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Looking for Free-riding: Energy Efficiency Incentives and Italian Homeowners

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Summary

We examine the effect of energy efficiency incentives on household energy-efficiency home improvements. Starting in February 2007, Italian homeowners have been able to avail themselves of tax credits on the purchase and installation costs of certain types of energy efficiency renovations. We examine two such renovations—door/windows replacements and heating system replacements—using multi-year cross-section data from the Italian Consumer Expenditure Survey and focusing on a narrow period around the introduction of the tax credits. Our regressions control for dwelling and household characteristics and economy-wide factors likely to influence the replacement rates. The effects of the policy are different for the two types of renovations. With window replacements, the policy is generally associated with a 30% or stronger increase in the renovation rates and number of renovations. In the simplest econometric models, the effect is not statistically significant, but the results get stronger when we allow for heterogeneous effects across the country. With heating system replacements, simpler models suggest that the tax credits policy had no effect whatsoever or that free riding was rampant, i.e., people are now accepting subsidies for replacements that they would have done anyway. Further examination suggests a strong degree of heterogeneity in the effects across warmer and colder parts of the country, and effects in the colder areas that are even more pronounced than those for windows replacements. These results should, however, be interpreted with caution due to the low rate of renovations and the imprecisely estimated effects.

Keywords: Energy Efficiency Policy, Household Behavior, Italy, Energy Consumption Survey

JEL Classification: Q41, D12, H3

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Looking for Free-riding: Energy Efficiency Incentives and Italian Homeowners

By

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Abstract

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The effects of the policy are different for the two types of renovations. With window replacements, the policy is generally associated with a 30% or stronger increase in the renovation rates and number of renovations. In the simplest econometric models, the effect is not statistically significant, but the results get stronger when we allow for heterogeneous effects across the country. With heating system replacements, simpler models suggest that the tax credits policy had no effect whatsoever or that free riding was rampant, i.e., people are now accepting subsidies for replacements that they would have done anyway. Further examination suggests a strong degree of heterogeneity in the effects across warmer and colder parts of the country, and effects in the colder areas that are even more pronounced than those for windows replacements. These results should, however, be interpreted with caution due to the low rate of renovations and the imprecisely estimated effects.

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Looking for Free-riding Opportunities: Energy Efficiency Incentives and Italian Homeowners

by

Anna Alberini, Andrea Bigano and Marco Boeri

1. Introduction and Motivation.

In recent years, incentives such as rebates and tax credits have been offered to homeowners in the US and several European countries to encourage energy-efficiency home renovations and appliance replacement. Surprisingly little is known about the effectiveness of these policies. Hassett and Metcalf (1995) document that taxpayers are responsive to tax credit incentives, to the point that a 10% increase in such incentives leads to a 24% increase in the likelihood of performing energy-efficiency improvements in the home.

One concern with these policies, however, is that they might result in free-riding behavior, which occurs when the economic agents targeted by the policy take the incentives, but would have done the home renovations or appliance replacement anyway. This may happen because i) the energy efficiency characteristics of the renovation are not separable from other technical or aesthetic features that would have motivate the renovation anyway (new windows that are both pleasant to look at and more heat efficient), ii) the agents were already convinced that the resulting efficiency improvement was worth its cost, or iii) the agents replace existing equipment only when it breaks beyond repair. Clearly, in these cases, the policy might be wasting government funding and might be attaining reductions in energy usage and in carbon emissions at unnecessarily high costs.

Grosche and Vance (2009) examine renovations using cross-section data from the 2005 German Residential Energy Consumption Survey, and conclude that free-riding, which they define as the situation in which a household's willingness to pay for renovations exceed their cost, occurs in 50% of the cases. An earlier meta-analysis of demand-side management programs conducted by the utilities suggests that the share of free-riders ranges between 0 and 50% (Joskow and Marron, 1992), whereas Malm (1996) estimates that 89% of the households he examined would have purchased a high-efficiency heating system even in the absence of subsidies.

Is free riding widespread in the presence of incentives, and is always as severe as these earlier studies have found? In this paper, attention is focused on a tax credit policy for homeowners that has been in place in Italy since February 2007.[2] Effective from February 19, 2007, a national law allowed homeowners (as well as owners of buildings used for commercial purposes), to deduct from their income taxes up to 55% of the expenses sustained to implement certain types of energy efficiency renovations or source of renewable energy in existing homes (commercial buildings).[3] (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, attic and wall insulation, windows and doors replacement, the entire building envelope, and solar panels to be used for heating water (photovoltaics are specifically excluded because they are addressed by other laws and programs). Applications for the tax credits 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

[2] DM 19/02/07 and subsequent laws. Currently ruled by DL 6/12/2011

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

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 windows and doors replacement, 30% for heating system replacement, 15% for thermal solar panels, 4% for attic or floor insulation ("horizontal" in the language of the law), and 2% for "vertical" wall insulation.

In this paper, we use household-level data from the Italian Consumer Expenditure Survey to examine the rate at which (potential) energy-efficiency home improvements are done, and to see whether this rate was affected by the tax credit policy. We take care to avoid attributing to the policy effects that are due to long-term trends or macroeconomic shocks. Specifically, we limit the sample to a narrow "window" (2004-2009) around the introduction of the tax credits policy, test for pre-trends, and control for factors likely to affect energy efficiency renovations.

Attention is focused on windows/doors replacements and heating system replacements. We find that door and window replacements increase when the policy is introduced, especially at location with harsher climates. The findings are less clear for heating system replacements. The simplest models find that the policy has had no effect whatsoever on heating system replacements, or that free riding must have been pervasive. Further analyses, however, suggest that there is a considerable degree of heterogeneity of the effects across the territory, and that the policy raises the replacement rates and numbers considerable in the colder parts of the country (Northern Italy).

The remainder of the paper is organized as follows. We present data and models in section 2. Section 3 describes the data. Section 4 presents the results. Section 5 provides concluding remarks.

2. Methods.

A. Data Sources

Unlike in other countries, in Italy at the time of this writing no official government-conducted surveys exist that are dedicated to residential energy consumption and energy-using appliances and equipment. Moreover, the individual taxpayer filings authorized by the 2007 tax credit law and described in the ENEA reports are not publicly available. For these reasons, we use information about energy-efficiency upgrades in the home using the Italian Consumer Expenditure Survey (Indagine sui Consumi delle Famiglie), which is conducted annually by ISTAT (Statistics Italy).

We have 13 waves of the Italian Consumer Expenditure Survey. Our dataset is multi-year cross-sections, covers a total of 13 years from 1997 to 2009, before and when the policy was in place, and contains about 23,000 households each year, for a total of 311,456 observations.

The Italian Consumer Expenditure Survey (henceforth abbreviated as I-CEX) gathers information about food and household expenditures incurred in the week prior to the survey, the most recent energy bills, home maintenance expenditures ("manutenzione ordinaria") and home renovation expenditures ("manutenzione straordinaria") incurred in the last three months prior to the interview. Within the latter category, the respondent is specifically asked whether he i) replaced windows and doors, ii) replaced the heating system, and iii) did other exterior and interior renovations. Clearly, items i) and ii) are two renovations targeted by the tax-deduction incentive policy, and so we can examine whether they have become more frequent when the incentive is present. The I-CEX questionnaire does not inquire about tax credits for specific energy-efficiency upgrades, and so what we do observe is simply whether or not the household did certain types of energy-efficiency renovations, regardless of any tax credits received.

In our regressions (described below), we must control for other factors that influence the propensity to undertake energy efficiency renovations. These include, among others, structural characteristics of the home (e.g., size and vintage of the home) and characteristics of the household, such as income, the number and ages of the household members, etc. (documented in the I-CEX). Energy prices were gathered from assorted sources, including ISTAT, the Italian Energy Authority, and Eurostat.

Weather information comes from the T3 Global Surface Summary of the Day records from the US National Oceanographic and Atmospheric Agency (NOAA). We obtained daily temperatures from the weather stations in each Region,[4] and used them to create daily and monthly heating degree days (HDDs) and cooling degree days (CDDs) at the Region level. We further aggregated HDDs and CDDs to annual totals in twelve months prior to the time of the survey. Although we have weather data at a fine geographical resolution (the monitoring station level), we use regional aggregates because the I-CEX dataset only identifies the Region where the household lives.

We use unemployment rates by Region and year dummies to control for the state of the economy, and the sales of homes in the Region, normalized by the population of that Region, to control for the conditions of the housing market. The number of home sales comes from the Italian Agenzia per Il Territorio, whereas unemployment and population figures are provided by ISTAT.

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[4] In Italy, a Region is a jurisdiction with authority similar to that of a US State, a Canadian Province, or a German Länder. There are a total of 20 Regions in Italy.

B. Theoretical Considerations

It seems reasonable to assume that a household will replace the heating system, put in new energy-efficient windows or do another energy-efficiency upgrade in the home if the net benefits of this renovation (namely, the value of the heating services or thermal integrity, plus other benefits, minus the costs) are greater than those of the existing equipment.

Various factors can affect this basic benefit-cost calculus. The benefits of energy-efficiency upgrades should depend on the structural characteristics of the home and household characteristics (e.g., the presence of small children or elderly household members, income, etc.), and are reasonably expected to be larger in harsher climates. One would also expect energy-efficiency upgrades to be more attractive than keeping the existing equipment when energy prices are rising or at locations where the energy prices are high.

The costs of a renovation are comprised of the initial outlay to purchase and install the equipment, plus maintenance and operating costs. A government incentive lowers the initial outlay and increases the attractiveness of a home energy efficiency renovation attractive, but only if the cost of applying for the incentive is smaller than the incentive. We would therefore expect incentive-subsidized renovations to account for fewer than 100% of the total number of renovations.

C. Econometric Approach

Ideally, to assess the effect of a policy, one would like to have observations before and after the policy from two groups of economic agents—a group that is subject to the policy, and one that is unaffected and thus serves as a control group. Unfortunately, it is not possible for us to implement such a "difference-in-difference" study design due to the lack of a control group in our main source of data.[5]

Given these data limitations, we simply compare the behaviors of (different samples of) homeowners before and after the implementation of the tax credits policy. To avoid attributing to the policy effects that are truly due to other factors, we i) restrict the sample to a relatively narrow window around the passage of the tax credit law so as to keep conditions relatively constant and free from long-term effects, ii) carefully test for pre-trends, and iii) control for economy-wide shocks and for the conditions of local housing markets.

We check for pre-existing trends by estimating the linear probability model:

(1) $$y_{it}^{(k)} = \alpha + \mathbf{x}_{it}\boldsymbol{\beta} + \sum_{t} \gamma_t D_t + \varepsilon_{it}$$

where (k) denotes the type of energy-efficiency renovation covered by the policy (e.g., heating system, doors and windows, etc.), *y* is a dummy that takes on a value of one if the renovation was done in the three months prior to the interview, *i* denotes the household, *t* the year and the sample is limited to pre-policy years. Vector **x** is comprised of house, household and economy-wide factors thought to affect the decision to do an energy-efficiency home renovation, and the *D*s are year dummies. We then test the null hypothesis that the coefficients on the year dummies are jointly equal to zero.[6]

[5] Renters do not constitute a legitimate control group. Their landlords are still entitled to the tax credits, provided that they meet the other requirements of the law, and at any rate the I-CEX questionnaire does not collect any information on home renovations from those households who rent their homes. Likewise, households living in multi-family housing or the homeowners association are eligible to receive the tax credits. One option might be to select renovations not covered by the tax credits and regard this type of renovations as the "control group." Unfortunately, the Italian Consumer Expenditure Survey gathers data about home renovations using such broad definitions that it is impossible to identify an unambiguous "control" type of renovations.

[6] An alternate specification that produces similar results simply enters a linear time trend in the right-hand side of equation (1) in lieu of the year dummies.

After making sure that there are no pre-existing trends, we estimate two econometric models. The first is the linear probability model:

(2) $$y_{it}^{(k)} = \alpha + \mathbf{x}_{it}\boldsymbol{\beta} + \delta \cdot POLICY_t + \varepsilon_{it}$$

where POLICY is a dummy that takes on a value of one in 2007-2009. We test the null hypothesis that δ=0. Failure to reject this null hypothesis would imply that either the policy has no effect (i.e., it hasn't been sufficient to stimulate energy-efficiency renovations), or that there is free-riding.

The second is

(3) $$y_{it}^{(k)} = \alpha + \mathbf{x}_{it}\boldsymbol{\beta} + \sum_t \gamma_t D_t + \delta \cdot POLICY + \lambda \cdot (POLICY_t \times HDD_{it}) + \varepsilon_{it}$$

which posits that the attractiveness of the incentives depend on local climate. In equation (2), HDD denotes the annual degree days.

In this paper, we present regression results for two alternate dummy dependent variables, namely (i) replacing doors and windows and (ii) replacing the heating system. These renovations are covered by the tax credit policy, as long as the homeowner is willing to comply with the filing requirements and does file with the tax authority, and indeed replacing doors and windows alone accounted for 49% of the filings in 2009, according to ENEA (2010).

We estimate equations (1)-(3) by weighted least squares (using the probability sampling weights provided by the Italian Statistics Institute), and since many variables are measured at the Region level, we cluster the standard errors around the Region (Moulton, 1990; Wooldridge, 2010, p. 865), which means that our standard errors and *t*-statistics are both heteroskedasticity-robust and robust to the presence of correlation between observations from the same Region. Our sample is restricted to owners of single-family homes and apartments in multi-family dwellings with their own heating system, as long as they live in the homes they own.[7] We reason that this makes them the bearers of the cost and the beneficiaries of any savings and other consequences of their renovation decisions.

Vector **x** includes determinants of energy-efficiency investments, such as energy prices, heating and cooling degree days in the Region where the household resides, dwelling characteristics (size, type, vintage), household characteristics (size, ages and education of the household members, income) and month of the survey. Importantly, **x** includes controls for the conditions of the real estate market and for economy-wide factors that might affect a household's propensity to invest in its home.

D. Additional Specifications

For good measure, we also estimate the probit equivalents of (1)-(3). For example, the probit model corresponding to (3) is

(4) $$E(y_{it}^{(k)}) = \Pr(y_{it}^{(k)} = 1) = \Phi\left(\alpha^* + \mathbf{x}_{it}\boldsymbol{\beta}^* + \sum_t \gamma_t D_t^* + \lambda^* \cdot (POLICY_t \times HDD_{it})\right)$$

where $\Phi(\bullet)$ is the standard normal cdf. The probit is estimated by weighted maximum likelihood.

When estimating residential fuel demand, researchers often regard the choice of heating fuel as simultaneously determined with the demand for that fuel (e.g., Dubin and McFadden, 1984; Mansur et al., 2008). We likewise test for whether a household choice of natural gas as the primary heating fuel is endogenous with the decision to replace windows or the heating system itself. This can be accomplished in a number of ways, all of which are based on two equations.

[7] Depending on the year, 71-76% of the households in the I-CEX own their home, mirroring nationwide homeownership rates.

The first equation explains the decision to do the renovation conditional on all regressors *and* on whether piped gas is used as the heating fuel. The second equation explains whether the household uses piped natural gas for heating as a function of a set of instruments. We experiment with i) a bivariate probit model as in Evans and Schwab (1995), ii) two simultaneous linear probability models, which are estimated using two stages least squares (Evans and Schwab, 1995), and iii) a variant on the Heckman two-step approach.

Formally, approach i) posits that

(5) $$y_{it}^{(k)*} = \mathbf{x}_{it}\boldsymbol{\beta} + GASHEAT_{it} \cdot \beta_G + POLICY_t \cdot \delta + \varepsilon_{it}$$

(6) $$GASHEAT_{it}^{*} = \mathbf{x}_{it}\boldsymbol{\theta} + \mathbf{w}_{it}\boldsymbol{\tau} + \eta_{it}$$

where **w** is a vector of identifying instruments, $\boldsymbol{\theta}$ and $\boldsymbol{\tau}$ are vector of coefficients, and ε and η are correlated zero-mean error terms. Errors terms ε and η are assumed to be jointly normally distributed. By contrast, approach ii) does not make any assumptions about the joint distribution of the error terms and models the binary dependent variables directly (instead of the latent variables y* and GASHEAT*). Finally, approach iii) fits a probit of the decision to use natural gas heat, forms an inverse Mills ratio for it, and enters the latter in the right-hand side of a linear probability equation for the decision to do an energy-efficient home renovation.

In equation (6), our identifying instruments are the length of the gas network in the Region, and a proxy for the availability of network gas at the home of the respondent, which we construct as the length of the gas pipelines in the Region of residence interacted with whether the respondent lives in a city.

3. The Data

The CEX contains a total of over 311,000 observations over 1997-2009, but when attention is restricted to households that own single-family homes (or apartments in multi-family dwellings with their own heating system) and live in them, and we use only 2004-2009 (our preferred "window," see below) the sample size is 86,489. Descriptive statistics of this "restricted" sample are displayed in tables 1-6.

Figure 1 shows that in the late 1990s home improvements and renovations occurred at a rate of about 10% a year, and that they have generally been declining since. The rates of replacement for doors/windows, and heating systems followed similar trends, and were 2-3% per year by the last few years of our sample period. The average quarterly renovation rates are 0.8% for windows and 0.7% for heating systems. Other studies report similarly low annual energy-efficiency renovation rates (Gans, 2012; Grosche and Vance, 2009).

If we apply the renovation rates observed in the sample to the population of households the sample is supposed to be representative of (about 15 million households in 2009), we estimate a total of between 80,000 and 119,000 windows and door replacements, and between 90,000 and 107,000 heating system replacements, every year over the period from 2004 to 2009. We predict about 91,000 windows/door replacements, and a similar number of heating system replacements, for 2009, the last year in our sample.

Comparison with the filings for the tax credits reported by ENEA is difficult because the population the I-CEX represents does not completely overlap with the parties that are allowed to request the tax credits. Our sample is comprised of single-family homeowners and owners of units in multi-family buildings with their own heating systems. All of these households live in a home they own. The tax credit law, however, does not impose the restriction that the applicant should live in the building where the renovations are done, and applies to residential, commercial and industrial buildings. Both incorporated entities and individual taxpayers are allowed to apply for the tax credits. With these limitations in mind, ENEA reports that in 2009 there were about 115,000 filings for the tax credits for windows and doors, and 68,000 filings for heating system replacements.

Based on the sampling weights reported in the I-CEX, the average expenditure on windows and doors renovations on annual basis is €2298.53, and that for heating systems replacements is €2418.62. These figures are much smaller than the mean cost per incentive-subsidized renovation reported in the ENEA documents. In 2009, for example, the average cost of windows replacements was €9475 and that of a heating system replacement was €12,427. These figures are likely to be inflated by the extensive renovations done on large residential buildings (which account for some 30% of the total) and on commercial and industrial buildings (4% of the total). Unfortunately, the ENEA reports do not provide detailed information about other moments or order statistics of the distribution of the costs of the renovations.

Table 2 shows that over our preferred study period (2004-2009) about 71% of the households used network gas for heating, 10% used gas in bottles or tanks kept outside of the home, and 7% uses heating oil. Wood is used by about 9% of the households.

As shown in Table 3, almost 90% of the households in our sample use a central heating system that is independent of that of neighboring dwelling units, and about 8% have separate heating devices in different rooms within the home. The remainder (about 3%) relies on a central heating system that is shared with other units.

Characteristics of the dwelling, such as the number of rooms and age of the home, are summarized in Table 4. Annual heating degree days and gas prices are displayed in Table 5, whereas Table 6 describes the unemployment rate and the state of the housing market. Table 7 reports information about the demographic and economic circumstances of the household. This includes the time a household has been living in the house (duration and duration squared), the household's size and the number of household members aged 17 or younger (age1) or 65 and older (age4). The I-CEX does not disclose household income, so we proxy income and wealth with the ownership of a car, the number of homes owned and day-to-day consumption expenditures (on an annual basis).

4. Results

Figure 1 suggests that the rates at which households replaced windows or their heating systems declined between 1997 and 2009. All home renovations (inclusive of interior and exterior renovations, plus windows and heating equipment replacements) experienced a similar decline.

Our first order of business is, therefore, to identify a sufficiently stable period before the introduction of the tax credit program. We fit equation (1) for windows replacements and heating system replacements for various pre-program periods, and test the null hypothesis that the coefficients on the year dummies are jointly equal to zero. Both types of renovations appear to be stable when attention is restricted to 2004-2006, so our subsequent regressions use the data from 2004 to 2009, which results in a symmetric "window" around the tax credit law event.[8]

Regression results are reported in Table 8 for windows replacements during 2004-2009. We present three specifications. In all of them, the standard errors are clustered at the Region

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[8] For 2004-2006, the F statistic of the null that the coefficients on the year dummies are equal to zero is 1.65 (P value 0.2213) for window replacements and 0.83 (P value 0.4527) for heating system replacements. The F statistics are 2.05 and 3.82, respectively, for 2002-2006, with P values of 0.1320 and 0.0217. For 2001-2006, they are 1.70 and 2.24 (P values 0,1894 and 0.1081).A longer period (2000-2006) suggest that long-term trends are present (F statistics 6.07 and 8.13, respectively, with P values 0.0021 and 0.0003).

level. Specification (A) corresponds directly to equation (2), specification (B) to equation (3), and specification (C) keeps the interaction between the policy dummy and HDDs and enters year dummies to make sure that we are not incorrectly attributing to the policy the effect of other macroeconomic shocks.

Starting with specification (A), the model suggests that windows replacements are significantly associated with dwelling and household characteristics. The age of the home is a strong predictor of the likelihood that windows are replaced in any given period, as is the size of the home. There is no difference, however, between single-family homes and homes in multi-family dwellings, and rural urban locations. Wealthier and smaller households are more likely to replace their windows in any given quarter. Education and the age composition of the family are not important, but the latter effect is probably confounded by the inclusion of "duration" (the number of years a household has lived in the home), which clearly suggests that the longer the household has lived in the home, the less likely it is to undertake window replacements.

We have included the current price of natural gas and the two most recent changes in natural gas prices in the right-hand side of the model, but none of these variables is significantly associated with windows replacements. The coefficients on these terms are positive, but statistically insignificant, a result that may be due to measurement error (since we do not know exactly where a person lives, we are forced to attribute to a household the natural gas prices of the major city in the Region). Replacement rates are higher in places with colder climates: The coefficient on HDDs is positive and significant at the conventional levels. In general, despite the very low rate at which windows replacements are done, the model identifies a number of significant determinants of windows upgrades.[9]

[9] The F statistic of the null that the coefficients on all dwelling characteristics are jointly equal to zero is 13.96 (P value less than 0.0001) and that of the null that household characteristics do not matter is 57.23 (P value less than

In a regression not reported in this paper, we checked whether there are monthly patterns in windows replacement rates. We did not expect to find any, since 1) window replacements are usually not done on an emergency basis, and 2) windows can be quickly replaced within a day at any time of the year without inconveniencing the occupants of a home, and indeed the F statistic of the null that the coefficients on the month dummies are equal to zero is only 1.83, for a P value of 0.1275.

Turning to the policy, in specification (A) the coefficient on the policy dummy is positive and relatively large compared to the rate of occurrence of windows replacements. It is, however, estimated imprecisely and statistically insignificant. One possible interpretation of this result is that the policy is ineffective. Another is that the rate at which windows replacements are done is simply too low for us to isolate the effects of the tax credits policy. Alternatively, it is possible that the true workings of the policy do not comply with a single, uniform nationwide effect.

We relax this assumption in specification (B), where the interaction between policy and HDD has a positive and significant coefficient. The two policy variables imply that at the mean HDD (3342), the effect of the policy is 0.0022 (s.e. 0.0014), or about 31.8% of the average replacement rate. The magnitude of this effect is thus similar to, but slightly larger than, the one from model (A). The t statistic for this effect is, however, only 1.61.

Increasing the HDDs by one standard deviation (i.e., 1328), which is roughly the difference between Northern Italy and the rest of the country, has a very different effect, depending on whether the tax credit policy is in place or not. In the absence of the policy, windows replacement rates increase by 0.0014596 (s.e., 0.0009273). When the policy is in place,

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0.0001). A similar test also concludes that HDDs and gas prices matter (F statistic 6.60, P Value 0.0107), whereas unemployment and the conditions of the housing market are not important (F statistic 0.45, P value 0.6477).

they increase by 0.0031798 (s.e. 0.0009946). This latter effect is strongly statistically significant (t statistic 3.20) and represents a 37% increase with respect to the average replacement rate.

Using the results of specification (B), and taking the policy coefficients at face value, we can also predict the windows replacement rate with and without the policy, holding the regressors at the sample means for 2006 (the last year before the tax credits were passed). The model predicts a quarterly replacement rate of 0.006091 (2.4364% on an annual basis) in the absence of the policy. Had all else stayed the same, the model predicts a replacement rate of 0.008538 (3.4152% per year)—a 40% increase. Holding he universe of households the same as in 2006 (1,364,614; see table 1), we predict a total of 83,116 window-replacement renovations per quarter in the absence of the policy and 116,512 in the presence of the policy. The associated increase in expenditure is about €63.507 million (on an annual basis).[10]

In specification (C), we remove the policy dummy (which is always equal to one for 2007 and later years) and include year dummies. The coefficients on the year dummies indicate a decline in windows installations over time, but the coefficient on the policy-HDD interaction remains positive and marginally significant.

Turning to the heating system replacement equations (Table 9), dwelling and household characteristics and climate are significantly associated with the likelihood of replacing the heating system. The tax credit policy, however, enters with a negative and statistically insignificant coefficient, whether by itself or with the companion variable policy $\times$ HDD.

To illustrate, the average heating system replacement rate is 0.007 per quarter. Specification (B) predicts that at the mean HDD the effect of the policy is only 0.0000421, a statistically insignificant amount (t statistic 0.03), and that only 574 additional heating system

[10] This calculation uses the 2006 mean expenditure per window replacement (€2106.59 on an annual basis, 2009 euro).

replacements would take place every quarter, assuming that same universe of households as in 2006. These results seem to point to complete policy ineffectiveness and/or extremely high incidence of free riding: Most likely households replace their heating systems when they must (because the system is broken beyond repairs, or is at the end of its economic life) and this decision is unaffected by the tax policy.

The model results, however, are also compatible with strongly heterogeneous effects across the territory. In the absence of the tax credit policy, a one standard deviation increase in HDD increases the heating system replacement rate by 0.0031 (t statistic 3.77). If the policy is in place, the corresponding increase would be 0.0045 (t statistic 2.74). These two effects are large compared to the pre-policy rate of heating system replacement (e.g., 0.00685 in 2006), and imply 42,306 and 61,994 replacements per quarter, respectively, assuming the same universe of households as in 2006. The associated expenditures are €94,288 million and €138.169 million (on an annual basis), respectively.

We re-ran all models without weights and obtained results that were qualitatively and quantitatively similar. All results were confirmed when we ran probit regressions in lieu of least squares. With probit models, we computed the marginal effects of the policy and of heating degree days at the sample means and found that they were virtually undistinguishable from the ones for the linear probability specification.

We note that in all of the specifications reported in tables 8 and 9, having gas heat is regarded as exogenous. This is because when we tested for the endogeneity of the household's choice of natural gas as primary heating fuel, we found no evidence of such endogeneity. This was the case with all three of the approaches we deployed. The coefficient on gas heat is insignificant in all of the specifications in tables 8 and 9.

We also wondered whether the passage of the tax credit program may have encouraged households to wait until after February 19, 2007 to change their windows or heating systems, so that they could avail themselves of the credit. If this was the case, we would expect a “dip” in the replacements rates in 2006, followed by an increase in 2007. We would have expected this effect to be more pronounced for windows replacements, on the grounds of the non-emergency nature of these renovations.

To see if this is the case, we estimated models similar to equation (1) but included both pre- and post-policy years (2004 and later years). With both windows and heating system replacements, the coefficient on the 2006 year dummy was small and not statistically different from those of the previous and following year. We conclude that there is no particular evidence of “strategic” timing of equipment replacement. It must be recognized, however, that it is difficult to make inference from the low rates of equipment replacement observed in the sample.

5. Conclusions

This paper has examined the effect of energy efficiency incentives on household decisions to invest in energy efficiency improvements in their home. We used several waves of the Italy Consumer Expenditure Survey. This survey does not ask individuals whether they did receive a tax credit for their energy efficiency renovations, so we have simply examined whether energy-efficiency upgrades increased when the policy was in place.

Attention is restricted to households who own single-family homes or apartments in multi-family buildings, and live in their own homes. To avoid incorrectly attributing the effects of long-term trends to the incentive policy that was established in Italy in 2007, we have limited the sample to a relatively narrow window around the introduction of the policy (2004-2009), tested for pre-trends, and controlled for factors thought to influence home renovations in our regressions.

We have examined two types of energy efficiency renovations potentially covered by the policy—windows/doors replacements and heating system replacements. We reason that the former are unlikely to be dictated by emergency or equipment breakdowns, and they are often done as part of general update of the dwelling. The latter may be, since there is no market for used heating systems, and replacements are often done when the existing equipment breaks beyond repairs or at the end of its economic life. Free riding behaviour is possible and likely for either type of renovation.

Our analysis is motivated by simple theoretical considerations that posit that individuals derive utility from the housing and energy services of their homes, and will do energy-efficiency upgrades if the net benefits of doing so are greater than the net benefits of keeping the current equipment. Our econometric model is a linear probability model. Our simplest specification assumes that the effect of the policy is uniform over time and for all climates; we subsequently relax these assumptions.

The estimation results suggest that the tax incentive policy was more effective in encouraging windows replacements in harsher climate, and that, all else the same, the policy would raise windows replacements by 37-40% in sufficiently cold climates. Our simplest models suggests that the policy has no “bite” with heating system replacements, or that free riding is almost complete with this type of equipment. On further examination, however, the regression results indicate that the effects of the policy are heterogeneous across the territory and are in fact sizeable in the colder parts of the country.

Caution is needed when interpreting these results. The replacement rates are always very small, which in turn means that the effects of the policy are estimated imprecisely. We do not know whether a household actually applied for and received a tax credit for its renovations, or was even aware of the tax credits policy. Given the typical expenditure associated with the renovations documented in the I-CEX, we suspect that for most of the households here examined the administrative burden was sufficiently heavy to discourage filing, even if the household was aware of the tax credit policy.

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Figure 1. Annual Rates for Selected Home Renovations.

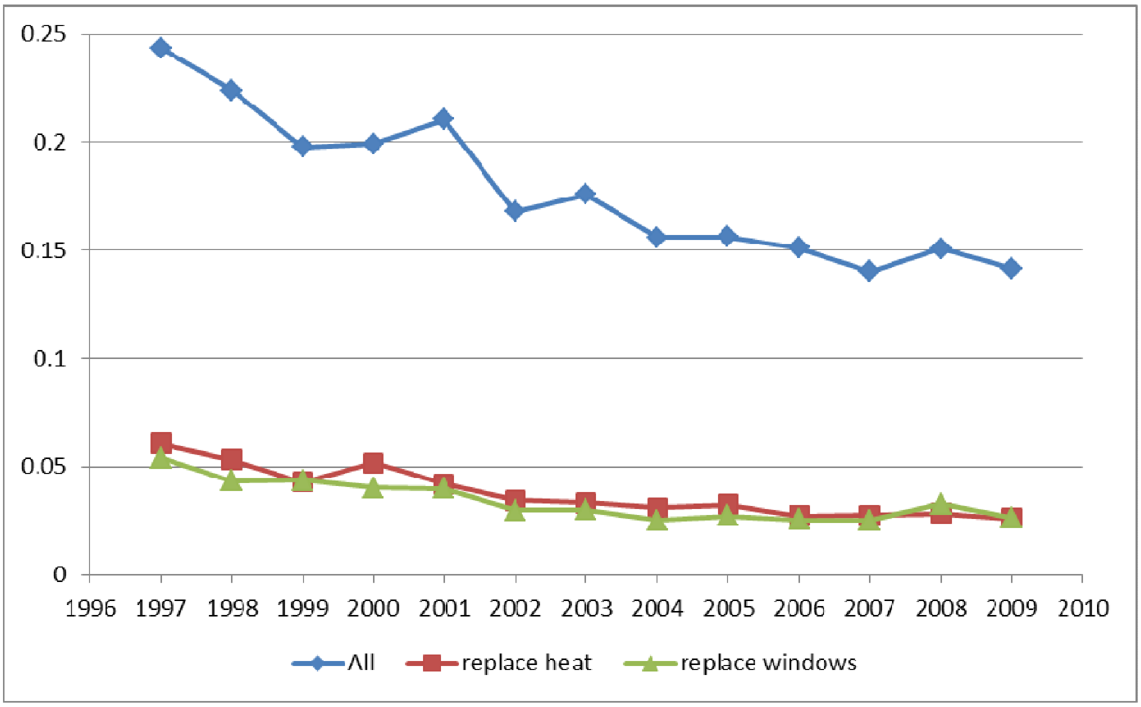

Table 1. Sample and population sizes, and predicted number of windows and heating system replacements by year.

Year	Obs in the sample	number of households in the population	number of windows replacements	Number of heating system replacements
2004	14482	12927203	80461	102257
2005	13967	13104484	81722	107269
2006	14177	13646139	85740	89853
2007	14942	14093871	88271	94144
2008	14685	14834778	119097	101973
2009	14236	14683559	91103	91596

Table 2. Heating fuels. N=86489

Variable	**Freq.**	**Percent**
kerosene, oil and other liquid fuels	6,064	7.01
gas (from pipelines)	61,419	71.01
gas (bottles or outside tanks)	8,881	10.27
coal, wood, coke and other solid fuels	7,534	8.71
other (electricity, solar, etc.)	2,439	2.82
don’t know	152	0.18

Table 3. Type of heating system. N=86489

Variable	**Freq.**	**Percent**
shared central heating system	2,318	2.68
independent central heating system	77,013	89.04
separate heating devices in each room	7,158	8.28

Table 4 Characteristics of the dwelling. N=86489

Variable	Mean	Std. Dev.	Min	Max
home 11-20 years old	0.134318	0.340995	0	1
home 21-30 years old	0.178497	0.382933	0	1
home 31-40 years old	0.182717	0.386437	0	1
home 41-50 years old	0.143845	0.350934	0	1
home more than 50 years old	0.178508	0.382942	0	1
home built before 1902	0.074183	0.26207	0	1
# rooms	4.666223	1.563559	1	65
home value	511.1908	268.5978	30.14311	1632.355
single family home	0.413787	0.492514	0	1
build-up-area	0.763797	0.424751	0	1

Table 5. Heating degree days (° F) and gas prices (constant 2009 euro/GJ). Source: Eurostat.

Variable	Mean	Std. Dev.	Min	Max
Annual heating degree days (° F)	3386.331	1238.733	1140	7473.183
gas prices (in euro 2009 per GJ)	19.14663	6.278643	0	28.26091

Title 6. Economy-wide variables: unemployment rate and home sales rates by Region.

Variable	Mean	Std. Dev.	Min	Max
unemployment rate	7.53197	4.156086	2.046852	18.67538
state of the housing market	0.013017	0.003317	0.006191	0.019379

Table 7. Characteristics of the household. N=86489.

Variable	Mean	Std. Dev.	Min	Max
own a car	0.847807	0.35921	0	1
own only one home	0.913931	0.280467	0	1
# of homes owned	0.1071	0.376915	0	8
day-to-day consumption expenditure, annual total, 2009 euro	11882.61	7746.782	0	130529.9
household size	2.395125	1.306664	0	10
age1	0.352241	0.719619	0	8
age4	0.514193	0.714579	0	5
duration	23.29881	16.70922	0	109
duration squared	822.0296	1088.86	0	11881

Table 8. Windows Replacement. N=81,905.

	Specification (A)		Specification (B)		Specification (C)	
	Coef.	**z**	**Coef.**	**z**	**Coef.**	**z**
gas (from pipelines)	0.00094	0.89	0.00089	0.85	0.00103	0.96
home 11-20 years old	0.00304	2.32	0.00306	2.35	0.00306	2.35
home 21-30 years old	0.00585	4.38	0.00588	4.42	0.00589	4.39
home 31-40 years old	0.00718	4.31	0.00719	4.32	0.00721	4.3
home 41-50 years old	0.00826	4.89	0.00830	4.92	0.00833	4.9
Home more than 50 years old	0.00832	4.12	0.00833	4.13	0.00838	4.14
home built before 1902	0.00975	6.34	0.00974	6.33	0.00978	6.31
# rooms	0.00065	1.99	0.00066	2.01	0.00066	2
home value	1.930E-06	1.71	1.800E-06	1.54	1.960E-06	1.68
single family home	0.00063	0.88	0.00063	0.87	0.00059	0.81
build-up-area	-0.00050	-0.47	-0.00047	-0.45	-0.00054	-0.52
annual heating degree days (° F)	2.040E-06	2.99	1.180E-06	1.57	1.580E-06	1.92
gas prices (in euro 2009 per GJ)	0.00003	0.42	0.00004	0.54	-0.00001	-0.23
delta gas price	0.00222	1.14	0.00206	1.04	0.00519	1.25
delta1gas price	0.00066	0.27	0.00074	0.31	0.00539	1.55
own a car	0.00114	1.3	0.00112	1.29	0.00122	1.47
own only one home	-0.00278	-1.69	-0.00281	-1.71	-0.00298	-1.97
# of homes owned	-0.00151	-1.4	-0.00154	-1.43	-0.00162	-1.74
day-to-day consumption expenditure, annual total, 2009 euro	1.970E-07	2.79	1.950E-07	2.76	2.000E-07	2.72
household size	-0.00071	-2.6	-0.00069	-2.50	-0.00084	-2.38
age1	0.00021	0.46	0.00021	0.45	0.00026	0.55
age4	0.00018	0.27	0.00018	0.26	0.00013	0.19
duration	-0.00019	-2.8	-0.00019	-2.79	-0.00019	-2.79
duration squared	1.400E-06	1.39	1.390E-06	1.39	1.360E-06	1.37
university degree	0.00166	1.27	0.00167	1.28	0.00164	1.27
unemployment rate	-0.00014	-0.74	-0.00017	-0.87	-0.00013	-0.69
home sale rate	0.00582	0.03	0.04519	0.23	-0.07941	-0.38
policy	0.00197	1.32	-0.00243	-1.29		
policy*annual hdd			1.3900-06	1.95	1.440E-06	1.99
2005					0.00046	0.37
2006					0.00027	0.22
2007					-0.00024	-0.09
2008					-0.00265	-1.03
2009					-0.00444	-1.75
constant	-0.00754	-1.25	-0.00511	-0.85	-0.00378	-0.65

Table 9. Heating Replacement. N=81,905.

	Specification (A)		Specification (B)		Specification (C)	
	Coef.	**z**	**Coef.**	**z**	**Coef.**	**z**
gas (from pipelines)	-0.00095	-0.65	-0.00100	-0.66	-0.00101	-0.65
home 11-20 years old	0.00231	1.85	0.00233	1.86	0.00233	1.86
home 21-30 years old	0.00384	2.41	0.00386	2.41	0.00386	2.4
home 31-40 years old	0.00388	4.49	0.00389	4.49	0.00389	4.5
home 41-50 years old	0.00423	2.65	0.00426	2.64	0.00427	2.66
Home more than 50 years old	0.00412	3.53	0.00412	3.51	0.00412	3.54
home built before 1902	0.00355	1.94	0.00355	1.94	0.00353	1.93
# rooms	0.00095	3.19	0.00096	3.21	0.00095	3.17
home value	-5.600E-07	-0.42	-6.700E-07	-0.52	-6.150E-07	-0.49
single family home	0.00008	0.11	0.00008	0.11	0.00008	0.1
build-up-area	0.00083	2.1	0.00086	2.08	0.00086	2.02
Annual heating degree days (° F)	3.230E-06	3.15	2.500E-06	3.77	2.560E-06	3.36
gas prices (in euro 2009 per GJ)	-0.00003	-0.9	-0.00002	-0.72	-0.00002	-0.44
delta gas price	-0.00106	-1.03	-0.00120	-1.14	0.00054	0.17
delta1 gas price	-0.00468	-1.84	-0.00461	-1.82	-0.00261	-0.61
own a car	0.00214	1.77	0.00212	1.77	0.00216	1.78
own only one home	-0.00002	-0.01	-0.00005	-0.02	0.00042	0.13
# of homes owned	0.00205	0.69	0.00203	0.68	0.00243	0.79
day-to-day consumption expenditure, annual total, 2009 euro	2.720E-07	3.94	2.710E-07	3.92	2.740E-07	3.99
household size	-0.00059	-1.03	-0.00058	-1.00	-0.00064	-1.1
age1	0.00135	1.56	0.00135	1.55	0.00137	1.58
age4	0.00098	1.34	0.00098	1.34	0.00095	1.3
duration	-0.00014	-1.32	-0.00014	-1.31	-0.00014	-1.31
duration squared	1.590E-06	0.96	1.580E-06	0.95	1.590E-06	0.95
university degree	-0.00013	-0.15	-0.00012	-0.14	-0.00013	-0.16
unemployment rate	0.00010	0.49	0.00008	0.41	0.00007	0.34
home sale rate	0.03297	0.25	0.06600	0.46	0.01046	0.06
policy	-0.00016	-0.11	-0.00385	-1.62		
policy*annual hdd			1.170E-06	1.07	1.200E-06	1.15
2005					0.00090	1.09
2006					-0.00085	-0.87
2007					-0.00276	-0.92
2008					-0.00411	-2.26
2009					-0.00438	-2.67
constant	-0.01428	-1.79	-0.01224	-1.89	-0.01206	-1.66

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