An Examination of How Energy Efficiency Incentives Are Distributed Across Income Groups

Grant D. Jacobsen*

University of Oregon

Last Updated: December 2018

Abstract

Many policies lead to the provision of incentives, such as rebates or tax credits, to consumers for the purchase of products that have high energy efficiency. This paper investigates how these incentives are distributed across income groups for three types of subsidies (manufacturer or retailer rebates, utility rebates, and tax credits) and eight types of equipment. While incentives are always somewhat concentrated in higher-income households, there is substantial heterogeneity in the magnitude of the concentration depending on how incentives are structured. Tax credits are the type of subsidy that is most concentrated in higher-income households and utility rebates are the least. Incentives for appliances that are not universally-owned, including dishwashers and clotheswashers, are more concentrated than are incentives for other types of equipment. Differences across income groups in the rates of equipment presence and turnover, willingness to purchase Energy Star models, and rates of homeownership contribute to the concentration. After controlling for these factors, utility rebates are no longer concentrated in higher-income households, but manufacturer / retailer rebates and tax credits remain so.

JEL Codes: Q48, Q52, Q38
Keywords: energy efficiency, energy rebates, energy tax credits, energy subsidies, distributional effects, energy policy

*Post: 1209 University of Oregon, 119 Hendricks Hall, Eugene, OR, 97403-1209, Tel: (541) 346-3419, Email: gdjaco@uoregon.edu. I am grateful for comments from Arik Levinson and for comments received at the World Congress of Environmental and Resource Economics and at the Oregon Resource and Environmental Economics workshop.

1 Introduction

Increasing energy efficiency has been a prominent public policy goal in recent years. A variety of policies that target energy efficiency have been enacted or strengthened to this end. Standards, such as building energy codes, have been used to set minimum allowable efficiency levels. Taxes, including energy taxes or carbon taxes, have been used to indirectly encourage investment in energy efficiency by raising energy prices. Energy efficiency incentives, which typically offer subsidies for high-efficiency goods through rebates or tax credits, have been used to subsidize the costs of energy efficiency investments. Labeling programs, such as Energy Star, have been used to help households identify high-efficiency products.

As energy efficiency policies have become more prominent, researchers have increasingly sought to carefully evaluate these policies. Many evaluations have focused on effectiveness and efficiency.[1] While effectiveness and efficiency are important factors, they may mask variation in the distributional effects of policies, which have been an key element in analyses of many environmental and energy policies (e.g., Grainger and Kosltad, 2010; Bento, Franco, and Kaffine, 2006). Distributional effects are important because, as modeled in optimal tax theory, policies that lead to a more equal distribution of resources will enhance social welfare, holding all else equal (Diamond and Saez, 2011). Additionally, distributional effects are often an important factor in determining whether enacting or retaining policies is politically feasible. Perhaps because of political factors, the distributional effects of conservation programs on low-income households is often of direct interest to utility managers and policymakers (Wichman et al., 2016). Analysis of distributional effects has been of

In this paper, I investigate an important component related to the distributional effects of energy efficiency incentives: how the incentives are distributed across income groups. I focus on energy efficiency incentives because, as I describe below, the distributional effects of energy efficiency incentives have been the subject of relatively few studies and because energy efficiency incentives are a large and growing component of energy policy. By 2025,

[1] Examples of this work include studies on , especially the certification of high-efficiency Energy Star products and buildings (Walls et al., 2017; Jacobsen, 2016a; Kahn and Kok, 2014; Brounen and Kok, 2011; Eichholtz et al., 2010); studies on standards, including building energy codes and appliance standards (Novan et al., 2017; Levinson, 2016a; Jacobsen, 2016b; Jacobsen and Kotchen, 2013); and studies on appliance rebates (Datta and Gulati, 2014).

spending on incentives for energy efficiency is expected to be about \$10 billion annually, doubling relative to 2010 levels (Barbose et al., 2015).

The analysis is based on a uniquely well-suited version the Residential Energy Consumption Survey from 2009 that includes a large set of detailed questions related to energy efficiency incentives. Using a variety of empirical techniques, I evaluate how the probability of directly benefiting from an incentive program relates to household income across three different types of subsidies (manufacturer or retailer rebates, utility rebates, and tax credits) and eight different types of equipment (refrigerators, dishwashers, clotheswashers, space heaters, central air-conditioners, light bulbs, windows, and insulation). The results indicate that almost all forms of incentives are concentrated in higher-income households, but there is substantial heterogeneity in the magnitude. Tax credits are the most concentrated type of subsidy and utility rebates are the least concentrated. Incentives for appliances that are not universally present in residences, such as dishwashers and clotheswashers, are more concentrated in higher-income households than are incentives for other types of equipment. The levels of concentration that are estimated are substantial. For example, regression models indicate that a household with an income of \$80k is three times more likely than a household with an income of \$20k to benefit from incentives. Differences across income groups in the rates of equipment presence and turnover, willingness to purchase Energy Star models, and rates of homeownership contribute to the concentration of incentives in higher-income households. After controlling for these factors, utility rebates are no longer concentrated in higher-income households, but manufacturer / retailer rebates and tax credits remain so.

The results are helpful for informing how energy efficiency incentives should be structured. As I describe in Section 2, many policies lead to the provision of energy efficiency incentives. The main implication of the results for policymakers is that policies that are designed to increase the provision of incentives tend to be more likely to directly benefit lower income households if the incentives are provided through utility rebates and if the incentives avoid appliances that are more likely to be owned by higher-income households. Optimal policy design will require consideration of a broader set of factors; such as cost-effectiveness, free-ridership, producer price responses, and effects on innovation, but distributional differences in who directly benefits from incentives are an important factor as policymakers evaluate policy options and the associated trade-offs across multiple different criteria.[2] It should further be noted that the analysis is descriptive in nature and focuses on capturing historical tendencies with respect to the average distributional effect of differnt types of energy efficiency incentives. The analysis is not necessarily predictive of distributional effects of any individual program, which will depend a large variety of factors which are not embedded in the present analysis.

This paper contributes to the literature on the distributional effects of energy efficiency policies. Four studies within this literature have provided evaluations related to the distributional effects of energy efficiency incentives. Borenstein and Davis (2016) and Neveu and Sherlock (2016) use tax return data to show that federal tax credits for residential energy investments primarily benefit higher-income Americans.[3] Sutherland (1994) presents survey evidence that higher-income households are more likely to participate in demand-side management programs, including utility rebates.[4] Bruegge (2017) applies a discrete-choice model to a refrigerator and clotheswasher rebate program offered by a large utility and finds that the program creates a loss in consumer surplus and that the loss is greatest for higher-income households.[5]

The primary contribution of this paper relative to existing work is that I examine incentives administered through several forms of subsidies and for multiple different types of equipment using the same sample and empirical framework. This feature allows me to describe how energy efficiency incentives are distributed across income groups in a more comprehensive manner than is available based on existing work and the ability to directly compare how different approaches to energy efficiency incentives lead to different distributions of recipients. In addition to providing a comprehensive evaluation that enables

[2]Another distributional consideration is how the costs of energy efficiency incentives are distributed and I address this issue briefly in Section 5.4.

[3]Residential energy investments are a combination of investments in energy efficiency and renewable energy (e.g., solar panels).

[4]While household income is associated with participation in DSM programs, there is less evidence it is linked to demand for environmental protection.

[5]Other studies have evaluated the distributional effects of other types of policies related to energy efficiency, including carbon taxes (e.g., Grainger and Kolstad, 2010), gasoline taxes (e.g. Bento et al., 2015), fuel economy standards (Davis and Knittel, 2016; Levinson, 2016b), and building energy codes (Bruegge et al., 2017).

comparisons of various types of incentives, I also evaluate types of incentives that have not previously been examined. In particular, to the best of my knowledge, no existing studies have examined how incentives provided through manufacturer / retailer rebates are distributed across income groups or how incentives for light bulbs, dishwashers, space heaters, or air-conditioners are distributed across income groups.

2 Background on Energy Efficiency Incentives

Energy efficiency incentives are primarily offered through rebates or tax credits. In order to be eligible for rebates or tax credits, products that are supported must meet certain efficiency standards (e.g., Energy Star standards). The incentives usually cover only a portion of the costs and are often capped at maximum dollar amounts.

Energy efficiency incentive programs that are operated by utilities and funded by ratepayers are typically rebate-based programs. These programs are required or encouraged under a variety of state policies, including energy efficiency resource standards, renewable portfolio standards that include eligibility for energy efficiency, statutory requirements that utilities acquire all cost-effective energy efficiency investments, system benefit charges, integrated resource planning, demand-side management (DSM) plans, and public purpose programs.[6] Two types of rebate programs are common. First, utilities can provide consumers with rebates directly. Alternatively, utilities can provide manufacturers or retailers with funding to administer a rebate program. The primary difference between the two options is how the rebates are marketed and disseminated. For example, while utility rebate programs typically require customers to complete a mail-in application, retailer rebate programs have the option of applying instant rebates at the time of purchase. With respect to marketing, utility rebates are typically marketed predominantly through mailings and on the utility's web site, whereas manufacturer / retailer rebates are more likely to be advertised at the point of sale. In practice, manufacturer or retailer rebates are more likely to be used for simpler improvements, such as purchasing a refrigerator, dishwasher, or clotheswasher, although it is not exceedingly uncommon to offer utility rebates for these types of equipment.

[6] See Barbose et al. (2013) for a description of states where each type of policy is enacted.

Tax credits also provide an incentive for the purchase of high-efficiency goods and have been in place periodically over the last several decades at various levels of government. For example, from 2006 to 2016, the Nonbusiness Energy Property Credit (NEPC) was available as a personal federal tax credit.[7] Under NEPC, households could claim tax credits for improvements in the building envelope of existing homes and for the purchase of high-efficiency heating, cooling, and water-heating equipment. The tax credit equaled 10% of costs (30% in 2009 and 2010) and was capped at $500 annually ($1500 in 2009 and 2010). There were additional equipment-specific caps as well. While the credits have expired, the federal government has a history of periodically offering incentives for energy efficiency investments, so it is likely that some form of incentive will be considered again in the future. States also commonly offer tax credits for energy efficiency. For example, Oregon's Residential Energy Tax Credit offers tax credits for a variety of types of equipment, with caps ranging from $100 to $6,000.[8]

With respect to understanding how the results in this paper may inform policy design, it is helpful to recognize that policymakers can structure policies related to energy efficiency to influence the extent to which each of the channels described above are utilized. For example, incentives at the federal level have typically been provided through tax credits, but other options are possible. An alternative approach would be to allocate federal grants to utilities or regional energy efficiency councils to expand rebate programs. There would be precedent for this type of approach to energy efficiency, as the Department of Energy (DOE) already provides funding and technical assistance to non-federal organizations through the State Energy Program and the State and Local Energy Efficiency Action Network. In general, policies related to energy efficiency incentives at any level of government could be written to prescribe the types of incentives that are acceptable and could allow or disallow certain types of incentives depending on distributional effects or other criteria.

[7] NEPC was created or extended through the Energy Policy Act of 2005, The Energy Improvement and Extension Act of 2008, and the American Recovery and Reinvestment Act of 2009.

[8] See dsireusa.org and energy.gov/savings for databases on energy efficiency incentives, including other examples of state tax credits.

3 Data

The analysis is based on the Residential Energy Consumption Survey (RECS). The survey collects information on energy-related characteristics and usage patterns for a nationally representative sample of housing units in the United States. The U.S. Energy Information Administration conducts the survey periodically with the most recent waves occurring in 2015, 2009, 2005, 2001, 1997, 1993, and 1990. The years of the survey waves correspond to the year the data were collected, as opposed to when they were released, which can differ substantially. For example, the 2009 RECS survey data were not fully released until 2013. Each observation in the sample represents a household. The survey includes both households living in owner-occupied housing and renters.

I focus on the 2009 wave of the survey, although I also present some results based on the 2015 survey. There are three reasons why the 2009 survey is best suited for an evaluation of energy efficiency incentives. First, it includes an unusually high number of detailed questions on energy efficiency incentives. In particular, it asks respondents whether households received assistance for thirteen different types of improvements and provides five different options that the households can select as the source of assistance.[9] In contrast, the 2015 wave of the survey only included six questions about energy efficiency assistance, all with simple yes/no response options. The 2005 wave of the survey only included three questions about energy efficiency assistance and did not mention anything specific to rebates, tax credits, or support for specific types of equipment. Earlier waves of the RECS also contain a shortage of questions regarding energy efficiency incentives and, at this point, are becoming dated. The second advantage of the 2009 RECS is that it contains relatively detailed data on income, with respondents selecting where their income falls in a menu comprised of twenty-four different ranges. Other waves of the RECS do not include such detailed income data. For example, the 2015 RECS only includes eight different ranges. The final advantage of the 2009 RECS survey is that the sample is nearly three times larger than any prior wave of the survey and more than twice as large as the 2015 wave.

[9] As I describe in more detail later in this section, I do not examine all types of equipment or sources of assistance.

The 2009 RECS includes questions related to energy efficiency incentives for thirteen different types of equipment or other energy efficiency improvements. Five of these – freezers, water heater blankets, window or wall air-conditioners, caulking/weather-stripping, and energy audits – constituted a very small amount assistance (less than 0.6% of the sample received assistance) and are therefore excluded from the analysis. The remaining types of equipment include refrigerators, dishwashers, clotheswashers, space heaters/furnaces, central air-conditioners (AC), and light bulbs. For each type of equipment, all households that indicated they had replaced, maintained, or installed the equipment since moving into the residence were asked whether they received assistance in paying for the equipment. They were then provided with a list of sources of assistance to choose from, which included manufacturer or retailer rebates, utility or energy supplier rebates, tax credits, subsidized loans, and the weatherization assistance program. I ignore assistance provided through subsidized loans because less than 0.1% of households received assistance through loans. I ignore assistance received through the weatherization assistance program because it is targeted at low-income households and has maximum income limits and therefore predominantly benefits low-income households by construction.

For the eight types of equipment included in the analysis, I create seven variables, including 1) a variable indicating whether the equipment is present in the residence,[10] 2) a variable indicating whether the household has replaced or installed the equipment since moving-in,[11] 3) a variable indicating whether the model of the equipment is an Energy Star version (for reasons described further later, this variable is only generated for households that have recently replaced the equipment), 4) three different variables indicating whether the household received the incentive through manufacturer / retailer rebates, utility rebates, or tax credits, and 5) an "Any Incentive" variable which is a summation of three source-specific variables.[12] All incentive variables equal one if the household indicated they

[10] The RECS only indicates whether the equipment is present. For renter households, it does not indicate whether the equipment is owned by the tenant or property owner.

[11] For light bulbs, this variable is based on a question that asks households whether they have installed *energy efficient* light bulbs. For insulation, the variable is based on a question that asks whether the household has added insulation. For all other types of equipment, the variable is based on a question that asks the household whether they have replaced the equipment (and asks nothing about whether the new version is high efficiency).

[12] Households can only select one form of assistance, so *Any Incentive* is always binary.

received an incentive and zero otherwise.

In addition to the variables related to equipment and incentives, the only other variables used in the analysis are household income and an indicator for whether a household is a homeowner or renter. Income is recorded using a categorical variable consisting of twenty-four categories that generally cover either a \$2.5k, \$5k or \$10k range. For portions of the analysis, I impute a continuous measure of income using the mid-points of the income category. The top category is "\$120k or More" and I drop households in this category due to the imprecision of the category. I present a histogram of income in Figure 1. Income is slightly right skewed and the most densely represented categories fall between \$10k and \$60k. Regarding homeownership, about 65% of households in the data are homeowners.

Means related to equipment or incentives are reported in Table 1. With respect to presence of each equipment in the residence, space heaters, refrigerators, windows, and insulation are nearly universally present, clotheswashers are present in four-fifths of households, and central AC and dishwashers are present in about half of households. Across types of equipment, about one in five households have typically replaced the equipment since moving in, although energy efficient light bulbs, with a post move-in installation rate of about 50%, are an exception. About three-quarters of the refrigerators, dishwashers, and clotheswashers that have been replaced since the household moved-in are Energy Star models. Typical rates of receiving some form of incentive are about 2%, with the highest levels being for light bulbs, windows, space heaters, and clotheswashers. Averaging across all types of equipment, rates of receiving each form of subsidy are similar on average, at 0.5-0.7%. However, there is some variation across types of equipment. Incentives for appliances (refrigerator, dishwashers, clotheswashers) are most likely to be provided through manufacturer or retail rebates. Incentives for heating and cooling equipment are provided at a similar rate across all three types of subsidies. Windows and insulation incentives tend to be provided through tax credits.

4 Distributional Measures

The goal of this paper is to describe how energy efficiency incentives are distributed across income groups. One of the ways by which I do this is by presenting graphs of the rates of receiving energy efficiency incentives across income groups.[13] These graphs frequently show clean, visually compelling evidence that higher-income groups are more likely to receive incentives. A drawback of the graphs, however, is that they do not succinctly summarize how incentives are distributed across income groups or allow easy comparisons of how incentives are distributed for different sources and types of equipment.

In order to more concisely describe of how energy efficiency incentives are distributed across income groups, I compute two overall distributional measures. The first measure is the ratio of the probability a household with an income of \$80k receiving an incentive to the probability of a household with an income of \$20k receiving an incentive. This ratio is calculated using the predicted probabilities of households with the corresponding incomes receiving an incentive based on a linear regression model of the receipt of an energy efficiency incentive on income. For these regressions, I use a continuous measure of income imputed using the mid-point of each income group (groups are indicated in the horizontal axis in Figure 1). The choice of income levels for the ratio is somewhat arbitrary, but \$20k was chosen because it is near the 2009 federal poverty line for households with three members (\$18.3k) or four members (\$22.1k). The top figure, \$80k, was chosen because four times the poverty line has been deemed as the point where households no longer qualify for government assistance under certain policies (e.g., households are no longer eligible for tax credits under the Affordable Care Act once income reaches four times the poverty line). I test whether the ratio significantly differs from 1, which would correspond to perfect equity, using the delta method. Note that in these regressions I deliberately do not include any control variables. Including controls would absorb various channels through which income could relate to the receipt of incentives (e.g., less educated households earning less and also being less likely to seek out rebates), which is undesirable from the perspective of characterizing the overall distribution of incentives across income groups.

The second distributional measure is a concentration index, which is a popular statistic for describing distributional effects. The concentration index is a continuous measure that falls between -1 and 1, with 0 representing perfect equity, -1 indicating all incentives going

[13]Throughout the analysis, I apply the sample weights included in the RECS to make the survey nationally representative.

to the lowest-income households, and 1 indicating all incentives going to the highest-income households. The benefit of the measure is that it is a flexible statistic that takes into account the entire distribution of the data. The weakness of the statistic is that it does not have a straightforward economic interpretation.[14] I report both the $\$80k$-to-$\$20k$ incentive ratio and the concentration index in all relevant parts of the analysis. The two measures are strongly correlated.

In addition to describing how incentives are distributed across income groups, I examine several potential mechanisms that could drive the observed distributional patterns. Factors that I consider include differences in the presence and replacement rates of equipment within residences, differences in the proclivity for households to purchase Energy Star products, and differences in rates of homeownership.

A limitation of the analysis is that the RECS only includes a binary measure indicating whether a household received an incentive, as opposed to a measure of the dollar amount of the incentive received by the household. While it is hard to predict exactly how an analysis based on the dollar amount of incentives would differ, it seems most likely that an analysis based on take-up produces relatively conservative estimates of the extent to which incentives are concentrated in higher-income households, as well as the differences in concentration across types of incentives. For example, if higher-income households receive larger average incentives than lower income households because they tend to purchase more expensive models, then the distribution of incentive dollars would be more concentrated than the distribution of incentive take-ups. Similarly, if incentive programs that provide relatively larger incentives to higher-income households attract relatively greater participation rates from higher-income households, then the differences in the dollar-based concentrations across types of incentives will be greater than the differences in the take-up-based concentrations.

[14]The concentration index is constructed by plotting a concentration curve, which has the cumulative distribution of income on the horizontal axis and the cumulative distribution of the relevant outcome (in this case the total share of incentives) on the vertical axis, and then calculating the share of the data that falls in between the concentration and the 45 degree line. If the concentration curve falls above the 45-degree line, the confidence index is negative; otherwise, it is positive. See Maguire and Sheriff (2011) for an overview of various distributional measures, including the Gini Coefficient, Lorenz Curves, and the Concentration Index.

5 Results

5.1 Primary Results

I begin with an evaluation of how energy efficiency incentives are distributed across income groups for each type of subsidy (i.e. manufacturer / retailer rebates, utility rebates, or tax credits). For this analysis, I analyze the data in a pooled format in which each observation represents a household and a type of equipment. The pooled data has eight times more observations than the non-pooled data.[15]

Figure 2 presents means in incentive rates across income groups and shows that the probability of receiving an incentive is approximately linearly increasing as income increases across each type of subsidy. Notably, rates for very low-income households are nearly zero for tax credits and only slightly above that for manufacturer / retailer rebates. Additionally, the slope of the income gradient appears to be smallest for utility rebates.

I characterize the distribution of incentives more precisely using Table 2, which reports results from linear regressions of the receipt of an incentive on income, as well as the two distributional measures described earlier. Note that in these regressions, while it is helpful to see a statistically significant coefficient on income, the coefficient is of secondary interest relative to the two distributional measures that are reported at the bottom of the table.[16] Both distributional measures indicate incentives are substantially more likely to go to higher-income households. The ratio measure indicates that a household with an income of \$80k is 4.2 times more likely than a household with an income of \$20k to receive an incentive when it is distributed through a tax credit, but only 3.4 greater when a manufacturer or retailer rebate is used and 2.1 times greater when a utility rebate is used. Overall, the \$80k-household is about three times more likely to receive some form of incentive than the

[15]When computing test statistics using the pooled data, I cluster the analysis by household to account for within-household correlations.

[16]The coefficient on income is of secondary interest because characterizing how energy efficiency incentives are distributed depends both on how the rate of incentives changes with income and also how many incentives are received by the group that receives the fewest incentives. For example, a scenario in which the probability of a low-income household receiving an incentive is 1% and a high-income household receiving an incentive is 11% implies much more concentration of incentives in higher-income households than a scenario in which the probability of a low-income household receiving an incentive is 51% and a high-income household receiving an incentive is 61%, yet these two scenarios could generate the same coefficient on income.

20k$-household. The overall concentration index is .30 and subsidy-specific values range between .20 (utility rebate) and .36 (tax credit).

I next evaluate the distribution of incentives across income groups for each type of equipment. Figure 3 presents graphical evidence that the probability of receiving an incentive is again approximately linearly increasing in income for each type of equipment. While about five percent of the highest income households receive an incentive across all types of equipment, less than one percent of the lowest income households receives an incentive for most types of equipment.

Table 3 presents estimates and distributional measures by type of equipment. Setting aside windows and insulation, which may have elevated levels of concentration in higher-income households due to primarily being allocated through tax credits (see Table 1), the two types of equipment that are most concentrated are dishwashers and clotheswashers. The 80k$-household is over six times more likely to receive an incentive for a dishwasher than the 20k$-household and over three and a half times more likely to receive an incentive for a clotheswasher. Light bulbs have noticeably lower concentration measures, with the wealthier household being less than twice as likely to receive an incentive. The remaining types of equipment have roughly comparable levels of concentration and the $80k-household tends to be about three times more likely to receive an incentive.

Table 4 presents estimates and distributional measures for each combination of types of subsidy and type of equipment.[17] The benefit of this analysis is that it provides a more nuanced characterization of the distribution of energy efficiency incentives and it helps in evaluating whether the patterns described earlier with respect to differences in distribution across types of subsidies are due to correlations between the type of subsidy and the type of equipment that is being subsidized (or vice versa). This examination is important because, as shown in Table 1, there is a correlation between type of subsidy and type of equipment. All subsidy-equipment combinations that rarely serve as an avenue for incentives (i.e. less 2 out of 1,000 households receive the corresponding form of incentive) are presented in gray due to limited statistical power.

[17]For the remainder of the analysis, I focus on describing results from the regression and the concentration index because the results can be presented more compactly. However, I present analogous graphical output for much of the analysis in the Appendix.

Columns 3 through 5 in Table 4, which present results for clotheswashers, space heaters, and central air-conditions, are of perhaps greatest interest when comparing subsidies because each form of subsidy is utilized at a reasonable rate across panels. These results mirror those from earlier: utility rebates are always least concentrated in higher-income households and tax credits are always most concentrated. With respect to comparing equipment types, it is easiest to do so by comparing results within panels. Panel 1, for example, shows that dishwashers remain the most concentrated type of equipment even when just making comparisons across different types of manufacturer / retailer rebates. Panel 2, which presents utility rebates, shows that clotheswashers are most concentrated. Collectively, the results in Table 4 reinforce the results described in earlier in this section.

5.2 Mechanisms

I next focus on investigating the mechanisms behind the distributional patterns described in Section 5.1. I evaluate how several factors related to the ability to take advantage of energy efficiency incentives differ across income groups, including differences in the presence of equipment within residences, differences in equipment replacement rates, differences in the rate at which Energy Star models are purchased, and differences in the rates of homeownership. These results are primarily presented in Table 5.[18] I then examine whether energy efficiency incentives remain concentrated in higher-income households after controlling for these channels.

One potential channel through which incentives can be concentrated in higher-income households is that such households may be more likely to own the types of equipment that are subsidized. Panel 1 of Table 5 investigates this channel by evaluating how the probability that each type of equipment is present in a residence varies across income groups. Each column within the panel reports a linear regression of equipment presence on income and also reports the two distributional measures described earlier. Six of the eight ratio measures are substantially greater than one, showing that higher-income households are more likely to receive incentives in part because they are more likely to own the equipment that is subsidized. Note that the two types of equipment for which incentives tended to be

[18]See Figures A.1, A.2, and A.3 for graphs related to Table 5.

most concentrated in Table 4, dishwashers and clotheswashers, also are substantially more likely to be owned by higher-income households.

Another channel for concentration of incentives in higher-income households is that higher-income households may be more likely to upgrade or improve their equipment. I assess this channel by evaluating whether income is related to the probability that a household has replaced the equipment since moving into their residence. In this evaluation, the sample is limited to households that reported owning the equipment. Results are reported in Panel 2 of Table 5. Across equipment types, higher-income households are more likely to replace their equipment, and therefore more able to take advantage of energy efficiency incentives. The replacement rate distributional measures are positive, although mostly about one-third of the magnitude of the distributional measures for energy efficiency incentives.

Energy efficiency incentives may also be concentrated in higher-income households because higher-income households are more likely to purchase high efficiency equipment. I assess this channel by evaluating the relationship between income and owning an Energy Star model of the corresponding type of equipment. Information related to Energy Star is only available for refrigerators, dishwashers, and clotheswashers. To isolate this channel from the previous two channels, I restrict the sample to households that have a refrigerator, dishwasher, or clotheswasher and have replaced it since moving into the residence. Results are reported in Panel 3 of Table 5. Across all three equipment types, higher-income households are more likely to own Energy Star models and the corresponding Energy Star distributional measures indicate the \$80k-household is about 1.2 times more likely to own an Energy Star model.

The final mechanism that I examine that can contribute to the concentration of incentives in higher income households is differences in rates of homeownership across income groups. Conceptually, homeownership may be a mechanism because homeowners tend to have higher incomes than renters do and because rental properties often include certain types of equipment, thereby making renters less likely to have to purchase equipment and have an opportunity to receive an incentive. The data bear this out. Mean income levels for homeowners are about \$53k and mean income levels for renters are about \$38k. For each type of equipment, homeowners are more likely to receive incentives. The rates of incentives by equipment for homeowners and renters are as follows, with the rates for homeowners listed first within the parentheses: refrigerator (2.6%, 0.5%), dishwasher (1.7%, 0.0%), clotheswasher (3.1%, 0.2%), space heater (3.6%, 0.2%), central AC (2.5%, 0.1%), energy efficient light bulbs (2.9%, 1.6%), windows (3.3%, 0.1%), and insulation (1.2%, 0.0%).

The results described thus far related to mechanisms indicate that differential rates across income groups in the presence of equipment, equipment turnover, willingness to purchase Energy Star versions of equipment, and rates of homeownership contribute to the concentration of energy efficiency incentives in higher-income households. I next examine whether incentives remain concentrated in higher-income households after controlling for these factors. To do so, I limit the sample to observations in which the above mechanisms cannot explain any observed distributional patterns. Specifically, in Table 6, I present equipment-by-source distributional measures based on the sample of households that are homeowners who own the corresponding type of equipment and have replaced or installed it since moving in to the residence. I further restrict the sample to households that own an Energy Star version of equipment in Table 7. This restriction limits the sample to only refrigerators, dishwashers, and clotheswashers.

The most striking finding from the results that are reported in Tables 6 and 7 is that there is little evidence that utility rebates remain concentrated in higher-income households. Both the coefficient on income and the incentive ratio are consistently insignificant. Tax credits, in contrast, continue to show statistically significant evidence of substantial concentration. Manufacturer rebates fall in between these two cases. With respect to equipment, there is much less evidence of differences in the distributional measures across types of equipment. The magnitude of the differences between equipment types is relatively small and the ordering of the concentration across types of equipment varies by panel.

The primary implication of the results related to mechanism, in the context of policy design, is that they affirm the distributional advantages of providing incentives through utility rebates. After controlling for the mechanisms investigated in this section, which are likely to lead to incentives being somewhat concentrated in higher-income households regardless of how the incentives are structured, utility rebates appear to be an equitable way of distributing incentives. There is evidence that both manufacturer / retailer rebates and tax credits remain concentrated in higher-income households even after controlling for the mechanisms considered above. The reason why these sources remain concentrated is unclear. Manufacturer / retailer rebates may be concentrated because manufacturers or retailers attempt to structure rebates around more expensive models, which are more likely to be purchased by higher-income households. Tax credits are likely to be concentrated, at least in part, because they are not always refundable and therefore without value to low-income households without taxable income. Conversely, one of the reasons why utility rebates may be relatively more equitable is that they are typically allocated through time-consuming mail-in procedures. In contrast, retailer rebates can be administered through "instant rebates" that are processed at check out. If lower-income households have a lower value of time (Deacon and Sonstelie, 1985), then these mail-in procedures may make lower-income households relatively more likely to take advantage of incentives.

5.3 2015 Residential Energy Consumption Survey

I complement the analysis of the 2009 RECS with a brief analysis of the 2015 RECS. As mentioned earlier, the 2009 RECS constitutes the primary analysis because it contains a much richer measure of income and set of questions related to energy efficiency incentives than the 2015 survey. The 2015 survey, nonetheless, is helpful for showing that the results from 2009 survey extend to years that are more recent. The 2015 survey includes seven income categories (excluding the top-coded category) and I present a histogram of this variable in Figure A.4. The survey asks households yes/no questions regarding whether they have received assistance through free or subsidized light bulbs, free or subsidized home energy audits, utility appliance rebates, free recycling of appliances, tax credits, or other benefits. I graph mean rates of assistance across income for each type of assistance in Figure A.5.

Regressions results and distributional measures based on the 2015 RECS survey are presented in Table 8. The results reinforce those from the 2009 survey. Utility rebates are about as concentrated in 2015 as there were in 2009, with the \$80k household 2.3 times as likely to receive incentives as the \$20k-household. Based on the \$80k-to-\$20k incentive ratios, tax credits are almost twice as concentrated as utility rebates, at 4.3, which is comparable to the 2009 tax credit ratio (4.2). Lights continue to be a relatively less concentrated form of incentives. Audits also have low levels of concentration, likely because audit programs are often targeted at low-income households. Programs that offer free recycling of appliances have a similar concentration as utility rebates.

5.4 The Distribution of Program Costs

As mentioned earlier, the analysis focuses primarily on the how the direct benefits of incentives are distributed.[19] An analysis of the distribution of program costs is more complicated because the RECS does not include data on how incentive programs are funded. For ratepayer-funded rebate programs, programs tend to be funded either through an extra charge that is administered either as a flat fee or as a percentage of the monthly bill. Under a percentage structure, higher-income households are likely to contribute more because they have higher usage. However, even under this structure, the costs to higher-income households are not enough to offset their disproportionate benefits. A regression of the dollar amount of the electricity bill on income based on the 2009 RECS shows that higher-income households have higher bills, but that the expected bill for the \$80k-household is only 1.3 times greater than for the \$20k-household. For context, recall that the \$80k-household is 3.1 times more likely to benefit from an incentive. Evaluating the cost of tax credits is more complicated because it requires assumptions about how tax revenue would have been spent in the absence of the incentive program.

6 Conclusion

Energy efficiency incentives are increasingly being used to encourage consumers to purchase high efficiency products. This paper investigates how these incentives are distributed across income groups for three types of subsidies and eight different types of equipment. The results show that almost all forms of incentives are concentrated in higher-income households, but there are differences in the magnitude of the concentration depending on how the incentives are structured. Across types of subsidies, distributing incentives through util-

[19]From a policymaking perspective, the distribution of benefits may be of primary interest if policymakers are choosing how to utilize a fixed pool of money. For example, if utilities are choosing whether to administer their own rebate program or fund a retailer rebate program from a fixed pool of revenue, differences in distributional outcomes will be largely determined by differences in the distribution of program benefits.

ity rebates leads to the least concentration of incentives in higher-income households and distributing incentives through tax credits leads to the most concentration. Across types of equipment, incentives for appliances that are not universally owned, including dishwashers and clotheswashers, are more concentrated in higher-income households than are incentives for other types of equipment. Several mechanisms contribute to concentration of incentives in higher-income households, including differences across income groups in the rates of equipment presence and turnover, willingness to purchase Energy Star models, and rates of homeownership. After controlling for these factors, utility rebates are no longer concentrated in higher-income households, but manufacturer / retailer rebates and tax credits remain so. The primary policy implication from the findings is that incentive programs will be more likely to directly benefit lower income households if they provide incentives through utility rebates and if they avoid targeting appliances that tend to be disproportionately owned by higher-income households.

The results contribute to the literature on the distributional effects of energy and environmental policies, which has tended to find that such policies are regressive (Fullerton and Muehlegger, 2017). In this regard, criticism of energy efficiency incentives on the basis of distributional effects may be softened by that fact that alternative policies may also be more likely to benefit higher-income households. Further, a complete evaluation of how energy efficiency incentives compare to other policy options, which is beyond the scope of this paper, would require consideration of a broader set of factors, including effects on pollution levels, production costs, price responses, and rates of innovation. Regardless, energy efficiency incentives are currently a major component of the policy environment and appear poised to remain so. To the extent they do, this paper provides guidance on how the structure of incentives can be adjusted to influence an important distributional margin. Given the large variety of policies that address energy efficiency and the complexities involved in evaluating them, continued research on the effects of energy efficiency policies is likely to remain valuable for the foreseeable future.

7 References

Barbose, G. L., Goldman, C. A., Hoffman, I. M., and Billingsley, M. (2013). "The Future of Utility-Customer Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025," Ernest Orlando Lawrence Berkeley National Laboratory Paper LBNL-5803E.

Bento, A. M., Franco, S., and Kaffine, D. (2006). "The efficiency and distributional impacts of alternative anti-sprawl policies," *Journal of Urban Economics*, vol. 59(1): pp. 121-141.

Bento, A. M., Goulder, L. H., Jacobsen, M. R., and von Haefen, R. H. (2009). "Distributional and Efficiency Impacts of Increased US Gasoline Taxes," *American Economic Review*, vol. 99(3): pp. 667-699.

Borenstein, S. and Davis, L. (2016). "The Distributional Effects of US Clean Energy Tax Credits," *NBER Tax Policy and The Economy*, vol. 30: pp. 191-234.

Brounen, D. and Kok, N. (2011). "On the Economics of Energy Labels in the Housing Market," *Journal of Environmental Economics and Management*, vol. 62(2): pp. 166-179.

Bruegge, C., Deryugina, T., and Myers, E. (2017). "The Distributional Effects of Building Energy Codes," Working Paper.

Bruegge, C. (2017). "Distortionary Fundraising for Energy Efficiency Subsidies: Implications for Efficient and Equitable Program Design," Working Paper.

Datta, S. and Gulati, S. (2014). "Utility Rebates for Energy Star Appliances: Are They Effective?," *Journal of Environmental Economics and Management*, vol. 68(3): pp. 480-506.

Davis, L. and Knittel, C. (2016). "Are Fuel Economy Standards Regressive," Working Paper.

Deacon, R. T. and Sonstelie, J. (1985). "Rationing by Waiting and the Value of Time: Results from a Natural Experiment," *Journal of Political Economy*, vol. 93(4): pp. 627-647.

Diamond, P. and Saez, E. (2011). "The Case for a Progressive Tax: From Basic Research to Policy Recommendations," *Journal of Economic Perspectives*, vol. 25(4): pp. 165-190.

Eichholtz, P., Kok, N., and Quigley, J. M. (2010). "Doing Well by Doing Good? Green Office Buildings," *American Economic Review*, vol. 100: pp. 2494-2511.

Grainger, C. A. and Kolstad (2010). "Who Pays a Price on Carbon?," *Environmental and Resource Economics*, vol. 46: pp. 359-376.

Fullerton, D. and Muehlegger, E. (2017). "Who Bears the Economic Costs of Environmental Regulations?," NBER Working Paper No. 23677.

Jacobsen, G. D. (2016a). "Do Energy Prices Influence Investment in Energy Efficiency? Evidence from Energy Star Appliances," *Journal of Environmental Economics and Management*, vol. 74: pp. 94-106.

Jacobsen, G. D. (2016b). "Improving Energy Codes," *Energy Journal*, vol. 37(2): pp. 93-108.

Jacobsen, G. D. and Kotchen, M. J. (2013). "Are Building Codes Effective at Saving Energy? Evidence from Residential Billing Data in Florida," *Review of Economics and Statistics*, vol. 95(1): pp. 34-49.

Kahn, M. E. and Kok, N. (2014). "The Capitalization of Green Labels in the California Housing Market," *Regional Science and Urban Economics*, vol. 47: pp. 25-34.

Levinson, A. (2016a). "How Much Do Building Energy Codes Save? Evidence from California Houses," *American Economic Review*, vol. 106(10): pp. 2867-2894.

Levinson, A. (2016b). "Energy Efficiency Standards Are More Regressive Than Energy Taxes: Theory and Evidence," NBER Working Paper No. 22956.

Maguire, K. and Sheriff, G. (2011). "Comparing Distributions of Environmental Outcomes for Regulatory Environmental Justice Analysis," *International Journal of Environmental Research and Public Health*, vol. 8: pp. 1707-1726.

Neveu, A. R. and Sherlock, M. F. (2016). "An Evaluation of Tax Credits for Residential Energy Efficiency," *Eastern Economic Journal*, vol. 42: pp. 63-79.

Novan, K., Smith, A., and Zhou, T. (2017). "Residential Building Codes Do Save Energy: Evidence from Hourly Smart-Meter Data," Working Paper.

Sutherland, R. J. (1994). "Income Distribution Effects of Electric Utility DSM Programs," *The Energy Journal*, vol. 15(4): pp. 103-118.

Walls, M., K. Palmer, and Gerarden, T. (2017). "Is Energy Efficiency Capitalized into Home Prices? Evidence from Three U.S. Cities," *Journal of Environmental Economics and Management*, vol. 82: pp. 104-124.

Wichman, C. J., Taylor, L. O., and von Haefen, R. H. (2016). "Conservation Policies: Who Responds to Price and Who Responds to Prescription?," *Journal of Environmental Economics and Management*, vol. 79: pp. 114-134.

8 Figures and Tables

Table 1: Means for Variables Related to Equipment or Incentives

Equipment	Presence	Post Move-In	Energy Star	Any Incentive	Type of Subsidy: Manuf. / Retail Rebate	Type of Subsidy: Utility Rebate	Type of Subsidy: Tax Credit
Refrigerator	0.998	0.236	0.742	0.019	0.011	0.005	0.004
Dishwasher	0.557	0.129	0.796	0.011	0.009	0.001	0.001
Clotheswasher	0.803	0.243	0.780	0.021	0.012	0.006	0.003
Space Heater	0.989	0.149		0.025	0.006	0.006	0.013
Central AC	0.598	0.091		0.017	0.005	0.004	0.008
Energy Eff. Bulbs	0.589	0.518		0.025	0.008	0.017	0.000
Windows	0.994	0.299		0.023	0.002	0.002	0.019
Insulation	0.990	0.218		0.009	0.001	0.002	0.006
Average	0.815	0.235	0.773	0.019	0.007	0.005	0.007

Notes: The data source is the 2009 Residential Energy Consumption Survey. Each observation refers to a household. There are 10,694 observations. All variables are binary variables. *Present* reports whether the equipment is present in the residence. *Post Move-In* equals one if the equipment was replaced/installed by the household after they moved into their residence. *Any Incentive* records whether the household received any type of incentive to replace/install the equipment. *Manuf. / Retail Rebate*, *Utility Rebate*, and *Tax Credit* equal one if the incentive was provided through a manufacturer / retailer rebate, a utility rebate, or a tax credit, respectively.

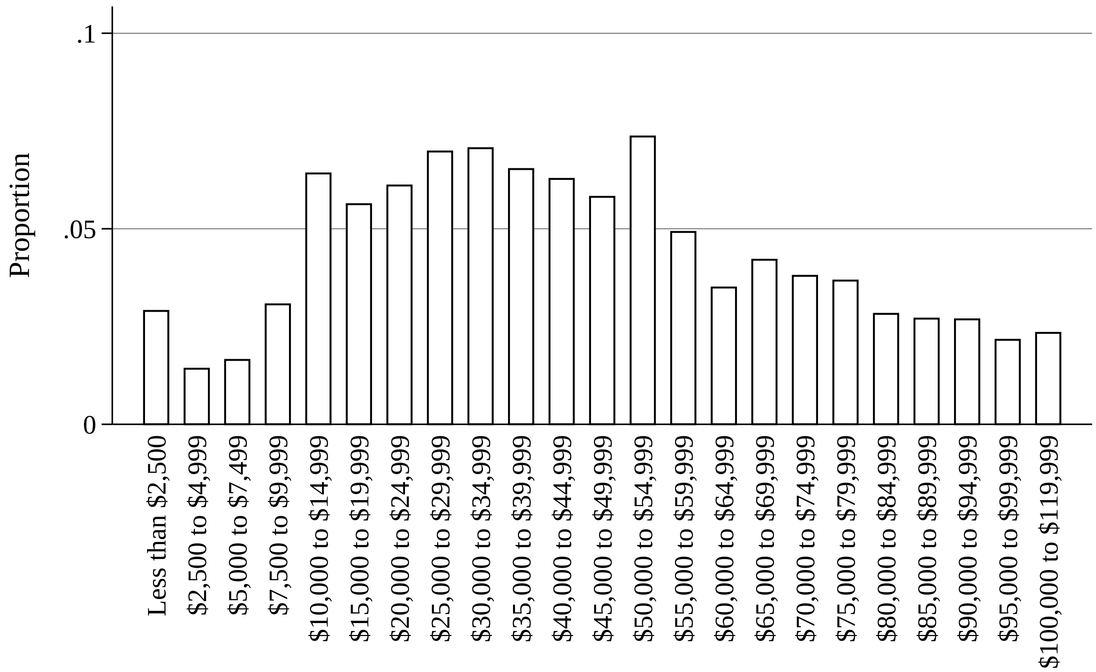
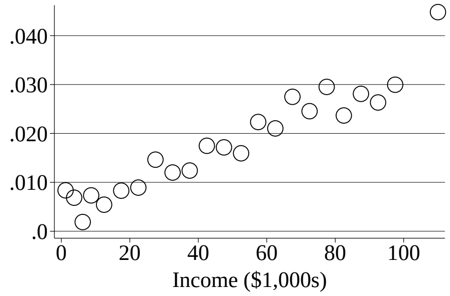
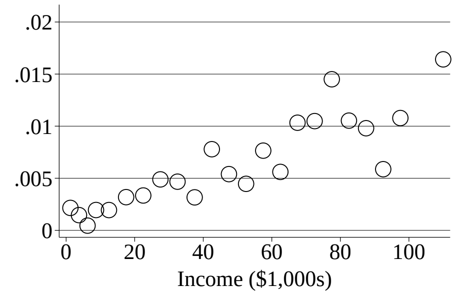


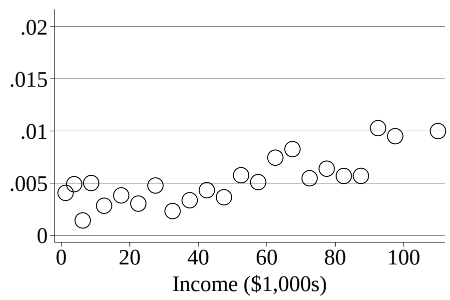
Figure 1: **Histogram of Income.** The unit of observation is a household (n = 10,694).



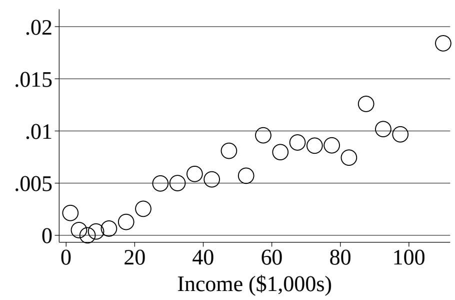
(a) Any Incentive



(b) Manuf. / Retail Rebate



(c) Utility Rebate



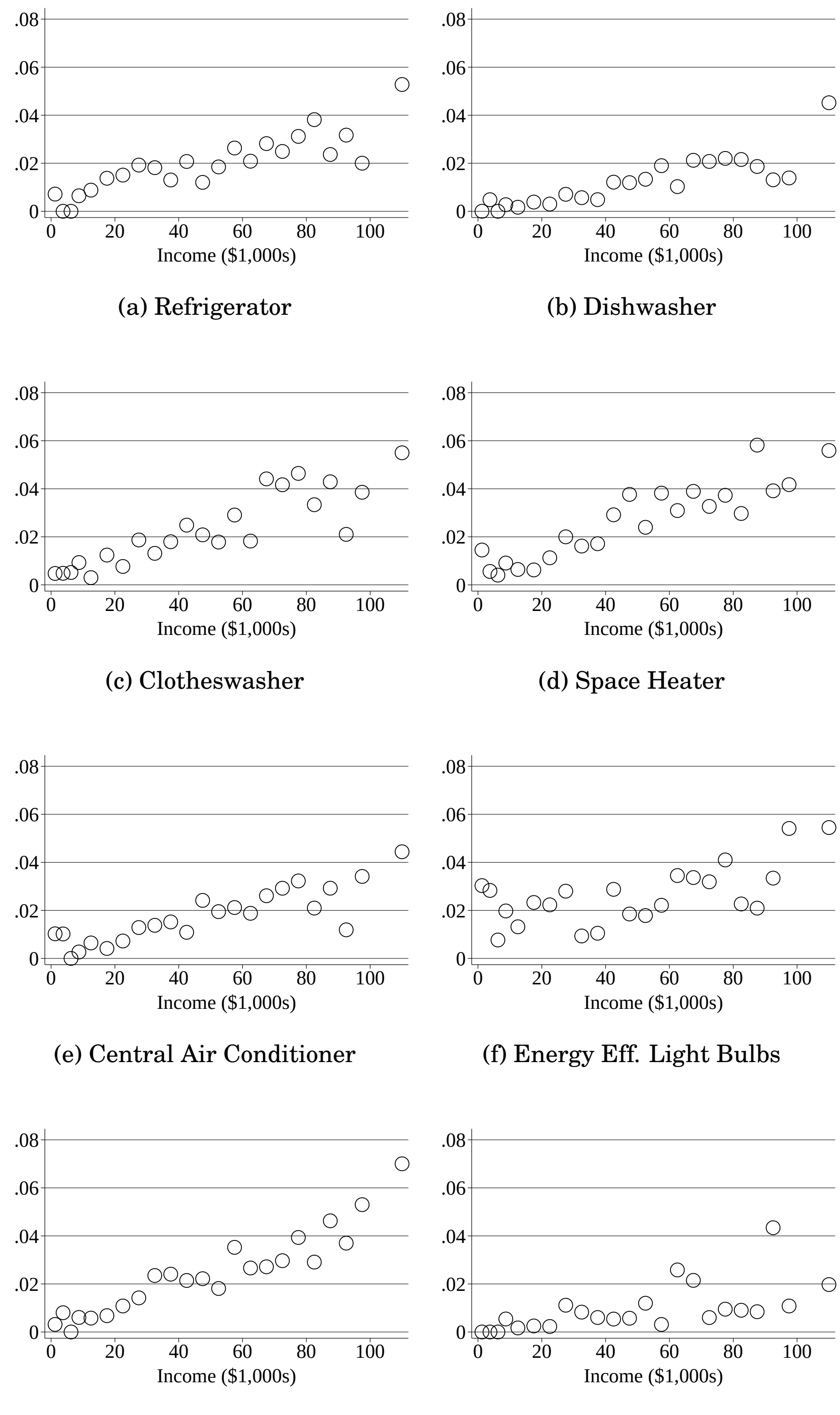
(d) Tax Credit

Figure 2: **Proportion of Households Receiving Incentives by Income - By Type of Subsidy.** The unit of observation is household-equipment (n = 85,552).

Table 2: Regressions of Receipt of Incentive on Income by Type of Subsidy

	Any Incentive	Man./Ret. Reb.	Util. Reb.	Tax. Cred.
	(1)	(2)	(3)	(4)
Income ($10,000s)	0.0032***	0.0012***	0.0006***	0.0014***
	(0.0002)	(0.0001)	(0.0001)	(0.0002)
Constant	0.0026***	0.0006	0.0022***	-0.0001
	(0.0009)	(0.0005)	(0.0005)	(0.0006)
$80*k*-to-$20*k* Ratio	3.123**	3.423**	2.064**	4.164**
Concentration Index	0.30	0.32	0.20	0.36
Observations	96,246	96,246	96,246	96,246

Notes: The dependent variable is whether the household received an incentive from the corresponding type of subsidy, as indicated by the column headings. All models are linear probability models. The unit of observation is household-equipment. There are eight observations per household, one for each type of equipment in the sample. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. Standard errors are clustered by household. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.



(a) Refrigerator (b) Dishwasher

(c) Clotheswasher (d) Space Heater

(e) Central Air Conditioner (f) Energy Eff. Light Bulbs

(g) Windows (h) Insulation

Figure 3: **Proportion of Households Receiving Incentives by Income - By Type of Equipment.** The unit of observation is household (n = 10,694).

Table 3: Regressions of Receipt of Incentive on Income by Type of Equipment

	Frg. (1)	Dishwsh. (2)	Clthswsh. (3)	Spc. Ht. (4)	Cen. AC (5)	Lghtg. (6)	Wndws. (7)	Insul. (8)
Income ($10,000s)	0.003***	0.003***	0.004***	0.005***	0.003***	0.003***	0.005***	0.002***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Constant	0.005*	-0.003	0.002	0.004*	0.002	0.013***	-0.000	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)
$80*k*-to-$20*k* Ratio	2.762**	6.423**	3.558**	3.065**	3.220**	1.863**	4.120**	3.615**
Concentration Index	0.27	0.43	0.33	0.31	0.31	0.16	0.36	0.34
Observations	10,694	10,694	10,694	10,694	10,694	10,694	10,694	10,694

Notes: The dependent variable is whether the household received an incentive for the corresponding type of equipment, as indicated by the column headings. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

Table 4: Regressions of Receipt of Incentive on Income by Type of Subsidy and Equipment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel 1: Manuf. / Retail Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.011	0.009	0.012	0.006	0.005	0.008	0.002	0.001
Income ($10,000s)	0.002***	0.003***	0.003***	0.001***	0.001***	0.001***	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.001	-0.003*	0.001	0.001	0.001	0.003**	0.000	0.001*
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)
$80*k*-to-$20*k* Ratio	3.447**	7.310**	3.536**	3.284**	3.042**	2.203**	3.034	1.415
Concentration Index	0.31	0.45	0.33	0.32	0.30	0.22	0.28	0.14
Panel 2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.005	0.001	0.006	0.006	0.004	0.017	0.002	0.002
Income ($10,000s)	0.001***	0.000**	0.001***	0.001**	0.000*	0.002***	0.001***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Constant	0.002**	-0.000	0.002	0.003**	0.002*	0.010***	-0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)
$80*k*-to-$20*k* Ratio	2.027**	5.751	2.738**	1.871*	1.765	1.714**	5.223	2.443
Concentration Index	0.20	0.41	0.28	0.18	0.17	0.13	0.39	0.26
Panel 3: Tax Credit	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.004	0.001	0.003	0.013	0.008	0.000	0.019	0.006
Income ($10,000s)	0.000*	0.000*	0.001***	0.003***	0.002***		0.004***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		(0.001)	(0.000)
Constant	0.001	0.000	-0.001	0.000	-0.001		-0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)		(0.002)	(0.001)
$80*k*-to-$20*k* Ratio	2.206	3.340	8.269	3.830**	4.672**		4.142**	4.695**
Concentration Index	0.20	0.32	0.48	0.36	0.39		0.36	0.39
Observations	10,694	10,694	10,694	10,694	10,694		10,694	10,694

Notes: The dependent variable is whether the household received an incentive from the corresponding type of subsidy for the corresponding type of equipment, as indicated by the panel and column headings. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. The bottom line reports number of observations, which are the same for each regression reported within a column. All subsidy-equipment combinations that rarely serve as an avenue for incentives (i.e. less 2 out of 1000 or fewer households receive the corresponding form of incentive) are presented in gray due to limited statistical power. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

Table 5: Investigating Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel 1: Equipment Presence	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Income ($10,000s)	0.000	0.059***	0.034***	0.001***	0.029***	0.024***	0.000	0.001***
	(0.000)	(0.002)	(0.001)	(0.000)	(0.002)	(0.002)	(0.000)	(0.000)
Constant	0.998***	0.293***	0.651***	0.984***	0.467***	0.480***	0.993***	0.984***
	(0.001)	(0.010)	(0.009)	(0.002)	(0.010)	(0.010)	(0.002)	(0.002)
$80*k*-to-$20*k* Ratio	1.001	1.863**	1.285**	1.006**	1.333**	1.277**	1.002	1.009**
Concentration Index	0.00	0.18	0.07	0.00	0.08	0.07	0.00	0.00
Observations	10,694	10,694	10,694	10,694	10,694	10,694	10,694	10,694
Panel 2: Post Move-In	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Income ($10,000s)	0.011***	0.015***	0.014***	0.003**	0.005***	0.006***	0.012***	0.015***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.186***	0.152***	0.237***	0.138***	0.127***	0.852***	0.246***	0.153***
	(0.008)	(0.013)	(0.011)	(0.007)	(0.009)	(0.009)	(0.009)	(0.008)
$80*k*-to-$20*k* Ratio	1.323**	1.487**	1.310**	1.122**	1.227**	1.040**	1.267**	1.479**
Concentration Index	0.08	0.11	0.08	0.04	0.06	0.08	0.07	0.11
Observations	10,676	6,128	8,691	10,551	6,440	6,459	10,694	10,694
Panel 3: Energy Star	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Income ($10,000s)	0.027***	0.020***	0.019***					
	(0.003)	(0.004)	(0.003)					
Constant	0.611***	0.679***	0.683***					
	(0.020)	(0.031)	(0.021)					
$80*k*-to-$20*k* Ratio	1.242**	1.164**	1.154**					
Concentration Index	0.04	0.02	0.03					
Observations	2,623	1,459	2,645					

Notes: In Panel 1, the full sample is used and the dependent variable is whether the equipment is present in the residence. In Panel 2, the sample is limited to residences in which the equipment is present and the dependent variable is whether the equipment has been replaced since moving into the residence. In Panel 3, the sample is limited to residences that have replaced the equipment since moving into the residence and the dependent variable is whether the equipment model is an Energy Star version. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the corresponding outcome occurring for a household with an income of $80*k* to the probability of the corresponding outcome occurring for a household with an income of $20*k*, as estimated based on the regression output. The bottom line reports number of observations, which are the same for each regression reported within a column. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

Table 6: Regressions of Receipt of Incentive on Income by Type of Subsidy and Equipment - Sample Limited to Homeowners that Own Each Type of Equipment and Have Replaced / Installed Equipment After Moving

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel 1: Manuf. / Retail Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.047	0.068	0.051	0.028	0.041	0.016	0.006	0.003
Income ($10,000s)	0.007***	0.007**	0.006***	0.004**	0.004	0.001	0.001	-0.000
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.000)
Constant	0.015	0.031*	0.024**	0.012	0.025*	0.011***	0.002	0.004**
	(0.011)	(0.018)	(0.011)	(0.009)	(0.015)	(0.004)	(0.003)	(0.002)
$80*k*-to-$20*k* Ratio	2.456**	1.965	1.995**	2.243	1.702	1.455	2.444	0.889
Concentration Index	0.24	0.19	0.19	0.28	0.15	0.13	0.21	0.00
Panel 2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.020	0.011	0.026	0.028	0.030	0.032	0.008	0.008
Income ($10,000s)	0.001	0.001	0.002	0.001	0.000	0.001	0.002**	0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Constant	0.014**	0.007	0.021**	0.030***	0.033**	0.026***	0.001	0.005
	(0.006)	(0.007)	(0.009)	(0.010)	(0.013)	(0.007)	(0.003)	(0.003)
$80*k*-to-$20*k* Ratio	1.495	1.616	1.380	1.163	1.024	1.269	3.470	1.576
Concentration Index	0.12	0.13	0.14	0.12	0.04	0.06	0.33	0.16
Panel 3: Tax Credit	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Receiving Incentive	0.015	0.009	0.011	0.079	0.086	0.000	0.062	0.028
Income ($10,000s)	0.001	0.000	0.002**	0.015***	0.013***		0.011***	0.005***
	(0.001)	(0.001)	(0.001)	(0.003)	(0.004)		(0.002)	(0.001)
Constant	0.015**	0.010	-0.000	0.021	0.028		0.015	0.005
	(0.008)	(0.007)	(0.005)	(0.015)	(0.022)		(0.009)	(0.007)
$80*k*-to-$20*k* Ratio	1.258	1.017	4.220	2.791**	2.424*		2.816**	2.952*
Concentration Index	0.12	-0.00	0.35	0.31	0.23		0.29	0.29
Observations	2,057	1,298	2,226	1,267	861		2,700	2,182

Notes: The dependent variable is whether the household received an incentive from the corresponding type of subsidy for the corresponding type of equipment, as indicated by the panel and column headings. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. The sample is restricted to homeowners that own each type of equipment and have replaced or installed it since moving in. The bottom line reports number of observations, which are the same for each regression reported within a column. All subsidy-equipment combinations that rarely serve as an avenue for incentives (i.e. less 2 out of 1000 or fewer households receive the corresponding form of incentive) are presented in gray due to limited statistical power. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

Table 7: Regressions of Receipt of Incentive on Income by Type of Subsidy and Equipment - Sample Limited to Homeowners that Own An *Energy Star* Version of Each Type of Equipment and Have Replaced / Installed The Equipment After Moving

	(1)	(2)	(3)
Panel 1: Manuf. / Retail Rebate	Frg.	Dishwsh.	Clthswsh.
Prob. of Receiving Incentive	0.059	0.083	0.062
Income ($10,000s)	0.008***	0.008**	0.006***
	(0.003)	(0.004)	(0.002)
Constant	0.022	0.040*	0.032**
	(0.014)	(0.023)	(0.013)
$80*k*-to-$20*k* Ratio	2.233*	1.842	1.859*
Concentration Index	0.21	0.18	0.17
Panel 2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.
Prob. of Receiving Incentive	0.026	0.014	0.032
Income ($10,000s)	0.001	0.001	0.001
	(0.001)	(0.001)	(0.002)
Constant	0.021***	0.010	0.029**
	(0.008)	(0.009)	(0.011)
$80*k*-to-$20*k* Ratio	1.256	1.442	1.229
Concentration Index	0.09	0.10	0.13
Panel 3: Tax Credit	Frg.	Dishwsh.	Clthswsh.
Prob. of Receiving Incentive	0.020	0.011	0.014
Income ($10,000s)	0.000	-0.000	0.003**
	(0.002)	(0.001)	(0.001)
Constant	0.023**	0.013	0.001
	(0.011)	(0.010)	(0.006)
$80*k*-to-$20*k* Ratio	1.059	0.914	3.569
Concentration Index	0.07	-0.03	0.32
Observations	1,624	1,065	1,779

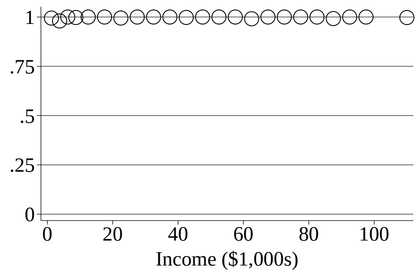
Notes: The dependent variable is whether the household received an incentive from the corresponding type of subsidy for the corresponding type of equipment, as indicated by the panel and column headings. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. All subsidy-equipment combinations that rarely serve as an avenue for incentives (i.e. less 2 out of 1000 or fewer households receive the corresponding form of incentive) are presented in gray due to limited statistical power. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

Table 8: 2015 Regressions of Receipt of Incentive on Income by Categories Reported in the 2015 Residential Consumption Survey

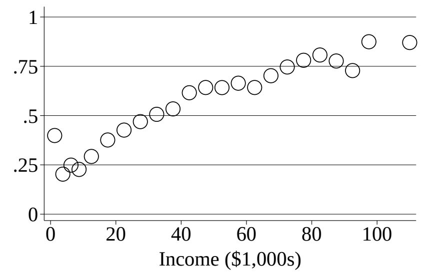
	Free/Sub. Lights	Free/Sub. Audit	Util. App. Reb.	Free Recyc. App.	Tax Credit	Other Ben./Asst.
	(1)	(2)	(3)	(4)	(5)	(6)
Income ($10,000s)	0.0012	0.0014**	0.0043***	0.0054***	0.0096***	0.0012**
	(0.0009)	(0.0007)	(0.0008)	(0.0010)	(0.0010)	(0.0006)
Constant	0.0438***	0.0136***	0.0104**	0.0234***	-0.0015	0.0150***
	(0.0055)	(0.0037)	(0.0040)	(0.0054)	(0.0043)	(0.0034)
$80*k*-to-$20*k* Ratio	1.158	1.517*	2.361**	1.947**	4.253**	1.420*
Concentration Index	0.05	0.13	0.26	0.22	0.38	0.11
Observations	5,102	5,102	5,102	5,102	5,102	5,102

Notes: The dependent variable is whether the household received an incentive for the corresponding category, as indicated by the column headings. All models are linear probability models. The unit of observation is a household. The *$80k-to-$20k Ratio* line presents the ratio of the probability of a household with an income of $80*k* receiving an incentive to the probability of a household with an income of $20*k* receiving an incentive, as estimated based on the regression output. White-corrected standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. For *$80k-to-$20k Ratio*, the null hypothesis is that the ratio is equal to 1 and significance is computed based on the delta method.

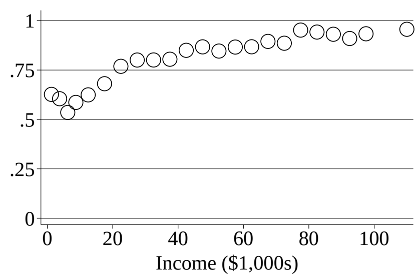
A Appendix



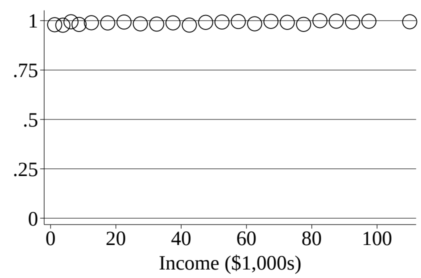
(a) Refrigerator



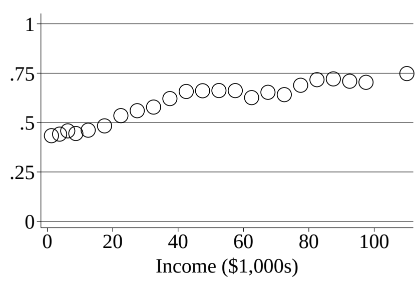
(b) Dishwasher



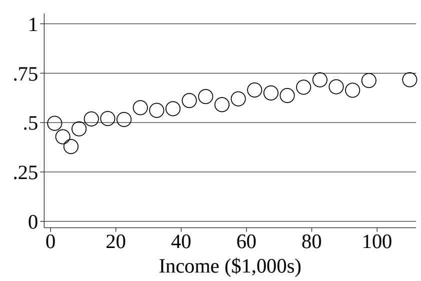
(c) Clothewasher



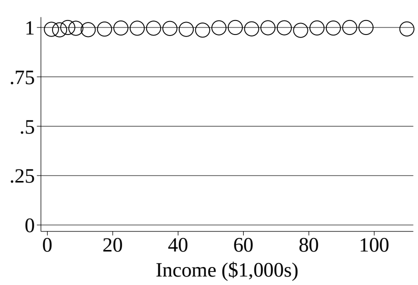
(d) Space Heater



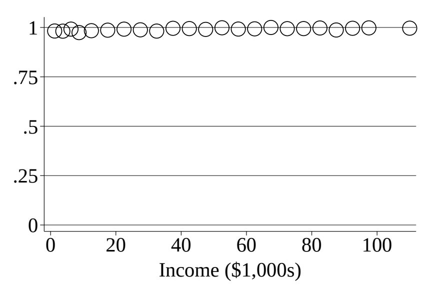
(e) Central Air Conditioner



(f) Energy Eff. Light Bulbs

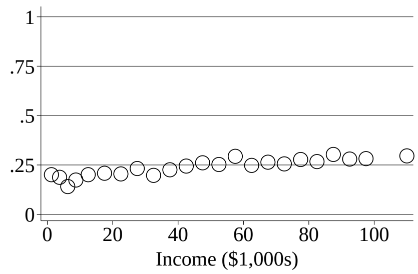


(g) Windows

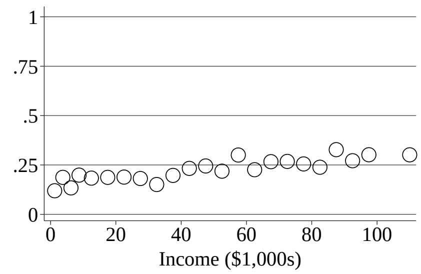


(h) Insulation

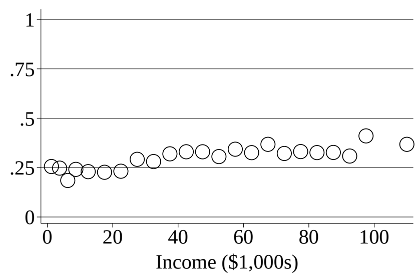
Figure A.1: **Proportion of Households in Which the Equipment is Present in Residence by Income.** The unit of observation is household (n = 10,694).



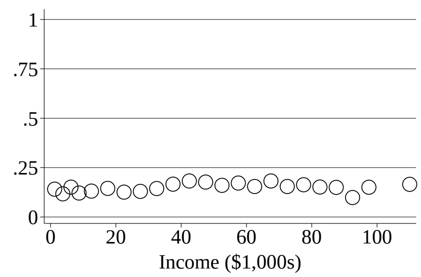
(a) Refrigerator



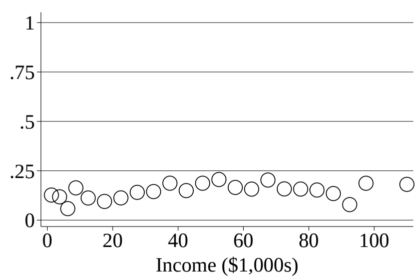
(b) Dishwasher



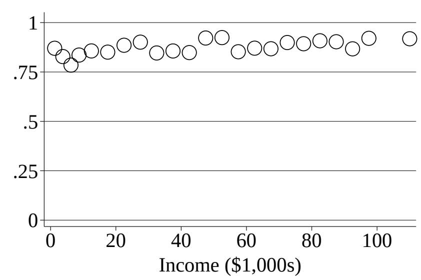
(c) Clothewasher



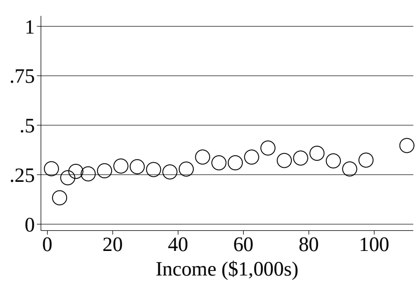
(d) Space Heater



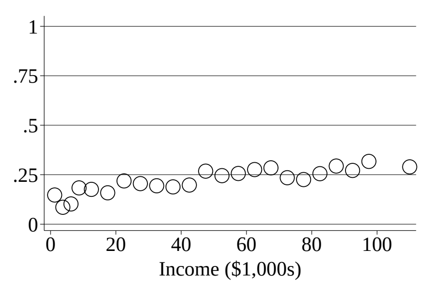
(e) Central Air Conditioner



(f) Energy Eff. Light Bulbs

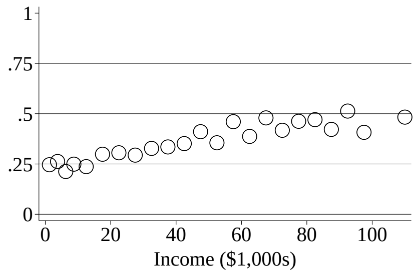


(g) Windows

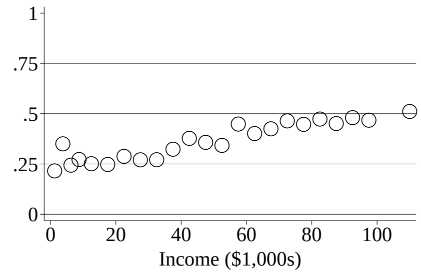


(h) Insulation

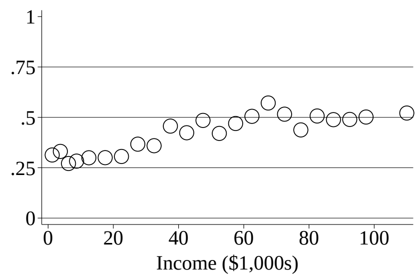
Figure A.2: **Proportion of Households Installing / Replacing Equipment After Moving In**. The unit of observation is household. The sample is restricted to households that report having the equipment present in their residence. See Panel B of Table 5 for the number of observations associated with each figure.



(a) Refrigerator



(b) Dishwasher



(c) Clothewasher

Figure A.3: **Proportion of Households that Own Energy Star Models**. The sample is restricted to households that report having replaced or installed the equipment since moving into their residence. See Panel 3 of Table 5 for the number of observations associated with each figure.

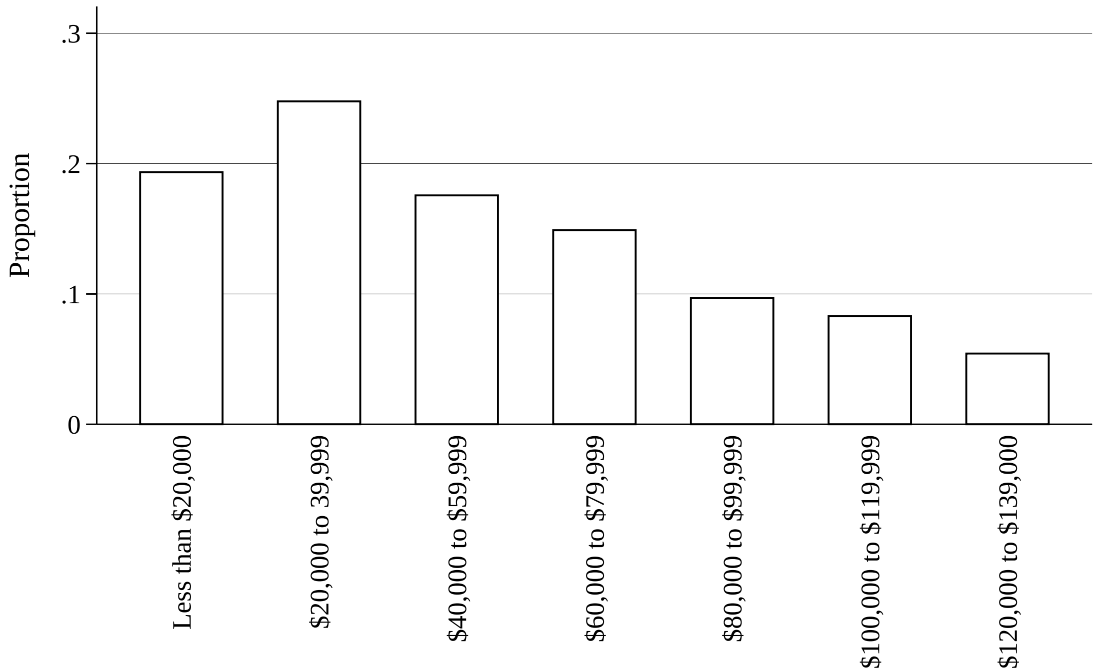
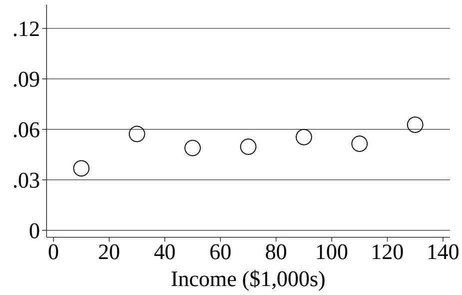
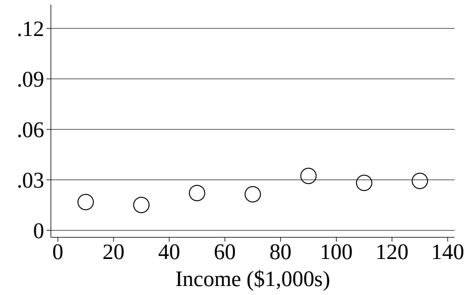


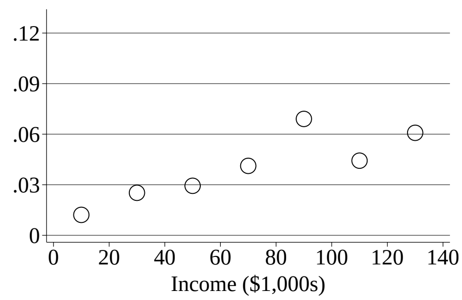
Figure A.4: **Histogram of Income - 2015 RECS.** The data source is the 2015 RECS. The unit of observation is a household (n = 5,102).



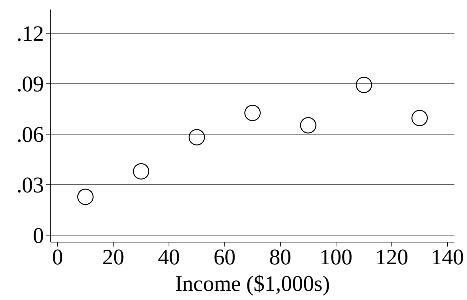
(a) Free or Sub. Lights



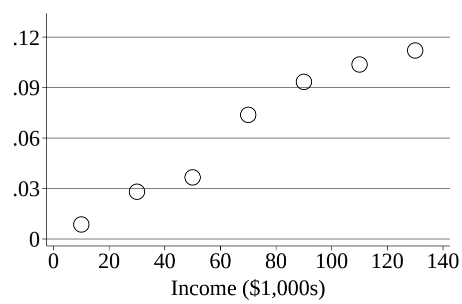
(b) Free or Sub. Audit



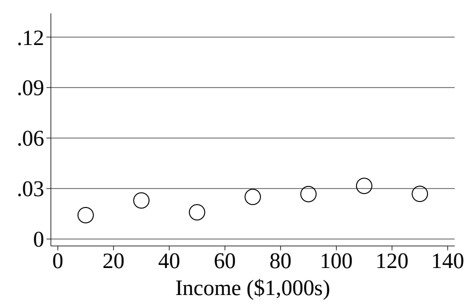
(c) Utility App. Reb.



(d) Free Recyc. App.



(e) Tax Credit



(f) Other Ben. or Asst.

Figure A.5: **Proportion of Households Receiving An Incentive by Income - By 2015 RECS Category.** The unit of observation is household (n = 5,102).