subjects to the original 3015 main survey respondents, we believe that the sample from the main survey is representative of the population of Italian homeowners and residential customers.

As mentioned, attention in this paper is restricted to heating equipment replacements. As shown in table 1, 841 households (27.89% of the sample) replaced their heating equipment between 2007 and the time of the survey. A total of 520 households (17.25%) have not changed their heating equipment in the last six years, but are planning to do so within the next five. The remaining 1654 stated that they didn't change their heating systems in 2007-2013, and are not planning to change them in the next five years. This is the group that received the questions about heating equipment replacement under well-specified hypothetical conditions. Since these respondents are not planning to change their heating equipment any time soon, we argue that they are exempt from free riding behaviors.[4] We focus on the answers to these hypothetical investment questions in the next section of this paper.

Figure 4 shows that over 71% of the respondents use a boiler to heat their homes, and that condensation boilers account for some 12% of the sample. Stoves account for 5.7% of the sample. Natural gas is the most popular heating fuel for the full sample (see figure 5).

It is noteworthy that respondent interest in reducing $CO_2$ emissions was modest for both incentive takers and non-takers, but stronger among incentive recipients, and that about a quarter of the incentive recipients reports that they wished to save money on their heating bills. In contrast with Alberini et al. (2013), concern about rising energy prices is minimal in this sample.

## 7. Results

[4] The questionnaire responses do suggest that among those who changed their heating system and received a tax credit free riding is pervasive: about 70% of them said that they would have done the same even in absence of any support.

As shown in table 3, a total of 654 out of the 1654 respondents who hadn't replaced their heating equipment in the last six years nor were planning to any time soon stated that they would be willing to replace it within the next 5 years if the new equipment cost €2000 and realized the benefits stated to them in the questionnaire. Those who were reminded of the $CO_2$ emissions reduction benefits were only 5 percentage points more likely to agree to the hypothetical replacement scenario (table 4).

As show in table 5, the likelihood of agreeing to the (hypothetical) replacement increases with the lifetime of the equipment (which is also the horizon over which the energy bill savings would be experienced), but respondents did not really distinguish between 13 and 15 years, and 20 and 25 years, respectively. Our respondents were sensitive to the extent of the savings made possible by the hypothetical new heater: Raising the percentage savings from 20 to 30% increases the acceptance of the hypothetical replacement by 7 percentage points, and further raising them from 30 to 40% increases them by 15 percentage points (table 6).

Table 7 shows that offering rebates got 23.2% of the "no" or "uncertain" respondents to agree to do the hypothetical replacement. Clearly, as shown in table 8, the likelihood of agreeing to the hypothetical replacement increases with the size of the rebate.

We recode "don't know" responses as "nos" and on the basis of this interpretation we construct bounds around the latent subsidy that must be offered to each respondent, as explained in Section 4. Our interval-data models are estimated by the method of maximum likelihood, and we report the results of basic specifications in table 9.

Panel (A) in table 9 shows that the mean and median subsidy is €362. The distribution of the latent subsidy variable has, however, a high dispersion: The standard deviation of the latent subsidy is €1385. Panel (B) indicates that the responses are internally valid: The greater the savings, and the longer the time horizon over which they will be realized, the lower the rebate that must be offered to the respondents for them to do the hypothetical heater replacement.

Many respondents reported detailed information about their heating bills, and we used that information to compute the exact savings—in euro per year—made possible by the hypothetical heater replacement that was described to them in the questionnaire. If respondents do not discount future savings, then the total savings over the heater lifetime are equal to the annual savings multiplied by T. We entered total savings in the model of panel (C), and the estimation results confirm that the responses are internally valid: The coefficient on total savings is negative and significant, indicating that the larger the savings, the less the rebate that must be offered to people for them to do the hypothetical heater replacement. The result is robust to accounting for persons who do not report their heating bill (panel (D)) and to discounting future savings at a rate of 5% per year (panel (E)).

Table 10 reports the results of variants on the specification of table 9, panel (C). Panel (A) of table adds a dummy for the $CO_2$ emissions reminder treatment. The coefficient on this dummy (here coded as 1 for no reminder and 2 for reminder) has the expected sign, in that the rebate that must be offered to the respondent, all else the same, is smaller when people are reminded of the $CO_2$ emissions reductions benefits of higher-efficiency heaters, but is not statistically significant at the conventional levels.

Further controlling for the age of the current system (when available) makes no difference (panel (B) of table 10). In panels (C) and (D) we add respondent characteristics (two educational attainment dummies) and household income dummies. The coefficients on these variables generally have the expected signs. For example, the rebate that must be offered to respondents for them to accept the (hypothetical) heater replacement is lower with persons who have a college (university) degree or have done graduate studies, but this effect is not significant at the conventional levels. Persons whose household income is below €30,000 a year must be offered a larger rebate (about €210 more), and this effect is significant at the 10% level. Persons who declined to report their household income require an even larger subsidy—about €422 more than the others, all else the same. This latter effect is significant at the 1% level.

We use the results of specification (C) in table 9 to construct curves that predict the share of the sample that will accept to do a hypothetical renovation for any given subsidy amount. We assume a heater lifetime of 17 years, which is roughly in the middle of the lifetimes offered to the respondents in the survey and is consistent with reports from persons who recently replaced their heating systems, and compute separate curves based on the standard normal cdf for 10%, 20%, 30% and 40% savings, respectively, assuming no discounting and an average annual heating expenditure of €812 (the sample average).[5]

We plot the curves for the 10% and 40% cases, along with their 95% confidence bands, in Figure 6. As shown in this figure, the curves actually approximate straight lines: For each €100 increase in the subsidy, "participation" (i.e., undertaking the proposed replacement) increases by 3 percentage points. At the stated conditions, 36% and 50% of the households would undertake the proposed heater replacement without a subsidy.

Focusing for the sake of the illustration on a population that is equal to the sample itself (1654 households) and assuming that all of them use natural gas for heating, we compute the $CO_2$ emissions reductions per year associated with various scenarios, and display the results for

[5] A total of 585 of the 841 persons who had replaced their heating equipment within the last 5 years provided information sufficient to compute the age of the previous heating system when it was replaced (in 2007 or more recently). On average, homeowners who received incentives retired their heating systems when they were 17.28 years old. Homeowners who replaced their heating system during the same period (2007 or later) but did not receive an incentive report an average age at retirement of 16.61 years. These averages are not statistically different from one another at the conventional levels (t statistic -0.89).

two such scenarios in Figure 7. For the 10% energy savings scenario, our estimates range from 119 to 216 tons $CO_2$ per year (at zero and €1000 rebate, respectively). For the 40% energy savings scenario, the $CO_2$ emissions reductions range from 654 to 1016 tons per year. These figures are based on parameters provided by the Italian Gas Authority, which indicates that the average household uses 985 $sm^3$ per year, and that the average $CO_2$ emissions per $sm^3$ is 2.0064 kg.[6]

We compute the cost-effectiveness of the public program that issues the incentive over what would have been the remaining life of the equipment, which we assume to be 5 years.[7] The emissions reductions occurring in the future during this lifetime are discounted at a 4% rate, and we ignore administrative costs. The results from this exercise for 10% and 40% energy usage reductions are shown in Figure 8. The cost per ton of $CO_2$ removed is reasonably good at low subsidy amounts when the energy usage and emissions reductions are large (40% of the baseline emissions). But with a rebate of €1000, which is approximately equal to the rebate offered by the 55% tax credit program in Italy for a high-efficiency boiler that costs €2000, the cost per ton of $CO_2$ removed is €279, which is high compared to the typical social cost of carbon figures used in other countries (e.g., the US and the UK),[8] and close to the cost-effectiveness from heating system replacements (€300 per ton) computed in the ENEA report for 2009.

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[6] The $CO_2$ emissions rate depends on the calorific rate of the gas, which in turn varies with the country of provenance. We took a sales-volume-weighted average of the emissions rates.

[7] Our study participants indicated that the average age of the replaced heating systems is 17 years. The 1654 persons who are not planning to change their system within the next 5 years report an average heating system age of 12 years. Should they replace their heater now, at the conditions stated to them in the survey, we thus assume the remaining life to be 5 years (=17-12).

[8] The UK government uses a figure of £25 per ton $CO_2$, and the US Environmental Protection agency figures ranging from \$21 to \$63 per ton $CO_2$. To our knowledge, Italian government agencies have not yet established a social cost of carbon figure for policy analysis purposes.

Emissions reductions of 40%, however, are unlikely. Even savings of 30% are considered optimistic in the case of a condensation boiler compared with a conventional one.[9] At lower and more realistic usage and $CO_2$ emissions reductions, the cost-effectiveness is less favorable (over €1000/ton for an incentive of €1000), but still reasonable as long as the rebate is €500 or less.

## 8. Concluding Remarks

This paper has looked at incentives for residential energy upgrades in Italy using data collected through an original survey of households, which we administered to over 3000 Italian homeowners between May and June 2013. For the purpose of this study attention is restricted to heating system replacements, and to the effect of monetary and non-monetary incentives on their propensity to replace their heating equipment with a more efficient one. Our non-monetary incentive is created through reminding half of the respondents about the beneficial effects of energy efficient equipment on greenhouse emissions reductions.

We focus on those persons that are the least likely to engage in free riding—persons who are not planning to change their heater any time soon. We use a stated preference approach to see under which circumstances they would do replace their heating equipment. Specifically, we ask whether savings in energy costs over a sustained horizon would be sufficient, or whether these households need incentives to replace their boilers or furnaces. We also inquire whether reinforcing one's awareness of $CO_2$ emissions helps.

We find that the responses to our survey questions are internally valid: Respondents are more likely to agree to a heating equipment replacement when the savings on the energy bills are larger and experienced over a longer horizon, and when rebates are offered to them. Each $100 increase in the incentive amount raises the likelihood of replacing the heating system at the

[9] See http://www.enforce-een.eu/ita/tecnologie/la-caldaia-a-condensazione (last accessed 10 January 2014).

stated conditions by 3 percentage points. The reminder about $CO_2$ emissions reductions and climate change, however, had little effect. This finding is potentially useful for effective policy targeting.

We further compute the $CO_2$ emissions reductions that can be expected of the households in our sample under the various scenarios in our study. We find that the associated cost per ton of $CO_2$ removed is reasonable, but only when high-efficiency heating equipment delivers large energy use and emissions reductions and the subsidy is small. When subsidies are as high as those that one would be able to claim under the Italian tax credit program for a €2000 boiler (the cost posited to the respondents in the questionnaire, which we based on market prices), the cost per ton of $CO_2$ emissions avoided is relatively high—even under the "best case" assumptions and without questioning whether respondents would truly behave as they say they would.

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**Figure 1.** Optimal choice of capital equipment (or home renovation) and energy use.

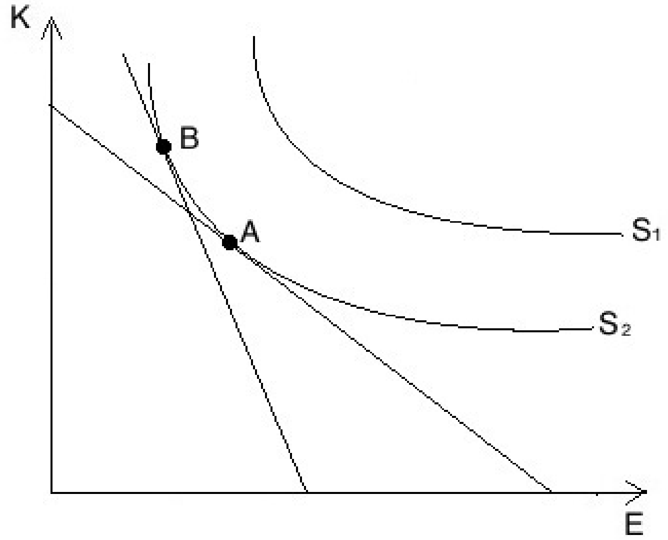


**Figure 2.** Social and private marginal benefits and free riding.

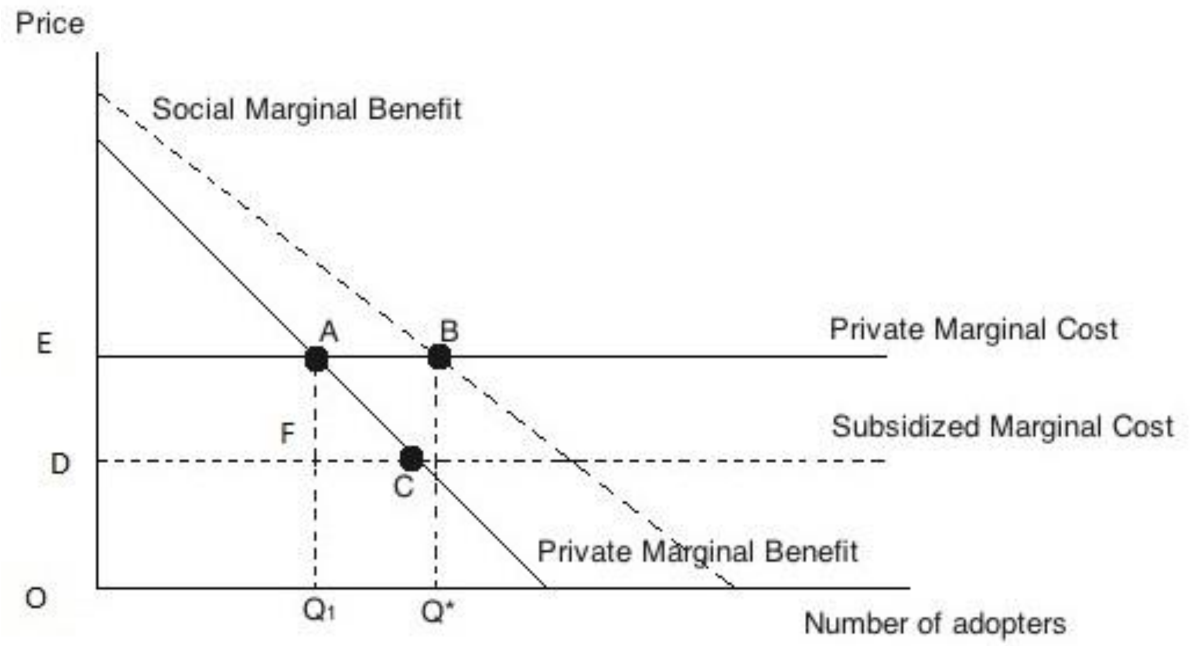


**Figure 3.** Structure of the hypothetical questions.

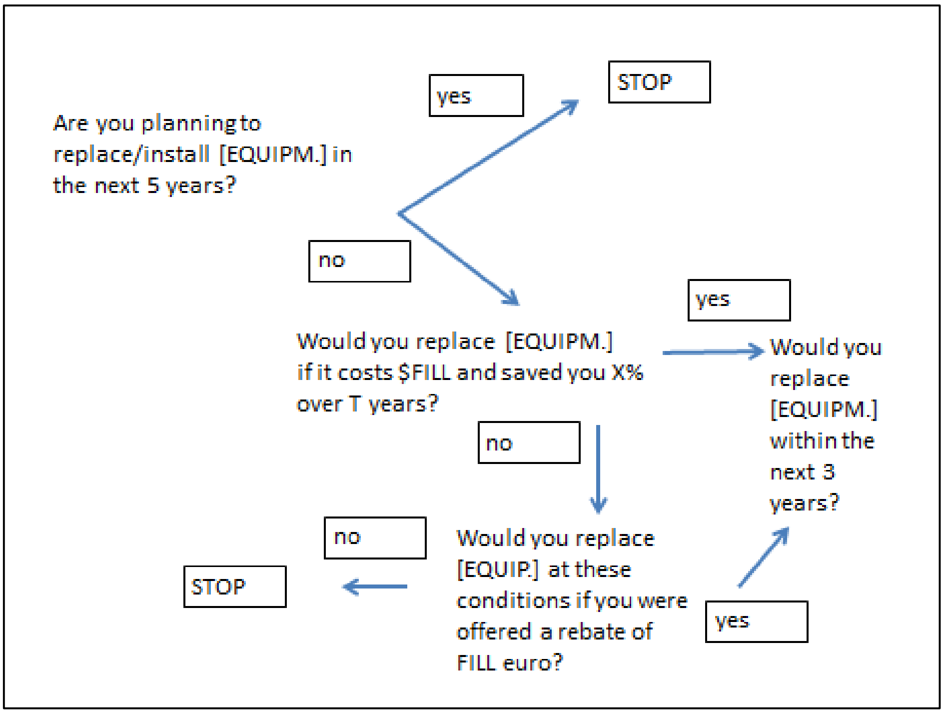


**Figure 4.** Heating System Types in the Sample.

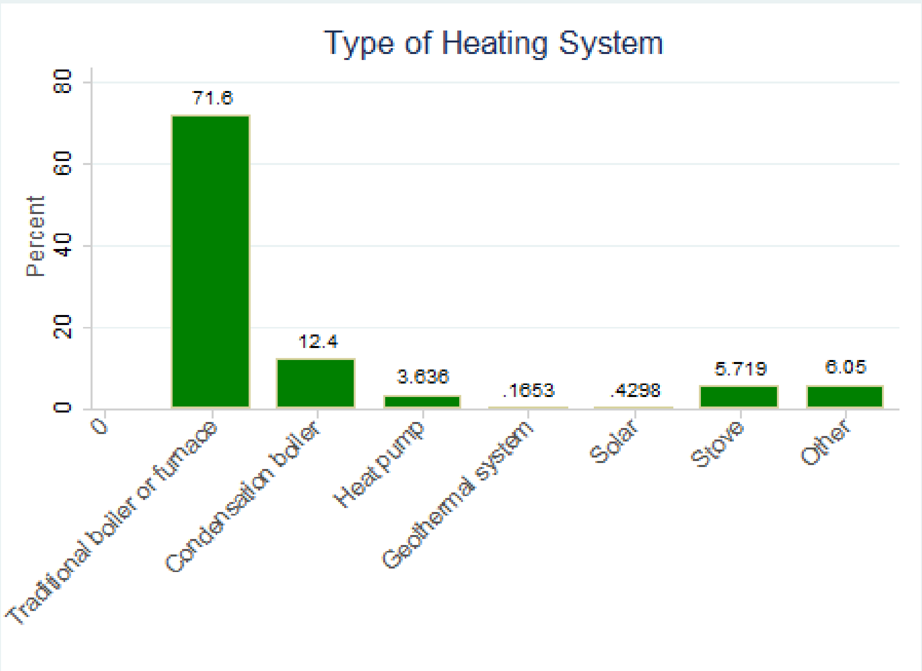


**Figure 5.** Fuels Used for the Heating System in the Sample.

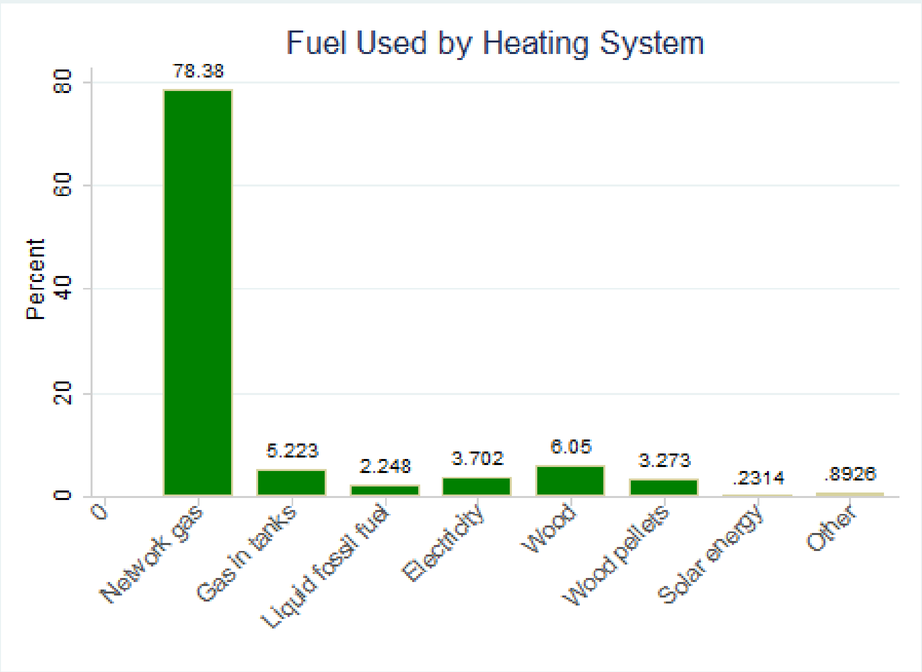


**Figure 6.** Energy-efficiency renovation curve (share of the population that would take the offer and replace the heating system), and 95% confidence bands, as a function of the incentive offer.

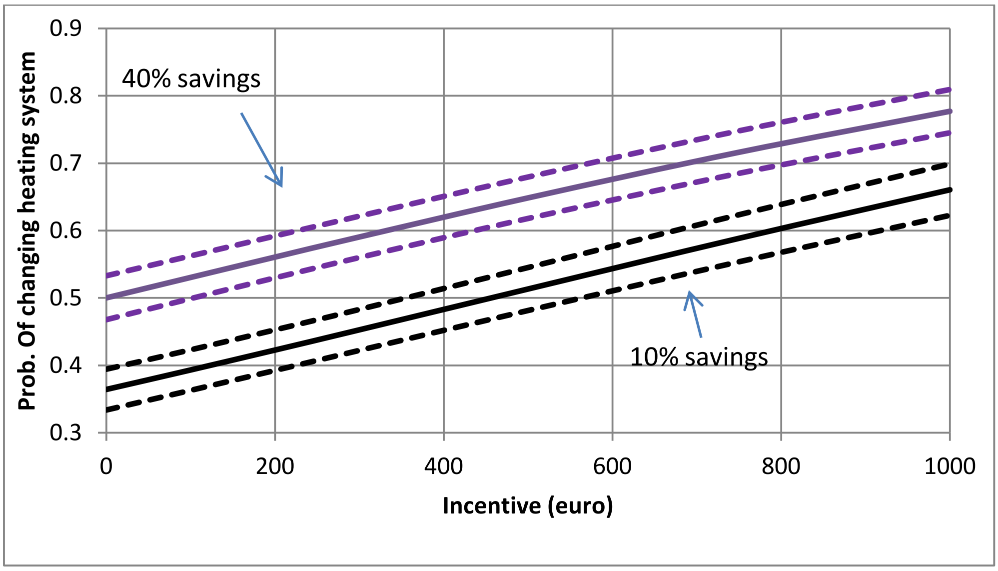
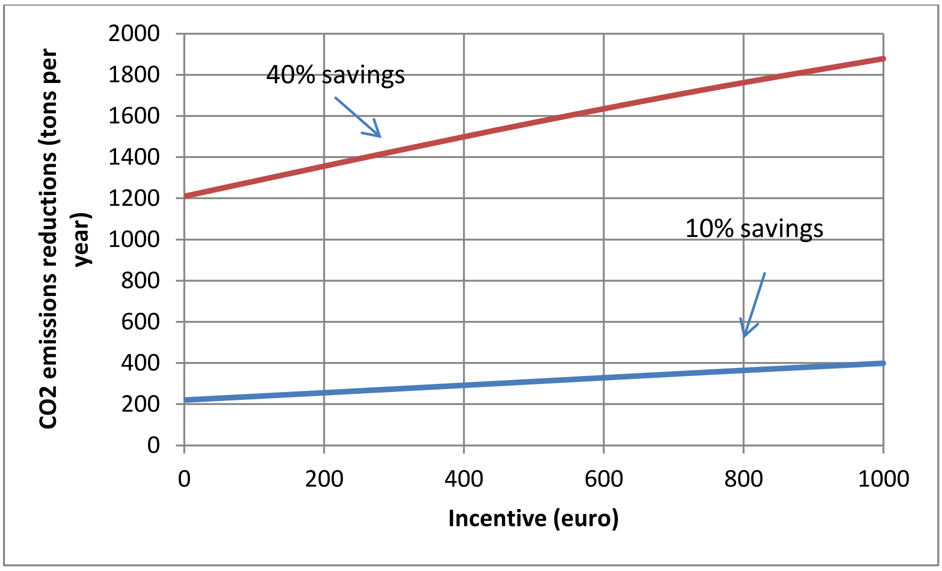
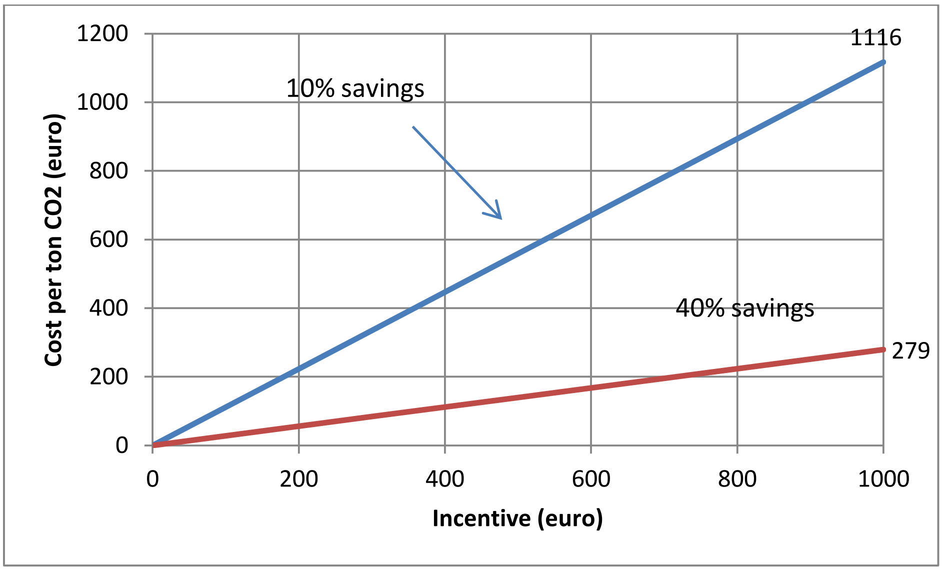



**Figure 7.** $CO_2$ emissions reduction curve for a population of 1654 households that use gas for heating.




Calculations assume that the emissions reductions are proportional to the savings stated to the respondent in the survey questionnaire, 985 $sm^3$ of natural gas use per household per year, 2.0064 kg $CO_2$ emissions per $sm^3$ of gas, stated lifetime of equipment of 17 years.

**Figure 8.** Cost-effectiveness of incentives under two energy efficiency scenarios: Cost per ton of $CO_2$ removed.




Calculations assume that the emissions reductions are proportional to the savings stated to the respondent in the survey questionnaire, 985 $sm^3$ of natural gas use per household per year, 2.0064 kg $CO_2$ emissions per $sm^3$ of gas, stated lifetime of equipment of 17 years.

**Table 1.** Heating system replacements and monetary incentives in the sample.

| Description | frequency | percent |
|---|---|---|
| has replaced the heating system in 2007-2013 | 841 | 27.89 |
| …and received rebates or tax credits | 244 | 29.01 |
| types of rebates or tax credits received | | |
| 36% tax credits | 9 | 3.69 |
| 55% tax credits | 158 | 64.75 |
| government rebate | 40 | 16.39 |
| manufacturer, retailer or installer rebate or discount | 33 | 13.52 |
| other | 4 | 1.64 |
| will change the heating system in the next 5 years | 520 | |
| will not change the heating system in the next 5 years or doesn't know | 1654 | |

**Table 2.** Reasons for changing the heating system in 2007-2013. N=841 respondents who changed their heating systems in 2007-2013.

| Reason | | received rebates or tax credits | | Test of the null that there is no difference across groups |
|---|---|---|---|---|
| | All | yes | no | T statistic |
| the previous one was broken | 32.58 | 26.23 | 35.17 | -2.61 |
| the previous one was old | 35.79 | 43.03 | 33.83 | 2.74 |
| the previous one was inadequate | 17.84 | 20.08 | 16.92 | 1.06 |
| I wanted a heating system that worked better | 18.31 | 25.41 | 15.41 | 3.16 |
| I wanted a heating system with better energy efficiency | 16.29 | 26.23 | 12.22 | 4.48 |
| I was doing other home renovations | 13.67 | 18.44 | 11.72 | 2.39 |
| I was or am thinking of selling this house | 0.59 | 1.23 | 0.33 | 1.2 |
| I wanted to change the type of heating system or the fuel | 9.27 | 12.29 | 8.04 | 3.78 |
| I was offered a good deal | 4.16 | 4.51 | 4.02 | 0.31 |
| rebates or tax credits were available | 9.27 | 31.15 | 0.33 | 10.34 |
| I wanted to help reduce $CO_2$ and pollution emissions | 7.49 | 15.57 | 4.19 | 4.62 |
| this was the least expensive system that was eligible for tax credits or rebates | 0.95 | 1.64 | 0.67 | 1.1 |
| I wanted to save on the heating bills | 20.1 | 25.81 | 17.75 | 2.51 |
| I was expected the energy prices to increase | 1.43 | 1.23 | 1.51 | -0.32 |

**Table 3.** Distribution of the responses to question E17 "At the mentioned conditions, would you change your heating system within the next 5 years?" N=1654 who did not change their heating systems in 2007-2013 and said they were not planning to change them within the next 5 years.

| Response option | frequency | percent |
|---|---|---|
| yes | 654 | 39.54 |
| no | 304 | 18.38 |
| don't know | 696 | 42.08 |
| | 1654 | 100.00 |

**Table 4.** Responses to E17 "At the mentioned conditions, would you change your heating system within the next 5 years?" by provision of the $CO_2$ emissions reminder. Column percentages in parentheses.

E17 v treatment

| | 1=no reminder | 2=reminder of $CO_2$ emissions | Row total |
|---|---|---|---|
| Yes | 318<br>(37.24) | 336<br>(42.00) | 654 |
| no | 157<br>(18.38) | 147<br>(18.38) | 304 |
| don't know | 379<br>(44.38) | 317<br>(39.63) | 696 |
| | 854<br>100% | 800<br>100% | 1654 |

**Table 5.** Frequency of "yes" responses to question E17 "At the mentioned conditions, would you change your heating system within the next 5 years?" by lifetime of the hypothetical equipment.

| FILL1_1 lifetime | Respondents | Freq Yes | % Yes |
|---|---|---|---|
| 13 | 419 | 155 | 36.99 |
| 15 | 401 | 143 | 35.66 |
| 20 | 411 | 176 | 42.82 |
| 25 | 423 | 180 | 42.55 |

**Table 6.** Frequency of "yes" responses to question E17 "At the mentioned conditions, would you change your heating system within the next 5 years?" by percentage savings made possible by the hypothetical equipment.

| FILL1_2 percent savings | Respondents | Freq Yes | % Yes |
|---|---|---|---|
| 10 | 419 | 124 | 29.59 |
| 20 | 412 | 136 | 33.01 |
| 30 | 407 | 164 | 40.29 |
| 40 | 416 | 230 | 55.29 |

**Table 7.** Cross-tabulation of E17 with E17b "Would you change your heating system within the next 5 years if you were offered a rebate of FILL1_3?"

| | E17b | | | Row total |
|---|---|---|---|---|
| E17 | yes | no | don't know | |
| No | 41 | 295 | 58 | 304 |
| | 13.49 | 67.43 | 19.08 | |
| don't know | 191 | 63 | 442 | 696 |
| | 27.44 | 9.05 | 63.51 | |
| | | | | 1000 |

**Table 8.** Distribution of "yes" responses to question E17b "Would you change your heating system within the next 5 years if you were offered a rebate of FILL1_3?" by FILL1_3 amount.

| FILL1_3 (rebate amount) | Respondents | Freq Yes | % Yes |
|---|---|---|---|
| 100 | 155 | 11 | 7.10 |
| 200 | 160 | 18 | 11.25 |
| 300 | 175 | 31 | 17.71 |
| 500 | 170 | 46 | 27.06 |
| 750 | 171 | 59 | 34.50 |
| 1000 | 169 | 67 | 39.64 |

**Table 9.** Interval-data models: Basic specifications. Respondents who did not change their heating equipment in 2007-2013 and are not planning to change it within the next 5 years.

| | (A) simplest | | (B) design variables only | | (C) total savings, discount rate=0 | | (D) same as (C) but keep those who don't report heating expenses | | (E) same as (C) but discount future savings at 5% rate | |
|---|---|---|---|---|---|---|---|---|---|---|
| | coeff | t stat | coeff | t stat | coeff | t stat | Coeff | t stat | coeff | t stat |
| Constant | 361.92 | 8.83 | 1420.64 | 7.28 | 608.86 | 8.98 | 627.83 | 9.28 | 618.10 | 8.97 |
| years over which savings are realized | | | -23.05 | -2.68 | | | | | | |
| percent savings on the energy bills | | | -25.58 | -6.67 | | | | | | |
| Total savings | | | | | -0.1096 | -7.05 | | | | |
| Total savings2 (recoded to 0 if missing) | | | | | | | -0.1135 | -7.3 | | |
| DK heating cost X 10% savings X T | | | | | | | 20.78 | 2.06 | | |
| DK heating cost X 20% savings X T | | | | | | | 22.42 | 2.09 | | |
| DK heating cost X 30% savings X T | | | | | | | 2.94 | 0.28 | | |
| DK heating cost X 40% savings X T | | | | | | | 16.13 | 1.41 | | |
| totsavings3 (discounted at 5%) | | | | | | | | | -0.1742 | -7.04 |
| Sigma | 1385.25 | 17.03 | 1357.56 | 17.07 | 1312.36 | 15.65 | 1332.77 | 17.10 | 1312.44 | 19.04 |
| N | 1654 | | 1654 | | 1339 | | 1654 | | 1339 | |
| log likelihood | -1614.99 | | -1585.64 | | -1287.85 | | -1558.06 | | -1288.2 | |
| LR test chi square of the null that all slopes are zero | | | 58.52 | | 64.61 | | 113.68 | | 63.90 | |
| p value | | | less than 0.00001 | | less than 0.00001 | | less than 0.00001 | | less than 0.00001 | |

**Table 10.** Interval-data models: Additional specifications. Respondents who did not change their heating equipment in 2007-2013 and are not planning to change it within the next 5 years.

| | (A) $CO_2$ emissions reminder | | (B) add age of the heating system | | (C) add education | | (D) add household income | |
|---|---|---|---|---|---|---|---|---|
| | coeff | t stat | coeff | t stat | coeff | t stat | coeff | t stat |
| Constant | 785.55 | 5.35 | 790.14 | 3.77 | 845.7681 | 3.99 | 635.7565 | 2.75 |
| Total savings | -0.1097 | -7.06 | -0.1099 | -7.03 | -0.11019 | -7.05 | -0.1061 | -6.79 |
| treatment (1=no reminder, 2=reminder) | -118.67 | -1.38 | -118.85 | -1.38 | -110.517 | -1.28 | -95.3166 | -1.11 |
| age of current heating system (recoded to 0 if missing) | | | 0.1059 | 0.01 | -0.71697 | -0.06 | -2.02974 | -0.18 |
| age of current heating system missing dummy | | | -10.86 | -0.06 | -19.7026 | -0.12 | -61.0202 | -0.36 |
| some college | | | | | -186.33 | -1.39 | -166.413 | -1.24 |
| college degree or graduate studies | | | | | 58.4347 | 0.4 | 87.35839 | 0.59 |
| income below 30,000 euro/year | | | | | | | 210.463 | 1.92 |
| income information missing | | | | | | | 421.6875 | 2.44 |
| Sigma | 1311.55 | 15.65 | 1311.53 | 15.65 | 1309.554 | 15.65 | 1305.556 | 15.65418 |
| N | 1339 | | 1339 | | 1339 | | 1339 | |
| log likelihood | -1286.89 | | -1286.88 | | -1285.42 | | -1387.85 | |
| LR test chi square of the null that all slopes are zero | 66.52 | | 66.54 | | 69.47 | | 64.61 | |
| p value | less than 0.00001 | | less than 0.00001 | | less than 0.00001 | | less than 0.00001 | |

**Table 11.** Cost effectiveness of $CO_2$ emissions reductions.

| subsidy (euro) | pct savings | number of participating households | baseline $CO_2$ emissions per household if natural gas (kg per year) | cost of the program to the government (year 1 only)(euro) | total $CO_2$ emissions reductions (tons per year) | total $CO_2$ assuming 5 years remaining life of heating system (disc. 4%) (tons) | public program cost effectiveness (euro per ton) |
|---|---|---|---|---|---|---|---|
| 0 | 0.1 | 602.0713 | 1976.304 | 0 | 118.9875852 | 539.2197 | 0 |
| 100 | 0.1 | 649.9866 | 1976.304 | 64998.66209 | 128.4571159 | 582.1331 | 111.656 |
| 200 | 0.1 | 698.9033 | 1976.304 | 139780.6647 | 138.1245434 | 625.9433 | 223.312 |
| 300 | 0.1 | 748.5533 | 1976.304 | 224565.9932 | 147.9368902 | 670.4102 | 334.968 |
| 500 | 0.1 | 848.9229 | 1976.304 | 424461.4384 | 167.7729677 | 760.302 | 558.2801 |
| 750 | 0.1 | 973.4037 | 1976.304 | 730052.7707 | 192.3741615 | 871.788 | 837.4201 |
| 1000 | 0.1 | 1092.706 | 1976.304 | 1092706.069 | 215.9519375 | 978.6361 | 1116.56 |
| 0 | 0.2 | 675.5442 | 1976.304 | 0 | 267.0161262 | 1210.045 | 0 |
| 100 | 0.2 | 724.8799 | 1976.304 | 72487.99394 | 286.5166248 | 1298.416 | 55.82801 |
| 200 | 0.2 | 774.803 | 1976.304 | 154960.607 | 306.2492674 | 1387.839 | 111.656 |
| 300 | 0.2 | 825.0281 | 1976.304 | 247508.4403 | 326.1012804 | 1477.803 | 167.484 |
| 500 | 0.2 | 925.2219 | 1976.304 | 462610.9319 | 365.703934 | 1657.272 | 279.14 |
| 750 | 0.2 | 1047.042 | 1976.304 | 785281.1704 | 413.8544849 | 1875.477 | 418.71 |
| 1000 | 0.2 | 1161.246 | 1976.304 | 1161245.613 | 458.9948699 | 2080.041 | 558.2801 |
| 0 | 0.3 | 751.0184 | 1976.304 | 0 | 445.2722097 | 2017.854 | 0 |
| 100 | 0.3 | 801.136 | 1976.304 | 80113.59885 | 474.9864776 | 2152.511 | 37.21867 |
| 200 | 0.3 | 851.4034 | 1976.304 | 170280.6894 | 504.7896113 | 2287.571 | 74.43734 |
| 300 | 0.3 | 901.5295 | 1976.304 | 270458.8464 | 534.5089 | 2422.251 | 111.656 |
| 500 | 0.3 | 1000.209 | 1976.304 | 500104.6805 | 593.0153283 | 2687.386 | 186.0934 |
| 750 | 0.3 | 1117.831 | 1976.304 | 838373.4664 | 662.752334 | 3003.415 | 279.14 |
| 1000 | 0.3 | 1225.694 | 1976.304 | 1225693.607 | 726.7029535 | 3293.222 | 372.1867 |
| 0 | 0.4 | 827.5102 | 1976.304 | 0 | 654.1647209 | 2964.499 | 0 |
| 100 | 0.4 | 877.7398 | 1976.304 | 87773.97911 | 693.872264 | 3144.443 | 27.914 |
| 200 | 0.4 | 927.6757 | 1976.304 | 185535.1476 | 733.3477088 | 3323.335 | 55.82801 |
| 300 | 0.4 | 977.0325 | 1976.304 | 293109.7562 | 772.3653114 | 3500.152 | 83.74201 |
| 500 | 0.4 | 1072.921 | 1976.304 | 536460.4523 | 848.1671502 | 3843.666 | 139.57 |
| 750 | 0.4 | 1184.972 | 1976.304 | 888728.7851 | 936.7457349 | 4245.08 | 209.355 |
| 1000 | 0.4 | 1285.483 | 1976.304 | 1285482.763 | 1016.201891 | 4605.154 | 279.14 |

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